SESSION TRACKS

TO1	Sub-18 GHz for terrestrial networks (5G/6G)	TO5	Positioning, localization, identification & tracking
TO2	Milimetre wave and THz for terrestrial networks (5G/6G)	TO6	Biomedical and health
TO3	Aerospace, space and non-terrestrial networks	TO7	Electromagnetic modelling and simulation tools
TO4	RF sensing for automotive, security, IoT, and other applications	TO8	Fundamental research and emerging technologies/processes
SW	Scientific workshop	KIS	Keynotes & Invited speakers
IW	Industrial workshop	WG	Meeting and Working groups (WG)

SUNDAY, APRIL 19th

Registration (13:00-17:30)

Short courses (14:00-17:30) with a coffee break (15:00-15:30)

Room	Short course
Prague	SC02 - Antenna Design using Optimization and Machine Learning
Gothenburg	SC03 - Spherical Near-Field Antenna Measurements - Theory and Practical Implementation
The Hague	SC04 - Multibeam Antennas and Beamforming Networks
Copenhagen	SC05 - Machine Learning Augmented Metasurface Design: From Theory to Practical Implementation
Dusseldorf	SC06 - Metasurfaces: Passive, Active and Applications in Antenna Designs

Room	Short course
Madrid	SC07 - Implementing IEEE Standards 1720 and 149 in Antenna Measurements: Principles, Practice, and Perspectives
Firenze	SC08 - Antennas for In-Body Sensing: Design Principles, Measurement Techniques, and Open Challenges
Glasgow	SC10 - Microwave Imaging and Sensing and Innovative Applications
Stockholm	SC12 - Nonlinear Periodic Circuits and Surfaces
Davos	SC14 - Fundamentals of Radar Cross Section Measurement

18:00-23:00 ALL TOGETHER DINNER

MONDAY, APRIL 20th

	08:00–08:30	08:30–09:30	09:30–10:15	10:15–10:45	10:45–11:30	11:30–12:15	12:15–13:45	13:45–15:45	15:45–16:15	16:15–18:15	
MAIN AUDITORIUM		Opening ceremony	Michael McLaughlin		Clare Allen	Christopher Holloway					
BARCELONA								A23: Metasurface Antennas and Techniques		A30: Reflectarray and Transmitarray Antennas	
COPENHAGEN								CS13: Toward Sustainable IoT: Innovations in RF and Antenna Materials, Design, and Fabrication		CS55: Wireless Power Transfer System and Roles of Antennas and Propagation	
DUSSELDORF								M06: Recent Advances in Antenna Test Ranges, Chambers, and Robotics		CS27: Novel Antenna Measurement Techniques and Data Processing for Electromagnetic Applications	
GOTHENBURG	REGISTRATION			COFFEE BREAK			LUNCH	CS7: Small Antennas: 20 Years of Innovation and the Road Ahead	COFFEE BREAK	P12: UWB, Millimetre-wave, and THz Propagation	18:15-20:00
KRAKOW								A32: RFID and Sensor Antennas		CS26: Physics-Compliant Modeling and Prototyping of Reconfigurable Metasurfaces	WELCOME RECEPTION
LONDON								CS28: Quantum Electromagnetics - From Photonics to Quantum Computing		M07: Recent Advances in Near Field Measurement	
PARIS								SW2: EuCAP Twentieth Anniversary Workshop		E12: Materials and Waveguides	
PRAGUE								P03: Deterministic Propagation Models		CS19: Antennas, Components, and Sensors for Life Science Applications of Electromagnetic Technologies	
ROME								A35: Waveguide Feed-Based Antennas		A25: On Board Satellite and Ground Station Antennas	
FIRENZE											
MADRID								E09: Electromagnetic Theory: Radiation		CS51: AMTA Convened Session: New Measurement Methods for Reverberation Chambers	
THE HAGUE										IW1: Industrial Workshop - ETS-Lindgren	
STOCKHOLM							WG5: EurAAP Early Careers in AP WG				

TUESDAY, APRIL 21st

	08:00–09:40	09:40–10:10	10:10–11:50	12:00–12:40	12:40–13:30	13:30–14:40	14:40–15:20	15:20–15:50	15:50–17:30	17:40–18:15
BARCELONA	E08a: Electromagnetic Theory: New Material Design 1		E08b: Electromagnetic Theory: New Material Design 2						E07a: Electromagnetic Theory: Components 1	
COPENHAGEN	A13a: Array Antenna, Feeds and Excitations 1		A13b: Array Antenna, Feeds and Excitations 2						CS16: Passive Intermodulation in RF Antennas and Base Stations	
DUSSELDORF	CS10a: Recent Advances on Propagation Research and Its Impact on Localizations 1		CS10b: Recent Advances on Propagation Research and Its Impact on Localizations 2		WG2: EurAAP Propagation WG				A04: Advanced Antenna Manufacturing Techniques	EURAAP AWARDS CEREMONY
GOTHENBURG	A18a: Hybrid Lens Antenna Solutions 1		A18b: Hybrid Lens Antenna Solutions 2						CS17: Advances in Multi-Antenna Channel Sounding and Modeling for 6G: From Far-Field to Near-Field	
KRAKOW	CS31a: Antennas and Arrays for Radio Astronomy 1	COFFEE BREAK	CS31b: Antennas and Arrays for Radio Astronomy 2		LUNCH	POSTER SESSION		COFFEE BREAK	A21: Lens Antennas	
LONDON	CS42a: AMTA Post Processing Techniques in Antenna Measurements 1		CS42b: AMTA Post Processing Techniques in Antenna Measurements 2						CS14:Recent Advances on Theory and Applications of Characteristic Models in Antenna Modelling and Design	
PARIS	CS4a: Challenges in Accessing Human RF Exposure to Existing and Emerging Mobile Radio Technologies upto 6G 1		CS4b: Challenges in Accessing Human RF Exposure to Existing and Emerging Mobile Radio Technologies upto 6G 2						M01: Material Characterisation and Non-Destructive Testing	
PRAGUE	CS25a: Electromagnetic Medical Imaging: Inversion Algorithms and Novel Data Processing Strategies 1		CS25b: Electromagnetic Medical Imaging: Inversion Algorithms and Novel Data Processing Strategies 2						A07: Antenna Interactions and Couplings at Sub THz and THz Frequencies	
ROME	CS37a: Advances in Dynamic Metasurface Antennas/Reconfigurable Holographic Surfaces for Next-Generation Wireless Applications: Design, Development and Applications 1		CS37b: Advances in Dynamic Metasurface Antennas/Reconfigurable Holographic Surfaces for Next-Generation Wireless Applications: Design, Development and Applications 2						E19: Reconfigurable and Frequency/Polarisation Selective Surfaces	
FIRENZE	P08a: Propagation Models for Non-Terrestial Networks 1		P08b: Propagation Models for Non-Terrestial Networks 2		WG1: EurAAP Small Antennas WG				CS11: Advances in Study and Design of 2D Leaky-Wave Antennas	
MADRID	SW7a: 4-CAD: Advancing Over-The-Air Testing in Vehicular Communications and Automotive Radar Sensing		SW7b: 4-CAD: Advancing Over-The-Air Testing in Vehicular Communications and Automotive Radar Sensing		WG8: EurAAP Measurements WG				E18: RCS Reduction	
THE HAGUE	SW3a: Recent Advancements and Applications for Antenna Arrays and Systems (IEEE AP-S Technical Committee 2 "Array")		SW3b: Recent Advancements and Applications for Antenna Arrays and Systems (IEEE AP-S Technical Committee 2 "Array")						CS45: Scattering in 6G and Integrated Communications and Sensing	
GLASGOW	SW8a: From RFID to Wireless Sensing and IoT: Antenna Innovations for Non-linear Transponder Systems		SW8b: From RFID to Wireless Sensing and IoT: Antenna Innovations for Non-linear Transponder Systems						SW4: Advances in Active Phased Array Antennas: Modelling, Integration, and Characterisation	
STOCKHOLM	IW8: Industrial Workshop IEEE Antennas and Propagation Society – Advancing Careers		IW4: Industrial Workshop – TICRA						IW3: Industrial Workshop – Taoglas	
DAVOS			IW2: Industrial Workshop – Westermo							
EDINBURGH				Lars Jacob Foged			Ke Guan			
BERLIN				Richard W. Ziolkowski			Zoya Popovic			
LISBON				IEEE P3720 WG						

Information about the Poster sessions

P1-A01: Active and Passive Arrays

P1-A02: Aerospace, Space and Non-Terrestial Networks

P1-A03: EM Modelling and Simulation Tools

P1-A04: Reflectors, Reflectarrays and Feed Systems

P1-A05: Wearable and Implantable Antennas for Biomedical and Health

P1-E01: Electromagnetic Surfaces and Absorbers

P1-E02: Optimisation and FSS Techniques

P1-P01: Propagation Measurements and Channel Characterisation

WEDNESDAY, APRIL 22nd

	08:00–09:40	09:40–10:10	10:10–11:50	12:00–12:40	12:40–13:30	13:30–14:40	14:40–15:20	15:20–15:50	15:50–17:30	17:40–20:00
BARCELONA	A11a: Antennas for Satellite Communication 1	COFFEE BREAK	A11b: Antennas for Satellite Communication 2			POSTER SESSION			E15: Metasurfaces in Antenna Design	WiAP-ECAP WG EVENT
COPENHAGEN	E06: Electromagnetic Theory: Components 2		E07b: Electromagnetic Theory: Components 3						P06: Propagation Measurements and Channel Sounding	
DUSSELDORF	P10a: Sensing, Localisation, and ISAC – Part I 1		P10b: Sensing, Localisation, and ISAC – Part I 2		WG10: EurAAP WG Chairs				M04: Radar and RCS Measurement	
GOTHENBURG	A12a: Array Antenna Deployments and Interactions 1		A12b: Array Antenna Deployments and Interactions 2		LUNCH			COFFEE BREAK	CS36: EuMA Session: Active Antennas for Sensing and Communication	
KRAKOW	A15a: Control and Evaluation of RIS and LIS Systems 1		A15b: Control and Evaluation of RIS and LIS Systems 2						A37: Wireless Power Transmission and Harvesting	
LONDON	CS5a: Propagation for Smart Mobility Scenarios 1		CS5b: Propagation for Smart Mobility Scenarios 2						CS9: Advances in OTA Chambers, from Reverberation Chambers to Hybrids	
PARIS	CS30a: New Progress in AI-driven Antenna Design 1		CS30b: New Progress in AI-driven Antenna Design 2						A14: Array Antennas at Sub-THz and THz Bands	
PRAGUE	CS44a: Pre-Clinical and Clinical Microwave Devices – from Diagnosis to Treatment 1		CS44b: Pre-Clinical and Clinical Microwave Devices – from Diagnosis to Treatment 2			Best Student Paper			CS18: Advancements in Electromagnetic Field Exposurre Research in 5G and Beyond	
ROME	CS8a: Advanced Quasi-Periodic Electromagnetic Structures for Metasurface, Transmitarray and Reflectarray Applications 1		CS8b: Advanced Quasi-Periodic Electromagnetic Structures for Metasurface, Transmitarray and Reflectarray Applications 2						E20: Reflection and Scattering from Metasurfaces	
FIRENZE	SW6a: Innovative Methods for Enhancing Antenna Measurement Accuracy and Data Interpretation	MENTORING EURAAP BOOTH	SW6b: Innovative Methods for Enhancing Antenna Measurement Accuracy and Data Interpretation			CMSIG Annual Meeting			E04: Computational and Numerical Techniques: Physical Optics Approaches	
MADRID	A29a: Reconfigurable Antennas 1		A29b: Reconfigurable Antennas 2			WG6: EurAAP Education WG			ES1: European School of Antennas Meeting	
THE HAGUE	SW5: Emerging mm-Wave and sub-THz Antenna Arrays: Recent Technological Advances and Applications								CS46: Theory and Applications of Antennas for Biomedical Devices	
GLASGOW										
STOCKHOLM			IW5: Industrial Workshop – 3DS							
DAVOS										
EDINBURGH				Christian Fager			Naoki Shinohara			
BERLIN				B. Shanker			Ana Benarroch			

Information about the Poster sessions

- P2-A01: Adaptive and Reconfigurable Antennas
- P2-A02: Fundamental Research and Emerging Technologies/Processes
- P2-A03: Lens Antennas and Transmitarrays
- P2-A04: Sub-6 GHz Antennas for Mobile and Terrestial Networks
- P2-E01: Inverse Problems
- P2-E02: Metamaterials, Metasurfaces, Intelligent Surfaces
- P2-E03: Sensing and Tracking
- P2-M01: Measurement Topics 1
- P2-P01: Propagation Models

THURSDAY, APRIL 23rd

	08:00–09:40	09:40–10:10	10:10–11:50	12:00–12:40	12:40–13:30	13:30–14:40	14:40–15:20	15:20–15:50	15:50–17:30
BARCELONA	A09a: Antennas and Probes for Measurements 1	COFFEE BREAK	A09b: Antennas and Probes for Measurements 2			POSTER SESSION		COFFEE BREAK	CS47: Novel Designs and Applications of Conformal Metasurfaces and Antennas
COPENHAGEN	CS52a: AMTA Convened Session – Emerging Measurement Techniques for 5G and Beyond – 10th Anniversary Session 1		CS52b: AMTA Convened Session – Emerging Measurement Techniques for 5G and Beyond – 10th Anniversary Session 2						
DUSSELDORF	P11a: Sensing, Localisation and ISAC – Part II 1		P11b: Sensing, Localisation and ISAC – Part II 2		WG9: S&M WG				CS53: Advanced Direction-of-Arrival Estimation Techniques in Wireless Sensing and Communication
GOTHENBURG	CS54a: Recent Progress in Channel Modelling and Its Applications for mmWave and THz Bands 1		CS54b: Recent Progress in Channel Modelling and Its Applications for mmWave and THz Bands 2						CS24: Analysis Methods and Emerging Applications of Novel 1D Periodic Structures
KRAKOW	A26a: On Body and Implantable Antennas 1		A26b: On Body and Implantable Antennas 2		LUNCH				CS23: Metamaterials for Future Industrial Applications
LONDON	A02a: Active RIS Design and Synthesis 1		A02b: Active RIS Design and Synthesis 2			Best Paper Posters			A19: Implementation Methods for Sub-THz Antennas and Systems
PARIS	A06a: Antenna Array Theory and Synthesis 1		A06b: Antenna Array Theory and Synthesis 2						CS21: AMTA Session: Select Best Measurement Paper Candidates from AMTA Authors at EuCAP – Updates in 2026 on BEst Measurement Techniques
PRAGUE	CS40a: Approaches for Electromagnetic Dosimetry and Human Body Interaction in Life Sciences 1		CS40b: Approaches for Electromagnetic Dosimetry and Human Body Interaction in Life Sciences 2						CS29: Wireless and Wave-Based Technologies for Harsh and Complex Environments
ROME	CS34a: From Complex Simulations to Functional Antennas: Solving Challenges for Space Applications 1		CS34b: From Complex Simulations to Functional Antennas: Solving Challenges for Space Applications 2						E14: Metasurfaces Analysis and Design
FIRENZE	E03a: Computational and Numerical Techniques: Intergral Equations 1		E03b: Computational and Numerical Techniques: Intergral Equations 2		WG4: EurAAP WiAP WG				CS33: Propagation Data and Modelling for NGSO-Based Systems
MADRID	CS39a: Fundamental Challenges and Novel Methodologies in the NExt-Generation Computational Electromagnetics 1		CS39b: Fundamental Challenges and Novel Methodologies in the NExt-Generation Computational Electromagnetics 2		WG7: EurAAP EM Technologies for Life Sciences WG				A08: Antennas and Concepts for Communication, Radar and Sensing
THE HAGUE	CS32a: Electromagnetic Information Theory 1		CS32b: Electromagnetic Information Theory 2						CS22: Antennas and RF Propagation Modelling for Implants and Wearable Sensors
GLASGOW					WG3: EurAAP Active Array Antennas WG				
STOCKHOLM			IW6: Industrial Workshop – IMST						IW7: Industrial Workshop – CADFEM
DAVOS									
EDINBURGH				Zhong Chen			Christina Larsson		
BERLIN				Stefano Maci			Filiberto Bilotti		

Information about the Poster sessions

- P3-A01: Antennas for RFID and Sensors
- P3-A02: Millimetre-wave and THz for Terrestial Networks
- P3-A03: Slotted-Waveguide and Leaky-Wave Antennas
- P3-E01: Computational and Numerical Techniques
- P3-E02: Other Topics on Electromagnetics
- P3-M01: Measurement Topics 2
- P3-P01: Advances in Radar, Localisation and Sensing
- P3-P02: Propagation for Smart Electromagnetic Environments

19:00-22:45 Conference Dinner - Aviva Stadium



FRIDAY, APRIL 24th

	08:30–10:10	10:10–10:40	10:40–12:20	12:40–13:10
MAIN AUDITORIUM				Closing ceremony
BARCELONA	A28a: Phased Array Antenna Design 1	COFFEE BREAK	A28b: Phased Array Antenna Design 2	
COPENHAGEN	CS12a: Advances in Channel Sounding and Measurements for 6G: From cm-Wave to sub-THz 1		CS12b: Advances in Channel Sounding and Measurements for 6G: From cm-Wave to sub-THz 2	
DUSSELDORF	M05a: Recent Advances in Antenna Measurement and Over the Air Testing 1		M05b: Recent Advances in Antenna Measurement and Over the Air Testing 2	
GOTHENBURG	E02: Computational and Numerical Techniques: Array Analysis and Design		CS6: Advances in Antennas for Smart Terminals for Mobile and Satellite Communications and IoT	
KRAKOW	A27a: Patch-Based and Electrically Small Antennas 1		A27b: Patch-Based and Electrically Small Antennas 2	
LONDON	P02a: AI Techniques for Radio Propagation Assessment 1		P02b: AI Techniques for Radio Propagation Assessment 2	
PARIS	CS3a: Advanced Beam Manipulation with Metamaterial, Lenses, and Phased Arrays for 6G Communication and Sensing 1		CS3b: Advanced Beam Manipulation with Metamaterial, Lenses, and Phased Arrays for 6G Communication and Sensing 2	
PRAGUE	CS43a: Characterisation of Biological Tissues and Tissue Mimicking Materials for Electromagnetic Medical Applications 1		CS43b: Characterisation of Biological Tissues and Tissue Mimicking Materials for Electromagnetic Medical Applications 2	
ROME	A20a: Leaky Wave Antennas 1		A20b: Leaky Wave Antennas 2	
FIRENZE	SW9a: Efficient Wireless Power Transfer for Sustainable Smart Environment Sensors		SW9b: Efficient Wireless Power Transfer for Sustainable Smart Environment Sensors	
MADRID	P09a: RIS Modelling and Design for Smart Propagation Environments 1		P09b: RIS Modelling and Design for Smart Propagation Environments 2	
THE HAGUE	SW1a: AMTA Workshop: Toward Improved Standardisation of RCS Measurements		SW1b: AMTA Workshop: Toward Improved Standardisation of RCS Measurements	
GLASGOW				
STCOKHOLM				
DAVOS				

Monday, April 20

Monday, April 20 8:30 - 9:30

OC Michael McLaughlin - Think like a builder: A pragmatic approach to innovation

Room: Main Auditorium/Dublin

Monday, April 20 9:30 - 10:15

KN1 Michael McLaughlin - Think like a builder: A pragmatic approach to innovation

/ / Antennas
Chair: Adam Narbudowicz
Jobs were scarce in Ireland when Michael graduated from UCD in 1982 and he spent two years dividing his time between painting and decorating with his uncle "Dimmie" and writing code for a BBC Micro to do stock tracking and prescription labelling for pharmacies. He went on to work for Lake Datacomms (formerly Cornel Electronics) for 18 years. Then, after two years at Parthus Semiconductor, he decided to start his own venture, co-founding the microchip company Decawave in 2004. Decawave chips enable things and people to be located to millimetre level accuracy. It was the ideal application for Michael's Ultra-Wideband (UWB) inventions and has led to UWB being incorporated in every new smartphone design and car keyless entry systems. Michael's work was recognised by the Irish Academy of Engineering and he was awarded the 2019 Parsons Medal for outstanding achievement in Engineering Sciences. When Decawave was acquired by Qorvo in 2020, in Europe's largest tech exit of the year, Michael became a Senior Fellow and Head of Algorithm Development in the Qorvo UWB division. Michael has been at the forefront in defining international telecoms standards with the ITU and the IEEE since 1989 and is the inventor of 103 international patents.

Room: Main Auditorium/Dublin

9:30 Think like a Builder: A Pragmatic Approach to Innovation

Michael McLaughlin (Qorvo and Decawave, Ireland)

Theory is a powerful tool, but progress comes when we use it to build. This keynote introduces the concept of "thinking like a builder" - a pragmatic approach that applies first principles to create systems that solve real problems. As a central example, it presents the development of Complementary Zero-sum Cross-correlation (CZC) sequences, which resolve two seemingly conflicting requirements in channel sounding by achieving perfect channel estimation from a continuous periodic signal. The same practical mindset led to a new optimal convolutional code for IEEE 802.15.4a, fifty years after convolutional codes were first proposed. The keynote paper advocates applying theory through construction, where understanding becomes capability and ideas become working solutions.

Monday, April 20 10:45 - 11:30

KN2 Clare Allen - Advancing radio-wave propagation models by uniting international expertise

/ / Propagation
Chair: David Botha
Clare Allen is a specialist in the area of radiowave propagation and interference modelling with 25 years of experience in spectrum management at the UK communications regulator, Ofcom. Part of the RF Propagation team in Spectrum Group, Clare is involved in propagation research, provides advice on propagation modelling and undertakes sharing and coexistence studies in support of the efficient use of spectrum. Clare has been an active member of ITU-R Study Group 3, Radiowave Propagation, since 2008. In 2020 she became Chair of ITU-R Working Party 3M responsible for Point-to-point and Earth-space propagation. At the 2023 Radiocommunications Assembly in Dubai Clare was appointed Chair of the ITU-R

Room: Main Auditorium/Dublin

10:45 Advancing Radio-Wave Propagation Models by Uniting International Expertise

Clare Allen (Ofcom, United Kingdom (Great Britain))

The global spectrum environment is undergoing rapid transformation, driven by growing demand from a range of services and emerging technologies. Radiocommunication Study Group 3 of the International Telecommunication Union (ITU-R SG3) develops radio-wave propagation prediction models to support informed, data-driven decisions for efficient and equitable use of this finite resource. Environmental factors such as terrain, land cover, and atmospheric conditions influence radio-wave propagation and should be adequately represented. Integrating geospatial and meteorological data can improve the accuracy and reliability of predictions. However, as models become more data-intensive, it is important to balance the richness and resolution of input data with computational efficiency for accuracy and scalability. To ensure these prediction methods underpin the broader work of ITU-R Study Groups, especially in preparation for World Radiocommunication Conferences, they must be supported by high-quality, globally representative measurement data. Such datasets are essential for validating and refining prediction methods, enhancing accuracy and applicability.

Monday, April 20 11:30 - 12:15

KN3 Christopher Holloway - Rydberg Atom-Based Sensors: "Transforming Measurements and Detection of Radio-Frequency Fields and Time-Varying Signals

/ / Measurements
Chair: Anouk Hubreschen
Dr. Christopher Holloway is a NIST Fellow and an IEEE Fellow and has been at NIST for over 25 years. He is also on the Graduate Faculty at the University of Colorado at Boulder. He is an expert in electromagnetic theory and metrology, quantumoptics, Rydberg-atom systems, atom-based

atom-based and quantum-based sensors. He has a publication h-index of 69 with over 380 technical publications and has over 18,500 citations of his papers. He has 10 patents in various fields in engineering and physics. He is the Project Leader for the Rydberg-Atom-Sensor Project and is the Group Leader for the Electromagnetic Fields Group, both at NIST.

Room: Main Auditorium/Dublin

11:30 Rydberg Atom-Based Sensors: "Transforming Measurements and Detection of Radio-Frequency Fields and Time-Varying Signals"

Christopher Holloway (National Institute of Standards and Technology, USA)
Rydberg atoms offer unique properties for radio-frequency (RF) spectroscopy, enabling sensors that detect time-varying fields and communication signals without traditional antennas or front-end electronics. These atom-based devices replace conduction-electron antennas with vapor cells containing atomic-bound electrons, opening the door to new metrology tools with unprecedented accuracy. Atom-based measurements have already transformed standards for length, frequency, and time, and recent advances aim to extend SI-traceable metrology to electric and magnetic fields. Rydberg atom sensors now provide direct SI-traceable measurements of electric fields and RF power, fueling rapid progress over the past decade and inspiring diverse applications such as field and power metrology, phase and amplitude detection, angle-of-arrival, spectrum analysis, plasma sensing, sub-wavelength imaging, thermometry, and even wireless video transmission. A particularly promising application is the reception of time-varying signals. Rydberg receivers function as electrically small, broadband antennas-detecting and demodulating signals from kHz to THz with high dynamic range-while eliminating much of the conventional receiver front-end. Their capabilities will be important for future 6G systems, especially for calibrations above 100 GHz. This talk will review the development of Rydberg atom-based sensing technology and highlight its expanding range of applications.

Monday, April 20 12:15 - 13:45

WG5 EurAAP Working Group on Early Careers in Antennas and Propagation (lunchtime meeting)

Room: Stockholm

Monday, April 20 13:45 - 15:45

A23 Metasurface Antennas and Techniques

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Zvonimir Sipus (University of Zagreb, Croatia), Alberto Toccafondi (University of Siena, Italy)

Room: Barcelona

13:45 Holographic Time-Reversal Mirror with Interference Cancellation Technique for Spatially Selective Wireless Communication

Jihwan Lee (Pohang University of Science and Technology (POSTECH), Korea (South)); Sirous Bahrami (Pohang University of Science and Technology, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))
This paper proposes a holographic antenna system that acts as a time-reversal mirror to achieve multi-focus spatial beamforming scenarios with interference cancellation in the near-field region. The system utilizes an inverse design method grounded in time-reversal principles to synthesize the desired field distribution. A dipole channel matrix is introduced to generate the target wavefront by selectively activating dipole sources at specific user locations. Using time-reversal impedance modulation, the synthesized object wave is subsequently encoded onto the holographic surface to design a time reversal mirror device. An interference cancellation algorithm based on Gram-Schmidt orthogonalization is also proposed to enhance the spatial resolution between closely spaced beams. We investigate various spatial beamforming scenarios with interference cancellation for single- and multi-user applications. The proposed antenna system enables spatially selective communication, offering flexible beam shaping, polarization control, and nulling at intended locations, with applications in secure multi-user communications, wireless power transfer, and adaptive sensing.

14:05 Inverse Design of Tensor Impedance for Modulated Metasurface Antennas

Marco Faenzi (University of Siena, Italy); David González-Ovejero (Université de Rennes, France); Enrica Martini and Stefano Maci (University of Siena, Italy)
This work presents a physically consistent inverse design method for metasurface antennas based on the synthesis of tensorial surface reactance profiles. The approach solves the Electric Field Integral Equation (EFIE) using the Method of Moments (MoM), with an Hermitian reactance tensor that ensures passive and reciprocal implementation. The main challenge is to recover a finite aperture current distribution that radiates a desired far-field pattern, while the spectral content outside the visible region remains unknown. The proposed iterative synthesis, inspired by the Gerchberg-Papoulis alternating projection method, reconstructs the missing spectral information while enforcing both spatial confinement and physical realizability of the impedance. Operating directly within the EFIE framework, the algorithm provides consistent updates of the current and impedance profiles. Implemented with Gaussian ring basis functions for localized resolution and analytical matrix evaluation, the method is computationally efficient and accurately produces complex and highly directive radiation patterns.

14:25 Design of a High-Gain, Low Side-Lobes Linearly-Polarized Metasurface Antenna for mmWave Applications

Marcello Zucchi (Fondazione LINKS, Italy); Andrea Scarabosio (LINKS Foundation, Italy); Giuseppe Musacchio Adorisio and Rossella Gaffoglio (Fondazione LINKS, Italy); Marco Righero and Giorgio Giordanengo (LINKS Foundation, Italy); Fabio Morgia (HUAWEI Technologies, Italy); Francesco Vernì (Huawei Technologies, Italy); Matteo Alessandro Francavilla (HUAWEI Technologies, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)
We present the design of a high-gain, linearly-polarized metasurface antenna at a mmWave frequency of 38.5 GHz. The antenna is circular, with a with a diameter of 35λ. The metasurface is modeled as an equivalent surface impedance layer. The impedance profile is parameterized and optimized with a gradient-free algorithm, requiring the solution of the corresponding integral equation at each iteration. After optimization, the impedance is implemented by means of double anchor patches chosen from a database of precomputed geometries by matching the impedance values. The feed is designed in isolation to provide optimal surface wave launching. The final layout has been simulated considering the final feed structure. The resulting design exhibits low side-lobe levels and is compliant with ETSI Class 3 constraints.

14:45 Multifunctional Metasurface Shaped Dome for Array Performance Enhancement

Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy); Federico Puggelli and Ren Chao (University of Siena, Italy); Bruno Biscontini (Huawei Technologies, Germany); Stefano Maci (University of Siena, Italy)

Steerable antennas exhibit degraded performance when the beam is scanned off-broadside. To improve the performance of antenna arrays, additional structures such as radomes have become increasingly important in recent years. The inclusion of a static metasurface (MTS) dome in the antenna system has been previously proposed. In this study, we propose the use of a metadome (MTD) aperture shaped according to a super-ellipse profile in a multifunctional manner. This approach aims to achieve a low-profile solution that provides gain enhancement while enabling a different functionality at a higher frequency. Numerical results are presented using an element-by-element physical optics (PO) analysis, in which the MTD phase insertion is tailored to provide gain enhancement at low frequencies and grating lobe suppression at higher frequencies. The proposed beamforming system is designed to provide gain enhancement while avoiding scan blindness and grating lobes across the target frequency band.

15:05 Generation of Circularly Polarized Bessel-Gauss Beams Through Anisotropic Modulated Metasurfaces

Edoardo Negri (Consiglio Nazionale delle Ricerche,Italy); Federico Giusti (Universityof Siena, Italy);David González-Ovejero (Université de Rennes; Enrica Martini (University of Siena, Italy); Walter Fuscaldo (National Research Council (CNR), Italy)

This contribution presents a leaky-wave (LW) approach for generating circularly polarized (CP) Bessel-Gauss beams through anisotropic, spiral-shaped, sinusoidally modulated metasurfaces. The proposed method employs radiating apertures that support an inward CP cylindrical leaky wave whose attenuation constant is radially tailored to achieve the desired Gaussian tapering. The LW design workflow is first validated through a full-wave method-of-moments analysis for a CP Bessel-beam launcher. Then, it is shown how it can be effectively used to generate CP Bessel-Gauss beams with varying beam-waists. Numerical results obtained with the proposed model are presented for several representative cases at a working frequency of 26.5 GHz, with a radiating device featuring a 15 cm aperture radius.

15:25 Z-Parameter-Guided Design of Stacked Intelligent Metasurfaces for Channel Orthogonalization

Giuseppe Pettanice (University of L'Aquila, Italy); Andrea Abrardo and Alberto Toccafondi (University of Siena, Italy); Marco Di Renzo (L2S-CNRS, CentraleSupélec, UPSaclay (FR), France)

This work introduces a circuit-based multi-port network model for the design and optimization of Stacked Intelligent Metasurfaces (SIMs), targeting near-field channel orthogonalization. The SIM structure, consisting of metallic dipoles printed on stacked layers above a finite ground plane, is characterized by its Z-parameter matrix, extracted from full-wave electromagnetic simulations to capture mutual coupling and near-field interactions. The Z-matrix serves as the electromagnetic signature of the system and enables offline optimization of dipole loading networks. The optimization, restricted to phase-only load tuning is formulated to synthesize transfer functions that enhance diagonal dominance, thereby reducing inter-channel interference and improving modal orthogonality. Results demonstrate that Z-parameter models effectively guide phase-only design of stacked metasurfaces, achieving accurate synthesis of target transfer behaviors within a circuit framework. The method provides a computationally efficient and scalable tool for early-stage functional optimization of SIM-based architectures.

Monday, April 20 13:45 - 15:45

A32 RFID and Sensor Antennas

TO4 RF sensing for automotive, security, IoT, and other applications / / Antennas
Chairs: Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok & The Sirindhorn International Thai-German Graduate School of Engineering, Thailand), Ignacio Gil (Universitat Politècnica de Catalunya, Spain)
Room: Krakow

13:45 Miniaturized and Ultra-Flexible RFID Temperature Logger for Smart Pharmaceutical Packaging

Adina B. Barba (University of Rome Tor Vergata, Italy & Radio6ense Srl, Italy); Nicola D'Uva (RADIO6ENSE srl, Italy); Sara Amendola (University of Rome Tor Vergata & Radio6ense srl, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy)

Temperature excursions during transportation and storage pose a significant threat to pharmaceutical drugs integrity, particularly for thermally sensitive formulations. While cold chain protocols are well established for refrigerated or frozen drugs, ambient formulations often lack adequate protection, particularly during logistics phases. This work presents a miniaturized and fully flexible Ultra High Frequency (UHF) Radio Frequency Identification (RFID) temperature logger, designed for integration into the cap of standard pharmaceutical bottles. The device integrates a compact Planar Inverted-F Antenna, fabricated on a flexible polyimide substrate, and is powered by two ultra-thin zinc printed batteries, enabling both passive and battery-assisted operation. A first prototype, with a total thickness of just 1.1 mm and a circular footprint of 26.5 mm in diameter, was fabricated and experimentally validated. Electromagnetic measurements demonstrated a realized gain of -11.5 dB, corresponding to a theoretical read range of 1.16 m.

14:05 Physical Unclonable Function (PUF) Based on Laser-Induced-Graphene (LIG) UHF Antennas

Francesca Nanni and Gaetano Marrocco (University of Rome Tor Vergata, Italy)

Physical Unclonable Functions (PUFs) provide lightweight authentication for the Internet of Things, enabling secure identification in low-cost, batteryless platforms such as passive RFID tags. This work demonstrates a wireless and eco-sustainable PUF implementation based on Laser-Induced Graphene (LIG) UHF-RFID antennas interrogated in the near field. The intrinsic fabrication randomness of LIG acts as a source of physical entropy, amplified by reactive coupling effects between tag and reader. A dedicated signal-processing pipeline converts amplitude and in-phase/quadrature (I/Q) responses into reproducible binary fingerprints, whose statistical properties were evaluated through standard cryptographic metrics. Experiments on 30 nominally identical tags reveal up to 70 independent bits, with entropy close to 1, and multiple uncorrelated key families generated by varying the interrogation orientation.

14:25 Textile-Based Bluetooth Antenna Sensor for Continuous Respiratory Health Monitoring

Mariam El gharbi and Jamal Abounasr (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat Politecnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain)

Wearable systems provide a promising approach for monitoring vital signs, with respiration being one of the most important health indicators. Conventional solutions remain limited due to discomfort, and robustness issues. In this work, we propose a wireless communication platform specifically designed for real-time respiratory monitoring. The system employs a stretchable belt incorporating an embroidered loop antenna sensor, integrated with a custom-designed compact Bluetooth transmitter (17.145 × 11.303 mm²) located on the abdomen.The antenna sensor operates at 2.4 GHz, where breathing activity is monitored through variations in the received signal strength indicator (RSSI) linked to abdominal motion during inhalation and exhalation. Measurements carried out on a male subject demonstrated reliable detection of diverse respiratory patterns, including eupnea, hypopnea, hyperpnea, and Biot's breathing.

14:45 Towards Wireless Passive Sensors Based on MEMS Resonators

Bocar Ndaw (CEA LETI, France & Université Grenoble Alpes, France); Pomme Hirschauer (LAAS-CNRS, France); Olivier Rance (Université Grenoble Alpes, France); Romain Alcesilas (Université Gustave Eiffel, France); Bernard Legrand (LAAS-CNRS, Université Toulouse, France); Hervé Aubert (Laboratory of Analysis and Architecture of Systems & Institut National Polytechnique de Toulouse, France); Christophe Delaveaud (CEA-LETI, France); Marc Sansa (CEA-Leti, France); Camille Jouvaud (CEA LETI, France)

This paper reports preliminary measurements on a MEMS resonator aimed at developing a passive wireless sensor based on intermodulation principles. By exploiting the nonlinear response of a low-frequency MEMS device, we demonstrate two-tone heterodyne excitation at distinct carrier frequencies, extending up to the 868 MHz ISM frequency band of the antenna in which the MEMS will be integrated. This technique offers a major advantage: it enables selective detection of the MEMS response while effectively rejecting electromagnetic clutter, thereby improving both the potential reading range and sensitivity for future wireless sensing applications.

15:05 A Passive Reconfigurable Monopole Array Controlled by Guided RFID Control Nodes

Francesco Lestini (University of Rome Tor Vergata, Italy); Alessandro Di Carlofelice and Piero Tognolatti (University of L'Aquila, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy)

The increasing demand for reconfigurable microwave networks in 5G/6G, satellite, and sensing applications requires solutions that are energy-efficient, scalable, and low-cost. Conventional active architectures based on beamforming chips or FPGA-controlled switches provide accurate control but suffer from high power consumption, complex wiring, and limited suitability for battery-less or distributed systems. To address these limitations, the authors recently introduced the concept of a guided-mode reconfigurable architecture, where commercial Radio Frequency Identification (RFID) Integrated Circuits (ICs) are directly embedded into transmission lines and act as passive, uniquely addressable control nodes. Unlike previous over-the-air schemes, this approach exploits the same guided-wave structure that carries the service signal to deliver power and control data, collapsing service and control layers in a more integrated architecture. In this paper, we present a proof of concept consisting of a four-monopole reconfigurable array, experimentally demonstrating the feasibility of RFID-enabled guided-wave reconfiguration for programmable and energy-autonomous microwave systems.

Monday, April 20 13:45 - 15:45

A35 Waveguide Feed Based Antennas

T03 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain), Qi Luo (University of Herfordshire, United Kingdom (Great Britain))

Room: Rome

13:45 Mm-Wave Pyramidal Horn Antenna with Printed Ridge Gap Waveguide Excitation

Desalegn Kassaw Belete (XLIM Research Institute University of Limoges, France); Marc Thevenot (XLIM-UMR CNRS 7252, University of Limoges, France); Cyrille Menudier (XLIM Université de Limoges, France)

In this paper, a 50Ω printed ridge gap waveguide (PRGW) has been designed and integrated with a transition to a hollow waveguide to efficiently excite the aperture of a planar pyramidal horn antenna operating in the 140-158 GHz frequency range. Impedance matching and field mode coupling between the 50 Ω line and the horn aperture are achieved through the use of a matching patch and a back-short cavity. The multilayer stepped horn is realized using PCB substrates, where the aperture is formed by stepped air cavities and the walls are implemented with an artificial magnetic conductor (AMC) surface. This configuration creates an inter-layer boundary between perfect electric conductor (PEC) and perfect magnetic conductor (PMC)surfaces, effectively preventing electromagnetic field leakage even in the presence of accidental gaps between layers. The planar horn excited with the transition achieves a maximum realized gain of 13.4 dBi and a bandwidth of 12.08%.

14:05 Design of a X-Band Substrate Integrated Waveguide to Circular TE01 Mode Combiner for High Power Applications

Fethi Arda Turgut (Istanbul Technical University, Turkey & Aselsan Inc., Turkey); Volkan Acıkel (Aselsan Inc., Turkey); Kamil Karacuha (Istanbul Technical University, Turkey)

Achieving high output power from a single source is limited by physical constraints, making the combination of multiple low-power sources a practical solution for highpower systems. Standard multi-stage combiners often introduce excessive loss and complexity, whereas single-stage techniques enable efficient power combination with reduced loss and compact implementation. In this work, a single-stage 40-port lowloss power combiner is developed using substrate integrated waveguide (SIW) technology coupled to an air-filled circular waveguide (CWG) cavity operating in the TE01 mode. The design achieves an insertion loss of 0.25 dB, return loss of 15 dB, and amplitude imbalance below 0.2 dB over 8.8-9.5 GHz. The 26.5 mm circular cavity radius allows high port density while maintaining impedance uniformity. Due to the azimuthally symmetric Eϕ-field and optimized stub matching at the SIW- CWG junctions, balanced power combining with less than 0.8 ◦ phase deviation is obtained, offering an efficient and compact X-band solution.

14:25 Coupler-Free Dual-Polarized Monopulse Antenna at V-Band Using Hybrid Ridge-Groove Gap Waveguides

Antonio González-López (Universitat Politècnica de València & Antennas and Propagation Lab - iTEAM, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Jose I. Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain)
This paper presents the design and full-wave simulation of a compact dual-polarized monopulse antenna operating at 60 GHz. The antenna is implemented entirely in metal using a hybrid Ridge Gap Waveguide (RGW) and Groove Gap Waveguide (GGW) architecture. Six radiation patterns are generated-two sum and four difference beams-enabling azimuth and elevation monopulse operation in both polarizations. Unlike conventional networks based on bulky hybrid couplers or multilayer assemblies, the proposed design exploits the intrinsic phase-shifting behavior of RGW and GGW dividers to realize each comparator network within a single metallic layer. Simulations demonstrate high radiation efficiency, deep nulls in the difference patterns, and strong inter-port isolation. The compact and modular topology makes the antenna a promising candidate for next-generation radar sensing and 6G communication systems.

14:45 Miniaturized Antenna with Configurable Radiation Pattern Based on SIW Pedestal Loaded Cavity Resonator

Thom van Zeijl (Eindhoven University of Technology, The Netherlands); Petrie Meyer and Leanne Bodenstein (Stellenbosch University, South Africa); Ulf Johannsen and Elmine Meyer (Eindhoven University of Technology, The Netherlands)
SIW pedestal resonator structures are miniaturized solutions with comparable Q to standard SIW resonators. Expansion to a filtering antenna (filtenna) has only been shown utilizing a patch radiator and the question is if the pedestal structure itself can be utilized as a radiator for pedestal filtenna design. Therefore, this paper investigates the pedestal resonator itself as antenna. Two different designs based on the integration layer of the antenna are discussed, where design 1 has a radiation pattern similar to a monopole and design 2 has a radiation pattern of one beam pointing in the broadside direction. To support integration with SIW pedestal resonators for higher-order filtenna responses, capacitive coupling is utilized for excitation. The antennas achieve a 10 dB return loss bandwidth of 0.9% and 1% at 7 GHz for design 1 and 2 respectively. Increasing ground plane size modifies the radiation pattern and improves antenna efficiency for design 1.

15:05 Single Ridge Slotted Waveguide Antenna for Ka-Band Airborne SAR Application

Alicja Schreiber (German Aerospace Center, Germany); Bernd Gabler (German Aerospace Center (DLR), Germany)
This work presents the development of a single ridge linear slotted waveguide antenna array featured by 56% reduced cross section, designed for a Ka-band airborne synthetic aperture radar system with the frequency of operation of 35.5 GHz. The modified dimensions offer the potential for creating a fully polarimetric antenna array that generates grating lobes free far field patterns in both azimuth and elevation planes. The applied differential feeding technique ensures the achievement of a stable antenna performance over the specified frequency band, guaranteeing a constant beam pointing. The introduced antenna exhibits a narrow beam in the azimuth plane with a half-power beamwidth of 4.5° and realized gain of 17 dBi. The antenna prototype has been manufactured by means of eroding and milling techniques and measured in an in-house compact antenna test range. The obtained results show very good agreement with the simulated data, validating the proposed design.

15:25 Interfacing Dual-Polarized Waveguide Direct Radiating Arrays with Front-End Electronics

Roger Montoya-Roca (Thales Alenia Space, Consiglio Nazionale Delle Ricerche and Politecnico di Torino, Italy); Carlos Vazquez-Sogorb (Thales Alenia Space, Italy); Fabio Paonessa (Consiglio Nazionale Delle Ricerche (CNR-IEIIT), Italy); Mauro Lumia (CNR, Italy); Giuseppe Addamo (Cnr-Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni, Italy); Oscar Peverini (IEIIT-CNR, Italy); Davide Maiarelli (Thales Alenia Space, Italy); Giovanni Gasparro (THALES ALENIA SPACE ITALIA, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)
This paper investigates the challenging interface between Ka-band waveguide-based arrays with the transmit/receive modules in printed circuit boards. To overcome the limitations associated with this integration, a novel and highly compact waveguide end-launcher is proposed. The design supports dual-circular polarization within the Ka-band downlink frequency range (17.7 - 20.7 GHz) without requiring re-meshing layers or expanders to interface with the transmit/receive modules. The proposed solution effectively addresses the constraints of conventional in-line waveguide end-launchers, which are restricted to single-mode or single polarization excitation per port.

Monday, April 20 13:45 - 15:45

CS13 Toward Sustainable IoT: Innovations in RF and Antenna Materials, Design, and Fabrication

TO4 RF sensing for automotive, security, IoT, and other applications / Convened Session / Antennas
Chairs: Gholamhosein Moloudian (Tyndall National Institute, Ireland), Chaoyun Song (King's College London, United Kingdom (Great Britain))

Room: Copenhagen

13:45 A Novel Broadband Omnidirectional Monopole Antenna for IoT Wireless Communication

Guan-Long Huang and Min-Hao Zhao (Foshan University, China); Zi-Yu Pang (University of Macau, Macao); Guangguang Yang (Foshan University, China); Wei Lin (The Hong Kong Polytechnic University, Hong Kong); John Ioannis Yiannis Vardaxoglou (South China University of Technology, China); Biqun Wu (Broadradio Communication Technology Company Limited, China); Khujayarov Ilyos (Samarkand Branch of Tashkent University of Information Technologies, Uzbekistan); Zaid Ahmad (Universiti Putra Malaysia, Malaysia & COMSATS University Islamabad, Pakistan); Asim Ali Khan (COMSATS University, Pakistan)
This paper presents a novel broadband omnidirectional monopole antenna integrated with an Archimedean spiral ring for indoor Internet of Things (IoT) wireless communications. The proposed antenna addresses coverage issues in weak signal areas by eliminating the radiation null at the zenith and widening the radiation beam compared with conventional monopoles. It achieves good impedance matching over the 3.4-5.5 GHz frequency range, with a relative bandwidth of approximately 50%. At 4.2 GHz, the antenna exhibits a zenith gain of 2.86 dBi and a minimum horizontal gain of -2.81 dBi. The design features a simple structure, stable omnidirectional radiation, and wide beam coverage, making it a promising candidate for mitigating indoor signal blind spots in 5G IoT applications.

14:05 Custermized ToolBox for Fast Path Loss Evaluation in Wearable and Implantable IoT Systems

Yiwen Ding and Chaoyun Song (King's College London, United Kingdom (Great Britain)); Panagiotis Kosmas (National Centre for Scientific Research Demokritos, Greece)
This paper presents a computational toolbox for rapidly evaluating in-body to on-body path loss in biomedical applications including wearable and implantable devices. The platform integrates a voxel-based human body model with a tissue dielectric database described by the Cole-Cole equation. Through a graphical user interface, users can select specific organs, skin regions, and operating frequencies (2.45 GHz and 5.8 GHz), and calculate the losses along multiple randomly sampled trajectories between implanted and external antenna locations. The model incorporates tissue absorption, reflection, refraction, scattering, and free-space loss, while applying a body mass index (BMI)-based scaling factor to represent individual variability. Simulation results indicate that the tool can reproduce general attenuation trends of in-body to on-body propagation under different frequencies and tissue conditions, providing a preliminary yet useful framework for analyzing electromagnetic signal propagation loss in wearable and implantable communication and IoT systems.

14:25 Laser-Induced Graphene Antennas Embedded in Thermoplastic Starch Films for Sustainable IoT Applications

Alessio Mostaccio, Federica Pucci, Alessandra Bianco and Gaetano Marrocco (University of Rome Tor Vergata, Italy)
This work presents the fabrication process for antennas entirely made from edible and biodegradable materials. The proposed technology combines a thermoplastic starch (TPS) film acting as dielectric substrate with a conductive trace made by Laser-Induced Graphene (LIG). A dedicated transfer process enables the integration of a pre-scribed LIG pattern, originally produced on a laser-compatible polymer, into the starch matrix. The method enables robust embedding of the conductive pattern without the need for metallic elements. A proof-of-concept C-dipole antenna operating in the UHF RFID band validates the approach, showing promising electromagnetic performance and high structural integrity, thus paving the way toward fully eco-friendly wireless systems for food and biomedical applications.

14:45 A Methodology to Maximize Source-to-DC Rectenna Charging Efficiency for Wirelessly Powering Multiple IoT Devices

Haowen Cai and Wei Lin (The Hong Kong Polytechnic University, Hong Kong)
This paper investigates a far-field wireless power transfer (WPT) system for simultaneously powering multiple Internet of Things (IoT) devices efficiently. A 3×3 rectenna array is employed to prove the concept, and a rectenna grouping strategy based on greedy algorithm is proposed to maximize source-to-DC energy conversion efficiency. The method optimizes rectenna allocation based on device power demands and combining losses. Experimental results show that the proposed approach improves overall efficiency by 7% compared with uniform allocation, achieving higher source-to-DC conversion efficiency and enhances energy utilization for single-source to multi-target far-field WPT networks.

15:05 RF Characterization of a Battery-Less LIG-Based Sweat Sensor Integrated with an NFC Antenna for Sustainable IoT Applications

Gholamhosein Moloudian and Hassan Hammidi (Tyndall National Institute, Ireland); Sanjeev Kumar (Tyndall National Institute, Ireland & University College Cork, Ireland); Stefan Kolev and Daniela Iacopino (Tyndall National Institute, Ireland); Aidan Quinn (Tyndall National Institute, India); Brendan O'Flynn (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland)
This work presents a sodium ion sensor based on laser-induced graphene (LIG) integrated with a near-field communication (NFC) platform for sustainable Internet of Things (IoT) applications. The LIG structure was directly patterned on flexible polyimide using a mask-free laser scribing process. Wireless sensing performance was evaluated using a magnetic H-field probe connected to a vector network analyzer (VNA) positioned 2 cm from the sensing area. The reflection coefficient (S_{11}) was monitored as NaCl solutions (25–150 mM, covering physiological sweat levels) were applied, showing distinct, concentration-dependent spectral shifts. For battery-free operation, a screen-printed NFC antenna was fabricated and integrated with the LIG sensor, enabling real-time wireless interrogation at 13.56 MHz. The observed S_{11} variations confirm sensitivity to sodium ions, demonstrating a low-cost, scalable, and energy-autonomous platform that supports environmentally sustainable, battery-free wireless sensing for next-generation IoT systems.

15:25 Sustainable and Portable Chipless RFID Tag Based on Liquid Metal Conductors and Injection Moulded Microfluidic Channels

XiaoChuan Fang, Euan McDonold, Nikolaj Gadegaard and Mahmoud Wagih (University of Glasgow, United Kingdom (Great Britain))
Sustainable and circular RF circuits and devices are becoming increasingly appealing for various applications, including RF sensing and identification. Gallium-based liquid metals have been demonstrated as promising materials for implementing sustainable circuits and devices, most existing designs lack portability due to the risk of liquid metal leakage. In this paper, we propose a sustainable and portable chipless RFID tag that employs a gallium-based liquid metal conductor encapsulated within injection-moulded microfluidic channels. The proposed RFID tag features an ultrathin microfluidic channel (0.4 mm), which promotes oxidation and stabilization of the liquid metal, thereby ensuring portability. Furthermore, the injection moulding allows the RFID tag to be massively produced in a very short time. The tag can generate three identification bits within the 2-3 GHz frequency range. At the end of its life cycle, the gallium-based liquid metal conductor can be recycled at room temperature with a recovery rate exceeding 97.9%.

Monday, April 20 13:45 - 15:45

CS28 Quantum Electromagnetics - From Photonics to Quantum Computing

TO8 Fundamental research and emerging technologies/processes / Convened Session / Electromagnetics
Chairs: Amir Boag (Tel Aviv University, Israel), Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain))

Room: London

13:45 On a Volume Integral Equation Approach Modeling the Electron Beam Spectroscopy of Metallic Nanospheres

Xuezhi Zheng (Katholieke Universiteit Leuven, Belgium); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

In this paper, we consider the optical response of swift electrons passing in proximity of a metallic sphere of deep-nm size. Especially, a material model accounting for the quantum spill-out effect is applied to describe the electromagnetic (EM) response of the constituent metal, i.e., the Quantum Hydrodynamic (QHD) Model. Then, the problem is treated as a scattering problem where the fast-passing electrons act as a line source and generate the incident field, and the deep-nm sphere is seen as a scatterer re-radiating the scattered field. A volume integral equation is set up and solved by the Method of Moments algorithm where vector spherical harmonics together with nodal basis functions are used as basis and testing functions. Then, quantitative checks are done for the classical case which is a simplified version of the QHD model, while physical check is performed for the QHD model. In both cases, good agreements are seen.

14:05 Topological on-Chip Quantum Photonics for Nonlinear Biphoton Entanglement

Hesam Zaravashan (5G and 6G Innovation Centres University of Surrey, United Kingdom (Great Britain)); Maryam Khodadadi and Ali Ali (University of Surrey, United Kingdom (Great Britain)); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain))

Integrated quantum photonics promises scalable quantum technologies but remains limited by fabrication-induced disorder, phase instability, and loss, which degrade interference and entanglement. In this paper, fully topological approach to both linear routing and nonlinear biphoton generation is demonstrated on the same chip. A valley--Hall lattice is engineered to create dispersion-stable edge mode that supports spontaneous four-wave mixing with efficient phase matching. The generated signal--idler photon pairs are routed by a topological power splitter that maintains a 50:50 ratio and preserves relative phase, even through a sharp 60 degree bend. Strong suppression of backscattering and minimal dispersion enable high-visibility two-photon interference without active recalibration. This unified platform simultaneously provides robust guiding, coherent splitting, and high-fidelity entanglement generation, overcoming key limitations of conventional integrated photonics. These results establish topological photonic structures as a practical route toward fabrication-tolerant, phase-stable, and scalable quantum light sources and circuits for next-generation quantum communication, computation, and sensing.

14:25 Physical Junction Modeling for Josephson Traveling-Wave Parametric Amplifiers

Matthias Hirschbichler (University of the Bundesweh Munich, Germany); Yongjie Yuan, Johannes Stowasser and Christian Jirauschek (Technical University of Munich, Germany); Michael Haider (University of the Bundeswehr Munich, Germany & Technical University of Munich, Germany)

We present our first steps towards a self-consistent one-dimensional physical modeling approach for Josephson junctions based on the microscopic Bogoliubov-de Gennes formalism. This enables accurate prediction of key junction parameters directly from material properties and the device's geometry. The model captures the mutual dependence between the superconducting energy gap and quasiparticle states through an iterative self-consistency loop, providing a microscopic foundation for device-level parameter extraction. We apply the obtained critical currents to a circuit quantum electrodynamics model for Josephson traveling-wave parametric amplifiers from the literature. The resulting amplifier characteristics, including gain and added noise, are reasonable. Our approach bridges the gap between microscopic superconducting physics and circuit-level amplifier design, providing a predictive and self-consistent tool for optimizing superconducting quantum devices.

14:45 Quantum Computational Electromagnetic Simulations in Time Domain

Emanuel Colella (CNIT, Parma & Università Politecnica Delle Marche, Italy); Luca Bastianelli (Università Politecnica delle Marche, Italy); Valter Mariani Primiani (Polytechnic University of Marche, Italy); Franco Moglie (Università Politecnica delle Marche, Italy); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain))

This work presents a quantum-computational framework for simulating electromagnetic wave propagation based on the Riemann-Silberstein formulation of Maxwell's equations. By combining the electric and magnetic fields into a single complex vector field, Maxwell's equations are recast into a quantum dynamics equation by a Hermitian Hamiltonian evolution operator. The spatial derivatives in this Hamiltonian are discretized using a finite-difference scheme, and decomposed into tensor products of Pauli matrices followed by Trotter-Suzuki decomposition enabling the system evolution to be computed on quantum hardware. The proposed method requires only log2(N) qubits to represent N spatial points, providing an exponential memory advantage over classical solvers. To validate the approach, the TM mode formulation is applied to two representative geometries-L-shaped and cross-shaped domains-under perfect electric conductor boundary conditions. Numerical results confirm that the quantum formulation reproduces EM field propagation and reflection phenomena highlighting the method's potential for scalable quantum simulations in computational electromagnetics and photonics.

15:05 Rydberg-Atom Superheterodyne 3×3 Receiver Array for Two-Dimensional Direction-of-Arrival Estimation

Xinyi Y. I. Xu (Zhejiang University, China); Yang Yan and Jinpeng Yuan (Shanxi University, China); Wei E. I. Sha (Zhejiang University, China)

We design, implement, and characterize a planar 3×3 Rydberg-atom superheterodyne receiver array for two-dimensional DOA estimation. Probe (780 nm) and coupling (480 nm) beams are each split into a 3×3 sub-beam lattice that overlaps inside a vapor cell, producing nine independent superheterodyne receivers with inter-element spacing d=lambda/2. Element responses are modeled by the optical Bloch master equation and solved under a steady-state approximation. Using the central element as a phase reference to remove common-mode error, we reconstruct nearest-neighbor and next-nearest-neighbor waveforms with L2-norm errors of 3.27% and 3.52%. Applying MUSIC to the full array yields a clear DOA peak at elevation 73° and azimuth 180°, demonstrating accurate phase-sensitive waveform reconstruction and two-dimensional angular recovery with atom-based receivers.

15:25 Quantum Electromagnetic Curvature Resilience: An Information-Geometry Metric for Wireless Quantum Networks

Vignesh Raman (Technische Universität Dresden & CeTI, Germany); Riccardo Bassoli (Technische Universität Dresden, Germany); Frank H.P. Fitzek (Technische Universität Dresden & ComNets - Communication Networks Group, Germany)

The impending transition of wireless quantum networks from laboratory prototypes to industry adoption punctuates a critical inflection point in the development of resilient connectivity, sensing, and distributed computing. We introduce a practical, theory-grounded resilience metric-Quantum Electromagnetic Curvature Resilience (QECR)-that improves upon traditional graph or percolation scores by not only embedding quantum information geometry, but also the physics of wireless links. QECR evaluates network robustness via coarse Ricci curvature computed on a task-aware ground cost that blends state fidelity and channel distance, with completely positive trace-preserving (CPTP) maps derived from free-space optical or microwave/Rydberg front-ends. We instantiate three application profiles: CV-QKD, teleportation, and distributed sensing, and discuss use-case topologies in different regimes. Higher QECR certifies faster damping of local impairments and clearer design levers, including decisions regarding which components to harden, the selection of wavelengths or filters, and the identification of shortcut edges that yield outsized gains.

Monday, April 20 13:45 - 15:45

CS7 Small Antennas: 20 Years of Innovation and the Road Ahead

T04 RF sensing for automotive, security, IoT, and other applications / Convened Session / Antennas
Chairs: Marta Cabedo-Fabrés (Universidad Politécnica de Valencia, Spain), Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France)

Room: Gothenburg

13:45 Beyond Compact: On Antenna Co-Design and Integration in Harmonic Radar Tags

Anastasia Lavrenko and Andrei Mogilnikov (University of Twente, The Netherlands)
This paper examines the design and characterisation of miniature harmonic radar tags, where the antenna, nonlinear element, and surrounding medium form a single inseparable system. In such highly miniaturised configurations, conventional antenna figures of merit cannot be accessed independently. Tag performance is instead described by its power-conversion efficiency and nonlinear radar cross section, which capture its combined nonlinear electromagnetic behaviour. We analyse how antenna geometry, diode impedance, and matching jointly determine these system-level quantities and discuss measurement strategies when individual component evaluation is infeasible. This highlights the need for iterative, multi-domain co-design as a prerequisite for reliable operation of ultra-compact harmonic tags, particularly in applications such as insect tracking.

14:05 Small Antennas with High Efficiency and Superdirective Performance

Ming-Chun Tang (Chongqing University, China); Richard W Ziolkowski (University of Arizona, USA)
This paper presents recent progress on high-efficiency, superdirective, small mixed-multipole antennas (MMAs). Each antenna is comprised of a single interconnected multi-element radiator with a single-feed. This design offers notable practical advantages over parasitic arrays and multi-feed arrays, particularly for a small physical footprint and high radiation efficiency. Two approaches are introduced to achieve the requisite magnitude and phase distributions for superdirectivity: custom-design feed structures and single-piece self-resonant radiators. Experimental validation of these compact and electrically small MMA implementations demonstrates superdirective performance that surpasses both the Harrington and Kildal-Best ka bounds. Moreover, by exploiting quadrupole and even octupole modes, these designs achieve near-theoretical-limit directivity with high efficiency at small electrical sizes. These compelling attributes render these systems highly promising for next-generation space-constrained high-performance wireless systems, such as Internet of Things (IoT), wireless sensors, and portable terminals.

14:25 Gain Optimization of an Electrically Small Huygens Source Antenna

Jiajun Li (École Polytechnique Fédérale de Lausanne, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia); Anja K. Skrivervik (EPFL, Switzerland)
Electrically small antennas typically suffer from significant ohmic losses. To achieve optimum gain, the antenna should be able to distribute the power into the most efficient modes. Aiming to verify and apply the above mentioned optimal theory of electrically small antenna, this work further reduces the size of an existing single-substrate Huygens source antenna design. Traditionally, the feeding power of a Huygens source antennas is equally distributed to two fundamental modes to achieve higher gain and front-to-back-ratio (FTBR). However, when the antenna size is considerably small, the ohmic losses differ across two modes and equal power distribution no longer results in the maximum gain. In this work, the power ratio between TE10 (loop) and TM10 (dipole) modes is optimized by adjusting the coupling between the loop and the dipole. By adjusting the FTBR, the proposed Huygens source antenna achieves a gain of 0.88dB within a small size of ka=0.36.

14:45 Small Antennas: Closing the Gap Between Fundamental Bounds and Automated Design

Miloslav Capek, Jonas Tucek, Vojtech Neuman and Lukas Jelinek (Czech Technical University in Prague, Czech Republic)
This contribution summarizes the progress made in evaluating fundamental bounds for arbitrarily shaped antennas and the development of automated tools for synthesizing optimal topologies. The focal point of this abstract is the existence of a gap between the best theoretical performance and the best achieved performance. The theoretical exposition is supplemented with an example that incorporates all the discussed features: symmetries, background structures, regularity, and acceleration.

15:05 Frequency-Agile Ultra-Wide Tunable Band Compact Directive Antenna: Concept Development

Marwan Jadid and Christophe Delaveaud (CEA-LETI, France); Serge Bories (CEA, France); Anthony Bellion (CNES, France)
This work provides an electrically small antenna design that covers the band from 500 MHz to 3000 MHz with an unusual stable directional radiation. The antenna is frequency-agile with narrow instant bandwidths near the lowest frequency band. The antenna showed 50 instant bandwidths, with stable directional radiation pattern all over the tunable bandwidth. The theoretical foundation behind such antenna structure is explained. The proposed antenna is composed of 2 crossed radiating elements to generate a right-hand or left-hand circular polarization, but can be used with a single element if a linear polarization is needed.

15:25 Compact Tri-Band Antenna with Integrated Slot-Strip Filtering for Wi-Fi 7 Multi-Link Operation

Melissa Zebboudj (Huawei, France & EURECOM, France); Jugurtha Derbah (Huawei & Sorbonne Universite, France); Francis Keshmiri (Huawei Technologies France, France)
This paper presents a low-cost, compact tri-band antenna with an integrated filtering function, realized using a dual-PCB architecture for Wi-Fi 7 Access Point (AP) applications. The first PCB implements a dual-band array of two dipoles covering the 2.4 GHz and U-NII-1/2A [5.17-5.33 GHz] bands, the second PCB integrates a single-band array of three dipoles operating in the U-NII-3 [5.735-5.835 GHz] band. Filtering features are embedded in the antenna structure to suppress unwanted signals: the dual-band array rejects the U-NII-3 band, whereas the single-band array suppresses the U-NII-1/2A band through slots and strips. Decoupling rings provide strong port isolation, with measured S21 reaching -33 dB. The measured gains are 2.37 dBi, 3.23 dBi, and 3.21 dBi at 2.4 GHz, 5.2 GHz, and 5.78 GHz, respectively, while the radiation efficiency reaches about 63 %. Its compact size makes it suitable for Multi-Link Operation (MLO), enabling reliable Wi-Fi performance in multi-AP/multi-user FTTR deployments.

Monday, April 20 13:45 - 15:45

EO9 Electromagnetic theory: Radiation

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Giuseppe Labate (TNO, The Netherlands), Anu Lehtovuori (Aalto University, Finland)

Room: Madrid

13:45 Non-Radiating Currents and Where to Find Them: From Scattering Theory to Antenna Experiments

Giuseppe Labate (TNO, The Netherlands); Tommaso Isernia (University of Reggio Calabria, Italy); Stefano Maci (University of Siena, Italy); Andrea Alù (CUNY Advanced Science Research Center, USA); Sarin VP (Calicut University, India); Giampiero Gerini (TNO - Defence, Security and Safety, The Netherlands)

A comprehensive history and review on how the fascinating topic of non-radiating currents has been investigated is presented in this paper. From inverse scattering problems to radiationless theorems, a unified research on non-radiating currents is highlighted for the very first time in this work. Applications of non-radiating currents span from improving images in inverse scattering problems to make feasible antenna design, with a possibility to switch between radiating and non-radiating states.

14:05 Design of Curved near-Field Beams for Propagation Around Obstacles via Ray-Caustic Synthesis

Federica Anfuso, Ahsan Ullah Khan and Gino Sorbello (University of Catania, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy)

This contribution presents an approach to near-field curved beam shaping via distributed ray caustics. We propose a methodology to synthesize a beam that follow arbitrary curved trajectories, which are able to follow a curved path around known obstacles while preserving focusing features. Numerical results demonstrate that the beam largely preserves its shape in presence of obstacles, exhibiting only minor diffraction effects near the obstacles. The analysis confirms the effectiveness of the method in controlling near-field beam propagation and highlights its potential in advanced communication systems.

14:25 Mode Scattering and Radiation for an Open Circular Waveguide with a Wraparound Metallic Cylinder

Martin Norgren, John Cederling and Herman Nilsson (KTH Royal Institute of Technology, Sweden)

An open circular waveguide with a finite section covered by a thin PEC cylinder is considered, where the excitation is a mode propagating in the open part of the waveguide. On the cylinder, the surface current density is determined accurately by using an expansion into Chebyshev polynomials of the second kind. The scattered waveguide modes are found by using the Lorentz reciprocity theorem and the radiated far field is determined by the saddle-point method. Numerical results are presented for how the incident power is distributed between reflection, transmission and radiation, when varying the frequency or the length of the cylinder. The numerical accuracy is verified with respect to reciprocity and energy conservation.

14:45 Comparison of Pattern Synthesis Methods Using Magnitude Least-Squares Fitting

Ville Hirvonen, Albert Salmi and Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

We present methods for antenna array pattern synthesis based on magnitude least-squares fitting. The non-convex optimization problem is approached using semidefinite relaxation, optimization on a Riemannian manifold, and an alternating projection algorithm. In addition, the applicability of the genetic algorithm and the Wirtinger flow phase retrieval technique for pattern synthesis is evaluated. We consider both amplitude-varying and phase-only excitations. Test cases demonstrate that direct non-convex algorithms provide significantly better results than relaxed formulations, both with and without constant modulus constraints on the excitations.

15:05 Compact Antenna Beam Models Using Spherical Wave Expansion and Sparse Frequency Interpolation

Michele Pugno (University of Antwerp, Belgium & University of Stellenbosch, South Africa); Annie Cuyt (University of Antwerp, Belgium); Dirk de Villiers (Stellenbosch University, South Africa)

This paper introduces a compact representation technique for antenna radiation patterns based on Spherical Wave Expansion (SWE) and sparse frequency interpolation. The method leverages Exponential Analysis (EA) to model the frequency dependence of Spherical Wave Coefficients (SWC) with a reduced number of parameters, enabling smooth and efficient broadband characterization. The proposed approach is validated using the simulated farfield of a wideband quad-ridge flared horn antenna, demonstrating a reduction of the SWC to approximately 5% of its original size while maintaining farfield reconstruction errors below 3.5%. The algorithm provides a tunable balance between compression and accuracy, offering a powerful tool for efficient storage and analytic modeling of antenna radiation patterns across wide frequency ranges.

15:25 Physics-Informed Neural Networks for Wavefield Estimation with Absorbing Boundary Conditions

Julian Carneiro, Ahmed Ashraf and Ian Jeffrey (University of Manitoba, Canada)

A proof-of-concept physics-informed neural network (PINN) solution to the Helmholtz equation with a first-order absorbing boundary condition (ABC) is presented. We show that with an ABC boundary-loss term, a Gabor-PINN produces accurate field solutions to simple impressed sources in homogeneous media. A preliminary cost analysis for the specific PINN used herein suggests that when a first-order ABC is applicable, it may be meaningfully computationally cheaper than a perfectly matched layer (PML) alternative for an equivalent sampling scheme, though further study is needed. Results and analysis suggest that an ABC-enabled PINN architecture, once extended to scattering targets, may serve as a robust forward model for microwave imaging applications.

Monday, April 20 16:15 - 18:15

IW1 Industrial Workshop - From Materials to Orbit: Advancing Antenna Technologies for Next-Gen Connectivity (ETS-Lindgren)

/ / Antennas Andy Chung, Director of Wireless Solutions at ETS-Lindgren (Taiwan), and Juan Antonio del Real, Sales Director for EMEA at Maury Microwave (France).

Room: The Hague

Andy Chung, Director of Wireless Solutions at ETS-Lindgren (Taiwan), and Juan Antonio del Real, Sales Director for EMEA at Maury Microwave (France)

This workshop explores cutting-edge antenna innovations spanning terrestrial and non-terrestrial networks. Participants will examine electromagnetic transparency techniques that enable compact, multi-band base station antennas to share apertures while minimizing interference. The program also addresses the challenges of next-generation satellite terminals, highlighting methods for achieving and validating robust circular polarization performance under dynamic NTN conditions. Together the workshop presentations provide a cohesive view of the materials, architectures, and testing environments shaping future wireless connectivity.

Workshop Outline: This workshop consists of three 30-minute talks given by speakers from industry. The presentations will be practical and application-oriented, enabling attendees to learn measurement techniques and troubleshooting methods they can apply in their work. The goal is to provide an informal and highly interactive workshop that encourages exchange between the speakers and the audience. Speakers include Andy Chung, Director of Wireless Solutions at ETS-Lindgren (Taiwan), and Juan Antonio del Real, Sales Director for EMEA at Maury Microwave (France).

Title: Dynamic Antennas and Arrays for Enhanced Security in Wireless Networks By: Jeffrey Nanzer, MSU Research Foundation Distinguished Professor, Electrical and Computer Engineering, Michigan State University, USA
Abstract: Future 5G wireless networks will rely on multiple levels of security to ensure reliable operations in emerging areas such as smart cities, automotive networks, and IoT. Aperture-based physical layer security represents a promising approach that can be implemented in concert with traditional cryptographic security techniques. We present the design of dynamic antenna elements and dynamic antenna arrays supporting directional modulation for physical layer security. By dynamically changing the location of the phase center of the antenna or array, complex signal modulation can be imparted on the wireless signal at a range of angles outside of an unperturbed information beam, corrupting the data and making it more challenging to demodulate. Signals within the information beam remain unmodulated and recoverable, thereby creating a spatial information filter that can be used jointly with other security approaches. We describe the theory behind dynamic antennas and present the design and experimental results of single-element antennas as well as multi-element arrays.

Title: Navigating the NTN Frontier: Robust Circular Polarization Testing and Environment Validation for Next-Gen Satellite Terminals By Andy Chung, Director, Wireless Solutions, ETS-Lindgren, Taiwan
Abstract: Achieving seamless Non-Terrestrial Network (NTN) integration requires satellite terminals to maintain high polarization purity under dynamic and often unpredictable link conditions. For industrial manufacturers, the challenge is no longer just designing a circularly polarized (CP) antenna but accurately characterizing its performance at scale. This presentation focuses on the critical methodologies required to establish and validate a robust CP testing environment.

Title: Uncertainty Analysis in Antenna S-Parameter Measurements By Juan Del Real, Sales Director for EMEA, Maury Microwave, France
Abstract: Accurate characterization of antenna performance relies heavily on precise S- parameter measurements; however, these measurements are inherently affected by multiple sources of uncertainty. This paper addresses the identification, quantification, and propagation of uncertainties in antenna S-parameter measurements, with particular emphasis on reflection and transmission coefficients obtained using vector network analyzers (VNAs). Key contributors to measurement uncertainty, including instrumentation accuracy, calibration procedures, connector repeatability, cable effects, environmental conditions, and antenna positioning, are systematically analyzed.

Monday, April 20 13:45 - 15:45

M06 Recent advances in antenna test ranges, chambers and robotics

T04 RF sensing for automotive, security, IoT, and other applications / / Measurements
Chairs: Amedeo Capozzoli (Università di Napoli Federico II, Italy), Zhong Chen (ETS-Lindgren, USA)

Room: Dusseldorf

13:45 Estimation of the Uncertainty of Wall Reflectivity Measurements Using Spheres

Marc Dirix (E&C Anechoic Chambers, Belgium & RWTH-Aachen University, Germany); Amin Enayati (Emerson & Cuming Anechoic Chambers, Belgium); Joachim Vanwesemael (E&C Anechoic Chambers, Belgium)
The wall reflectivity is a proven method for verifying the reflectivity of absorber materials after their installation on the chamber walls. While the method has become a staple tool offered to customers having large measurement chambers, questions have arisen as to what dynamic range can be expected and how to get an understanding of the achieved uncertainty of the measurement results. This paper addresses these topics by measuring well known reference objects in the form of spheres which have a radar cross section of comparable size to that of the absorber covered wall.

14:05 Characterization of Reverberation Chambers at 60 GHz for Wireless Device Testing

Paola Tili (Università Politecnica Delle Marche, Italy); Alfredo De Leo (Università Politecnica dell Marche, Italy); Luca Bastianelli and Franco Moglie (Università Politecnica delle Marche, Italy); Valter Mariani Primiani (Polytechnic University of Marche, Italy)
Reverberation chambers (RC) have been widely used to perform Electromagnetic Compatibility (EMC) testing due to their statistically uniform, isotropic, and well-scattered fields. Recently, because they can emulate realistic multipath propagation environments and provide repeatable test environments, their use in wireless device testing has increased rapidly. However, as the operating frequencies of wireless devices increase, it becomes essential to study and characterize RCs at these frequencies. This paper presents the characterization of a 60 GHz RC for millimeter-wave (mmWave) wireless testing through key metrics such as the quality factor (Q) and the Rician K-Factor, highlighting the differences with respect to lower frequency ranges. The testing on a real device confirms the results obtained during chamber characterization.

14:25 Virtual Reverberation Chamber Simulation for Broadband EMI Assessment: An Alternative to Plane Wave Methods

Pon Janani Sugumaran, Chin Keong Ang and Yang Yong (National University of Singapore, Singapore)
This study introduces a new simulation method for evaluating the broadband electromagnetic interference (EMI) shielding performance of metallic enclosures using a virtual reverberation chamber (RC) model. Unlike traditional plane wave approaches that requires multiple simulations at different incidence angles and polarizations, our virtual RC implementation in CST Microwave Studio provides comprehensive angular coverage and realistic multi-path conditions in a single broadband simulation. The RC approach inherently generates statistically uniform electromagnetic field distributions through cavity reflections, eliminating the need for multiple simulation runs while capturing realistic multi-angle incidence conditions. Experimental validation following IEEE 299.1-2013 guidelines across the 2-18 GHz range shows strong agreement, with discrepancies generally below 3-5 dB. This approach not only reproduces realistic measurement conditions but also significantly reduces computational effort, offering a practical and accurate tool for EMI assessment in complex electromagnetic environments.

14:45 Dimensioning Flat Circular Radiating Panels for Plane Wave Generation

Amedeo Capozzoli and Claudio Curcio (Università di Napoli Federico II, Italy); Lars Foged (Microwave Vision Italy, Italy); Angelo Liseno (Università di Napoli Federico II, Italy); Francesco Saccardi (Microwave Vision Italy, Italy)
This work addresses the dimensioning of circular radiating panels designed to reproduce prescribed multi-frequency plane waves within a spherical Quiet Zone (QZ). Relying on the Singular Value Decomposition (SVD) analysis of the radiation operator, the proposed method enforces field synthesis constraints over a planar Quiet Plane (QP) parallel to the panel and determines the minimal panel size required to generate the desired plane waves across the band of interest. Numerical results demonstrate the accuracy of the synthesized fields and validate the effectiveness of the proposed multi-frequency dimensioning strategy.

15:05 Comparison of Turn-Table Platform Stirring and Mechanical Stirring in a Reverberation Chamber

Wenjun Xia (Nanjing University of Aeronautics and Astronautics, China); Ling Wang (Nanjing University of Aeronautics and Astronautic, China); Lei Xing and Qian Xu (Nanjing University of Aeronautics and Astronautics, China)
Stirring efficiency is a key metric for evaluating the performance of stirring technique. However, traditional mechanical stirrers offer limited efficiency. In order to improve the efficiency, we replace two mechanical stirrers with three circular turn-table platforms with randomly distributed rectangular elements. Several characteristics, including correlation coefficient, independent samples, K-factor and field uniformity (FU) have been quantified to assess the performance. The measurement results indicate that the proposed platform stirring outperforms mechanical stirring.

15:25 Radiation Characterization of Scanning Antennas at D-Band Using a Robotic Arm

Jinglin Geng, Daniele Cavallo, Juan Bueno and Nuria LLombart (Delft University of Technology, The Netherlands)
This paper presents a robotic arm-based system for the radiation characterization of antennas at D-band (110-170 GHz). The system automates measurements across complex near-field and far-field grids, capturing both co- and cross-polar components. An integrated path-planning algorithm is developed that ensures smooth, collision-free trajectories by selecting optimal joint configurations. This approach is particularly suited for characterizing integrated antennas-in-package (AiP) at millimeter-wave frequencies. The system's accuracy is validated by measuring a standard conical horn antenna, demonstrating excellent agreement between near-field to far-field transformation and direct far-field results. Finally, its flexibility is showcased by characterizing a wide-scan lens antenna, by measuring its beam-steering capability over a plus/minus 45 degrees field of view.

Monday, April 20 13:45 - 15:45

PO3 Deterministic Propagation Models

TO7 Electromagnetic modelling and simulation tools / / Propagation
Chair: Ke Guan (Beijing Jiaotong University, China), Enrico M Vitucci (University of Bologna, Italy)

Room: Prague

13:45 Differentiable Ray Tracing for THz Radio Channel Characterization with Point Clouds

Niklas Vaara and Lafir Naveeth Mohamed (University of Oulu, Finland); Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Tuomas Maatta (CubiCasa, Finland); Lam Huynh, Pekka Sangi and Miguel Bordallo Lopez (University of Oulu, Finland); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland); Janne Heikkilä (University of Oulu, Finland)

Differentiable ray tracing-based radio propagation modeling is a powerful tool for learning material properties from channel measurements. Prior approaches rely on idealized, manually crafted triangle mesh models, which often lack smaller geometric details that become important at higher frequencies. In this paper, we perform differentiable ray tracing directly on a noisy point cloud created from RGB-D images, eliminating the need for handcrafted geometry. We optimize channel parameters using THz channel measurements collected at a center frequency of 318 GHz with a 4 GHz bandwidth. Our results demonstrate that the channel characteristics can be extracted well with available measurements and ray tracing. With the optimized parameters, we achieve a mean relative rms delay spread error of less than 5% and a mean absolute error for received power of about 0.36 dB at novel receiver locations.

14:05 Multimode Optical Modelling of the BISOU Telescope

Creidhe O'Sullivan (National University of Ireland Maynooth, Ireland); Neil Trappe (NUI Maynooth, Ireland); Saoirse Doyle (National University of Ireland, Maynooth, Ireland); Morgane Loquet Le Gall, Pierre Guiot and Bruno Maffei (Institut dAstrophysique Spatiale, Orsay, France)

In this paper we describe an optical analysis of BISOU, a balloon-borne pathfinder instrument for a future space mission to measure spectral distortions of the cosmic microwave background radiation. The BISOU optics consist of a polarizing Fourier Transform Spectrometer with inputs from a sky-facing telescope and an internal calibrator. Bolometer detectors on the spectrometer focal planes are fed by multimode pyramidal horns and there are separate focal planes for low and high frequencies in the 90-1500 GHz band. Our optical analysis begins with ray-tracing for an overall design layout followed by more detailed Gaussian beam mode and physical optics analyses of the system. Since our optics are few-moded at the low-frequency end and highly over-moded at the upper frequencies, a combination of techniques are required to model beam propagation. BISOU is a French National Space Agency (CNES) Phase A study.

14:25 Fast, Differentiable, GPU-Accelerated Ray Tracing for Multiple Diffraction and Reflection Paths

Jérome Eertmans (Université catholique de Louvain, Belgium); Sophie Lequeu and Benoît Legat (UCLouvain, Belgium); Laurent Jacques (University of Louvain, Belgium); Claude Oestges (Université catholique de Louvain, Belgium)

We present a fast, differentiable, GPU-accelerated optimization method for ray path tracing in environments containing planar reflectors and straight diffraction edges. Based on Fermat's principle, our approach reformulates the path-finding problem as the minimization of total path length, enabling efficient parallel execution on modern GPU architectures. Unlike existing methods that require separate algorithms for reflections and diffractions, our unified formulation maintains consistent problem dimensions across all interaction sequences, making it particularly suitable for vectorized computation. Through implicit differentiation, we achieve efficient gradient computation without differentiating through solver iterations, significantly outperforming traditional automatic differentiation approaches. Numerical simulations demonstrate convergence rates comparable to specialized Newton methods while providing superior scalability for large-scale applications. The method integrates seamlessly with differentiable programming libraries such as JAX and DrJIT, enabling new possibilities in inverse design and optimization for wireless propagation modeling. The source code is openly available at https://github.com/jeertmans/fpt-jax.

14:45 Robust Path Association for Grid-Based Channel Emulation Technique: Analysis on Spatial Consistency and Grid Resolution

Auksarapak Kietkajornrit, Nopphon Keerativoranan and Jun-ichi Takada (Institute of Science Tokyo, Japan)

Wireless channel emulation enables reproducible testing of communication systems by replicating realistic propagation conditions in cyberspace. Deterministic modeling based on ray tracing provides high site-specific accuracy but is computationally expensive for dynamic scenarios. Grid-based channel emulation offers a practical compromise, where multipath component (MPC) parameters are precomputed at grid nodes and interpolated to synthesize channel responses. A key challenge in this framework is path association, since MPCs estimated independently at each node in a grid must be linked to ensure spatial consistency. This work introduces an iterative DBSCAN-based association algorithm that provides flexible and robust associations, together with inter-grid handling mechanism to preserve consistency across neighboring grids. The proposed approach is validated in a simulated environment and compared with an existing method, with additional investigation into the effect of grid resolution on interpolation performance.

15:05 Impact of Antenna Orientation on RIS-Assisted mmWave Communication in Tunnel Environment

Yiran Wang (Beijing Jiaotong University, China); Aline Habib (IMT Atlantique, France); Charlotte Langlais (IMT Atlantique & Lab-STICC, France); Marion Berbineau (COSYS, Université Gustave Eiffel, IFSTTAR, Univ Lille & Railenium, France); Danping He and Ke Guan (Beijing Jiaotong University, China)

Millimeter-wave (mmWave) communication in tunnel environments faces issues of potential severe signal attenuation and limited coverage. Reconfigurable Intelligent Surfaces (RIS) can offer a promising solution to enhance tunnel channel performance. However, antenna deployment and orientation in RIS-assisted systems remain a challenge. Based on previous studies on RIS in tunnels, this paper employs ray-tracing (RT) simulations to evaluate the impact of different transmitter (Tx) and receiver (Rx) antenna settings on the received power in static and dynamic scenarios. The results demonstrate that proper optimization of the RIS deployment and antenna orientation can significantly improve signal coverage and link stability, with particularly notable benefits in dynamic communication environments. This study provides insights for RT-based RIS applications in complex tunnel scenarios and highlights research related to adaptive control and optimized deployment.

15:25 Analytical Model for the Coherent Scattered Field from Finite Gaussian Random Surfaces

Giacomo Melloni and Torbjörn Ekman (Norwegian University of Science and Technology, Norway)

This paper presents a novel, simple closed-form expression for the main lobe of the coherent scattered field from a finite Gaussian random surface. To reduce the effect of edge currents on the borders of the finite tile, a Gaussian tapering function is applied to the integral equation in the Kirchhoff Approximation under Physical Optics. Validation through Monte Carlo simulations using CST Studio Suite demonstrates strong agreement between the simulated pattern and the analytical expression for the main lobe, even for slant incident angles.

Monday, April 20 13:45 - 15:45

SW2 **EuCAP Twentieth Anniversary Workshop**

/ / Propagation

Room: Paris

Stefania Monni (EurAAP Chair, TNO, The Netherlands),
Conor Brennan (General Chair of EuCAP2026, Dublin City University, Ireland)
Juan Mosig (EurAAP Founder),
Bruno Casali (EurAAP Founder)
Cyril Mangenot (Former Chair of EurAAP)
Stefano Maci (Founder and Director of the European School of Antennas, University of Siena, Italy)
Oscar Quevedo Teruel (EuCAP2025 General Chair, KTH, Sweden)
George Goussetis (EuCAP2024 General Chair, Herriot Watt, UK)
Adam Narbudowicz (Chair of WG on Small Antennas, DTU, Denmark)
Bart Smolders (Chair of WG on Active Array Antennas, Eindhoven University of Technology, The Netherlands)
Tian Hong Loh (Chair of WG on Measurements, National Physical Laboratory, UK)
Thomas Kürner (EuCAP2027 General Chair, TU Braunschweig, Germany)
Lorenzo Luini (Chair of WG on Propagation, Politecnico di Milano, Italy)
Francesca Vipiana (EurAAP WG Coordinator, Politecnico di Torino, Italy)
Zvonimir Šipuš, (EuCAP StC Chair, University of Zagreb, Croatia)

EuCAP26 is the twentieth edition of the EuCAP conference. Since its beginning in Nice in 2006 EuCAP has grown to become one of the premier international conferences in the area of antennas, propagation, electromagnetics and measurements. This celebratory workshop will bring together past conference chairs, as well as EurAAP chairpersons and Working Group Chairs, to discuss the history, impact and future direction of EuCAP. Amongst other aspects the workshop will examine the development of our technical discipline through the lens of the EuCAP "Best Paper Awards" over the last 20 years. We close by discussing the future opportunities for EuCAP's development.

This two-hour scientific workshop brings together a series of presentations by key figures who have shaped EuCAP since its beginning, 20 years ago. Drawing on their unique perspectives and experiences, the talks will reflect on EuCAP's journey, from its origins and milestones to its current impact and future ambitions, offering an overview of past achievements, present challenges, and the horizons yet to be explored:

Welcome
The two main achievements of EurAAP: EuCAP and ESoA:
The foundation and history of EuCAP
The evolution from ACE to ESoA
Review of thematic areas of EuCAP through the lens of the best paper winners in the areas of Electromagnetics and Antenna theory, Applied antenna technology, Propagation and Measurements
Perspectives from the EurAAP Working Groups:
The future of EuCAP

The agenda is as follows:
13:45- 13:47 Stefania Monni (EurAAP Chair, TNO, The Netherlands), Conor Brennan (General Chair of EuCAP2026, Dublin City University, Ireland)
Welcome
13:47 - 14:12 Juan Mosig (EurAAP Founder), Bruno Casali (EurAAP Founder) and Cyril Mangenot (Former Chair of EurAAP), Stefano Maci (Founder and Director of the European School of Antennas, University of Siena, Italy)
The two main achievements of EurAAP: EuCAP and ESoA:
The foundation and history of EuCAP
The evolution from ACE to ESoA
14:12 - 14:27 Oscar Quevedo Teruel (EuCAP2025 General Chair, KTH, Sweden)
Review of thematic area: Electromagnetics & Antenna Theory
14:27 - 14:42 George Goussetis (EuCAP2024 General Chair, Herriot Watt, UK) Adam Narbudowicz (Chair of WG on Small Antennas, DTU, Denmark) Bart Smolders (Chair of WG on Active Array Antennas, Eindhoven University of Technology, The Netherlands)
Review of Thematic Area: Applied Antenna Technology
14:42 - 14:57 Tian Hong Loh (Chair of WG on Measurements, National Physical Laboratory, UK)
Review of Thematic Area: Measurements
14:57 - 15:12 Thomas Kürner (EuCAP2027 General Chair, TU Braunschweig, Germany) Lorenzo Luini (Chair of WG on Propagation, Politecnico di Milano, Italy)
Review of Thematic Area: Propagation
15:12 - 15:32 Francesca Vipiana (EurAAP WG Coordinator, Politecnico di Torino, Italy)
Perspectives from the EurAAP Working Groups
15:32 - 15:45 Zvonimir Šipuš, (EuCAP StC Chair, University of Zagreb, Croatia)
The Future of EuCAP

Monday, April 20 16:15 - 18:15

A25 On Board Satellite and Ground Station Antennas

TO3 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Benedetta Fiorelli (European Space Agency, The Netherlands), Zoya Popovic (University of Colorado at Boulder, USA)
Room: Rome

16:15 Additively Manufactured Quadrifilar Helix for Fast CubeSat Antenna Prototyping

Alfonso Tomás Muriel-Barrado and Belén Prada-Otero (Universidad Autónoma de Madrid, Spain); Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Antonio Alex-Amor (Universidad Autónoma de Madrid, Spain)

This paper presents the design, manufacturing and measurement of a Quadrifilar Helix Antenna (QHA) for fast CubeSat antenna prototyping. The design is made for Telemetry, Tracking, and Command (TT&C) applications centred on 2.2 GHz. The QHA is 3D printed in an stereolithography (SLA) printer and then electroplated to make it conductive. Prior to this, a parametric study is carried out and the impact of additive manufacturing is analyzed based on the diameter of the wire. Based in this analysis, a QHA prototype is manufactured and measured. The preliminary measurements are promising, and validate the proposed methodology, which provides a low-cost, rapid and efficient way to prototype and validate wire antenna designs for application in CubeSats.

16:35 Deployable L-Band Yagi-Uda Antenna for a 3U CubeSat Using a Pantograph Mechanism

Conor M Lambe, Geoffrey Hilton and Andrew C M Austin (University of Bristol, United Kingdom (Great Britain))

A deployable L-Band, 5-element Yagi Uda antenna with a collapsible pantograph mechanism is proposed for a 3U CubeSat platform. A rapid prototyping approach is used to validate the efficacy of the mechanism and antenna performance prior to design optimization. The fabricated antenna operates at 1.9 GHz with a measured 340 MHz bandwidth, (18% fractional bandwidth). A maximum directivity of 9.7 dBi is measured with side lobe levels of -13 dB and -8.4 dB, and beamwidths of 52.3 ◦ and 62.2 ◦ for the E- and H-plane respectively, which agree well with simulations. The possibility of extending the antenna beyond 5 elements is investigated through simulation, indicating that an increased directivity is possible with more directors.

16:55 Development of Antennas Operating in UHF and S-Band for 2U CubeSat Communication Systems

Magdalena Mbuy Miko Mikue (Universidade Federal Do Pampa, Brazil); Edson R. Schlosser (Universidade Federal do Pampa, Brazil); Juner M Vieira (Universidade Federal Do Pampa (Unipampa), Brazil); Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil); Abdou-Halique A. A. Bouari (Unipampa, Brazil); Luiz Gustavo GP Paulista da Silva (UNIPAMPA, Brazil)

This paper presents the design of two antennas for a 2U CubeSat: a sequentially rotated 2x2 antenna array composed of modified Yagi-Uda antennas for uplink in UHF and a dielectric resonator antenna (DRA) optimized for downlink in S-Band. Both antennas are designed to achieve right-hand circular polarization (RHCP) as the main polarization. The design of the feeding system for the UHF antenna along with its practical implementation are discussed. The results show that the integration of both antennas was successful, yielding very low-weight and compact solutions for CubeSat applications.

17:15 Dual K/Ka-Band 3D-Printed Ortho-Mode Transducer for CubeSat Applications

Federico Dogo (University of Trieste, Italy); Emanuele Vaglio (University of Udine, Italy); Nicholas Sesto Gorella (Picosats, European Union); Giulia Buttazzoni (University of Trieste, Italy)

Small satellites require compact, lightweight, costeffective, and high-performance antenna systems, including components like Ortho-Mode Transducers (OMTs). Traditional manufacturing methods limit OMT design complexity, creating procurement challenges. Additive Manufacturing (AM) offers new opportunities by enabling innovative materials, part lightweighting, intricate geometries, and advanced surface finishes. However, existing studies focus only on simple, single-band OMTs, leaving a gap in understanding the functional and economic impacts of AM. This study investigates a dual K/Ka-band OMT, specifically designed for CubeSats, featuring a compact, symmetric structure produced via Powder Bed Fusion - Laser Beam. The results show strong alignment between simulations and experimental data, confirming excellent functional performance. Additionally, the economic analysis demonstrates the cost-effectiveness of this approach, highlighting its suitability for small satellite applications.

17:35 Active Antennas Based on True Time Delay Discrete Lenses Twenty Years of Developments Supported by the European Space Agency

Pasquale Giuseppe Nicolaci (TICRA, Denmark); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

In this contribution the main results achieved in more than twenty years of research and developments supported by the European Space agency on active antenna based on true time delay discrete lens are presented. Particular emphasis is placed on three-dimensional lenses featuring some advantages and limitations as compared to bidimensional cylindrical configurations.

17:55 The Copernicus Imaging Microwave Radiometer (CIMR): Antenna Architecture and Development Status

Benedetta Fiorelli (European Space Agency, The Netherlands); Stefania Gemma (TAS-I, The Netherlands); Vincenzo Lubrano (Thales Alenia Space Italy, Italy); Riccardo Rigato (TAS-I, Italy); Pierluigi Cecchini (Thales Alenia Space Italia S.p.A., Italy); Pasquale Martinelli (Thales Alenia Space Italy, The Netherlands); Claudio Galeazzi (European Space Agency, ESTEC, The Netherlands); Andrea Marchetti (Thales Alenia Space Italy, Italy); Rolv Midthassel (European Space Agency ESTEC, The Netherlands); Giacinto De Paris (ESA ESTEC, The Netherlands); Rosaria Palummo (Thales Alenia Space, Italy); Marcello Sallusti and Mariel Triggianese (European Space Agency, ESTEC, The Netherlands); Craig Donlon (ESA/ESTEC, The Netherlands)

The Copernicus Imaging Microwave Radiometer (CIMR) is one of the six Copernicus Expansion (CopEx) Missions. The CIMR Antenna sub-system is conceived to respond to challenging RF and geometrical requirements demanded by the Instrument, a conical scanning total power, multi-channel microwave radiometer spinning at 7.8 rpm around the satellite nadir axis. The antenna provides high spatial resolution via an ~8 m Large Deployable Reflector Subsystem. Operating at five frequency bands ranging from L- to Ka-band, the antenna includes a 50-RF-port feed cluster that ensures the required image continuity. This paper presents an overview of the CIMR antenna architecture and sub-systems, its key design and implementation challenges, the EQM status and verification approach.

Monday, April 20 16:15 - 18:15

A30 Reflectarray and Transmitarray Antennas

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Antonio Clemente (CEA-Leti, France), Lei Wang (Lancaster University, United Kingdom (Great Britain))
Room: Barcelona

16:15 Efficient Transmitarray Layout Design for Future Wireless Communications

Daniel R. Prado (Lancaster University, United Kingdom (Great Britain)); Xuekang Liu (Imperial College London, United Kingdom (Great Britain)); Claudio Paoloni, Rosa Letizia and Lei Wang (Lancaster University, United Kingdom (Great Britain))

An efficient methodology is proposed for the analysis and design of transmitarray antennas. It is based on the use of an in-house method of moments (MoM) assuming local periodicity for the unit cell analysis. The incident field on the transmitarray is obtained from a full-wave simulation of the feed. This field is also simulated in an extended grid to account for spillover. The real angle of incidence at each element is employed in an iterative routine that adjusts the geometry of each unit-cell to match the required phase-shift. This procedure is employed to design a circular transmitarray antenna at W-band using a unit cell comprised of two sets of five parallel dipoles in two different layers. The overall procedure takes less than 30 minutes using the in-house MoM on a regular laptop, showing the capabilities of the proposed technique for the design of transmitarrays for future wireless communications.

16:35 Stacked Transmitarray Antenna with near-Zero Axial Ratio and Efficient Beam Scanning

Orestis Koutsos (CEA Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-Leti, France)

This paper presents a 2-bit passive stacked transmitarray antenna with near-zero axial-ratio performance and agile beam forming at Ka-band. The proposed design employs a 2-bit phase-shift element, used for beam steering, and a passive polarizer placed on top to enable circular polarization. A physical rotation of the CP patches is introduced on the polarizing panel to synthesize a fixed phase profile, enabling very low axial ratio across the entire operational bandwidth. The final stacked transmitarray achieves a peak gain of 27.9 dBic with 33.0% of aperture efficiency, and maintains an axial ratio less than 0.5 dB over 15% of bandwidth for all beam-scanning scenarios. The proposed configuration demonstrates a modular and scalable approach that simplifies the design constraints and serves as a preliminary work for future reconfigurable transmitarrays with dynamic and efficient control in circular polarization.

16:55 Low-Cost, High-Gain, High-Efficiency, Wide-Scan-Angle Modular Metalens Antenna for LEO Satellite Constellation Ground Station

Cedric W. L. Lee, Rajbala Solanki, Peng-Khiang Tan and Theng Huat Gan (National University of Singapore, Singapore)

As more small satellites with limited power are launched into Low Earth Orbit (LEO) for global coverage, there is a need for ground station antennas that are low-cost, high-gain, high-efficiency, and offer wide-angle coverage for datalink applications. Existing solutions primarily use multi-faceted panels-often in the shape of a pyramidal frustum-composed of phased array antennas. However, phased array antenna solutions are costly and complex. Therefore, we propose a hybrid solution using multiple panels of wide-scan-angle metalens antennas fabricated with PCB technologies. Specifically, our design requires far fewer beam-forming control elements compared to phased arrays. For example, only a small number of discrete feeds (e.g., 13 to cover principal and diagonal planes) are needed per panel, versus about 529 (23×23) elements for traditional phased arrays of the same size. This demonstrates that our approach achieves high performance with much less complexity and lower cost.

17:15 A Broadband Dual Reflectarray for mm-Wave Long-Distance Communications

Alberto Hernández-Escobar (Universidad de Málaga, Spain & Institute of Science Tokyo, Japan); Kenichi Okada (Institute of Science Tokyo); Takashi Tomura (Institute of Science Tokyo, Japan)

This paper presents a dual reflectarray antenna system designed for long-distance communications in the millimeter wave band at 130 GHz. By integrating a main reflectarray with a subreflectarray in a perpendicular feeding configuration, the proposed design mitigates the blockage problems common in densely packed antenna arrays while maintaining a low-cost and lightweight solution. The design methodology emphasizes an optimized phase difference of the radiating elements and an efficient illumination to reduce losses from different sources, achieving a theoretical gain of approximately 40.6 dBi for a 123-mm-diameter reflector. Furthermore, the system demonstrates a gain drop of only 3 dB across the 115-155 GHz range, indicating a promising bandwidth performance.

17:35 High-Efficiency Ka-Band All-Dielectric Reflectarray Antenna in Zetamix: Design and Experimental Validation

Michele Beccaria (Télécom SudParis, Polytechnique de Paris, France & DET- Politecnico di Torino, Italy); Andrea Massaccesi (Politecnico di Torino, Italy); Mauro Lumia (CNR, Italy); Giuseppe Addamo (Cnr-Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni, Italy); Angelo Freni (Università degli studi Firenze, Italy); Paola Pirinoli (Politecnico di Torino, Italy)

The paper details the design, fabrication, and experimental validation of a fully dielectric Ka-band Reflectarray Antenna (RA) produced through 3D printing with Zetamix ceramic, a material with a nominal relative dielectric constant of 7.5. Specifically, controlling the infill during 3D printing adjusts the material's effective permittivity, offering an additional degree of freedom for Unit Cell (UC) optimization and, ultimately, improved array performance. The dielectric properties are characterized on test brick samples printed with varying process parameters, determining the measured dielectric constant and loss tangent. The results of the material experimental characterization were used to design a medium-aperture all-dielectric RA (20$7.44\lambda_0$ aperture and $0.44\lambda_0$ thickness) working in a frequency band centered at 30 GHz. A prototype was manufactured and its measurements aligned with numerical analysis, showing a flat 28-31 GHz band and aperture efficiency over 50%, confirming the printing process and the potential of ceramic additive manufacturing for high-performance RAs.

17:55 Full-Wave Analysis of Metallic Reflectarrays Using Spherical Mode Domain Decomposition

Dayan Pérez-Quintana (KTH Royal Institute of Technology, Sweden); Rafael Gómez Alcalá (University of Extremadura, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain); Jesús Rubio (University of Extremadura, Spain)

In this research, a full-wave analysis method is presented, which is based on the domain decomposition of the entire structure by employing spherical modes and translation addition theorems. This formulation significantly reduces the simulation times required by commercial full-wave software when analyzing electrically large structures. To validate the proposed formulation, the analysis of a fully metallic reflectarray with a diameter of 18λ at 29 GHz is carried out using both the new method and the commercial full-wave simulator FEKO. The results of both studies show perfect agreement, with the difference that the proposed formulation for each new analysis in an optimization process requires only 109 seconds, whereas commercial software takes more than seven hours.

Monday, April 20 16:15 - 18:15

CS19 **Antennas, components and sensors for life science applications of electromagnetic technologies**

T06 Biomedical and health / Convened Session / Propagation
Chairs: Lorenzo Crocco (CNR - National Research Council of Italy, Italy), Matteo Bruno Lodi (University of Cagliari, Italy)

Room: Prague

16:15 An in-Body Far Field Wireless Power Transfer Link Under Homogenous Tissue Assumption

Mahdi Salimitorkamani and Burak Ferhat Ozcan (Bogazici University, Turkey); Ahmet Bilir (EPFL, Switzerland); Mehmet Cakicioglu and Sema Dumanli (Bogazici University, Turkey)

This paper presents the design, simulation, and experimental validation of an in-body far-field wireless power transfer link. The link consists of an electrically small, low-profile Huygens Source Implant Antenna resonating at 1.8 GHz and a wide-band on-body slot antenna operating between 1 GHz and 2 GHz. A Capacitively Loaded Loop, driven with an SMA port via an unbalanced microstrip feed network acts as primary source of the Magnetic Dipole. The bottom layer hosts a pair of symmetric Near-Field Resonant Parasitic elements coupled to the central Capacitively Loaded Loop, generating the orthogonal Electric Dipole component. The final dimensions of the antenna are $0.072\lambda_0 \times 0.090\lambda_0 \times 0.015\lambda_0$. The Huygens Source Antenna exhibits an efficiency of 0.18%, confirming its suitability for power-efficient implant-to-surface communication and integration into Wireless Power Transfer systems. A robust channel transmission coefficient ($|S_{21}|$) of -20.9 dB was achieved for an implant depth of 20 mm through phantom measurements.

16:35 Dual-Band, Single-Layer Magnetic Metasurface for Biomedical Wireless Power Transfer Applications

Alessandro Luigi Dellabate and Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (Pisa University & CNIT, Sweden)

This paper presents the design and analysis of a single-layer dual-band magnetic metasurface tailored for biomedical Wireless Power Transfer applications. The proposed 3×3 meta-array of resonant unit-cells is designed through an analytical formulation enabling a full independent operation at two distinct ISM frequencies (13.56 MHz and 40.68 MHz). Full wave simulations demonstrated significant improvements in power transfer efficiency at both frequencies compared to conventional two-coil WPT systems. In particular, the efficiency increased from 8.6% to 12.2% at 13.56 MHz and from 48.9% to 64% at 40.68 MHz. Moreover, a dedicated investigation carried out on a stratified biological phantom proved that the electromagnetic exposure due to the metasurface remains comparable to traditional WPT systems, thus guaranteeing safety together with an enhanced efficiency. The proposed approach provides a compact, passive, and low-cost solution to enable efficient multi-frequency power transfer, paving the way toward next-generation multi-functional implantable systems.

16:55 Real-Time Temperature Reconstruction in Microwave Hyperthermia: ESHO Models Validation

Maryam Firuzalizadeh (Politecnico di Torino, Italy); Rossella Gaffoglio (Fondazione LINKS, Italy); Giorgio Giordanengo and Marco Righero (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

Accurate temperature monitoring remains a challenge in microwave hyperthermia (HT), in particular for deep-seated tumors. Recent work has demonstrated that combining scarce temperature measurements with precomputed simulation libraries enables real-time 3D temperature reconstruction in the entire region of interest (ROI). In this study, we validate this reconstruction strategy using the standardized benchmark models released by the European Society for Hyperthermic Oncology (ESHO), strictly following all ESHO guidelines for numerical simulation and verification in hyperthermia treatment planning (HTP). Results obtained with the "Alex" head and neck benchmark model confirm the possibility to achieve an average error lower than 0.4°C in 95% of the ROI even when the sensor points used in the reconstruction are scarce and affected by noise.

17:15 On the Decoupling of an on-Body-Matched Microwave Antenna for Head Screening

Martina Gugliermino, David O. Rodriguez-Duarte, Alex Ramiro Masaquiza-Caiza and Cristina Origlia (Politecnico di Torino, Italy); Alessia Delpiano and Maaz Khalid (EPF Elettronica, Italy); Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

Microwave-based head screening is a challenge that requires a sensitive and responsive antenna capable of identifying, discriminating, and sensing variations in the scattering response due to internal dielectric contrast. These variations might be degraded by external interferences from other applications, sharing the frequency band and by multipath interference caused by non-through-body traveling waves, both of which limit accuracy. This paper examines the inclusion of an immediately attached back-self and inter-element absorbing foam layer, that can be a practical, low-cost, off-the-shelf solution, in an on-body-matched-antenna array, to mitigate unwanted interferences. The study employs numerical and experimental tests and finds a suitable and industrially scalable setup. Finally, a pneumatic system is proposed as an adaptability mechanism that adjusts the antenna-to-head attachment regarding the head size, eliminating unwanted air gaps between the antenna and the head.

17:35 Channel Characterization and Shielding Requirements for Secure Dual-Band IMD Communication Systems

Francesco Lestini, Sofia Corti and Gaetano Marrocco (University of Rome Tor Vergata, Italy); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy)

Wireless communication has enabled advanced functionalities in Implantable Medical Devices (IMDs), such as remote monitoring and post-surgical reconfiguration. Modern systems employ dual-band links, using the MICS band for telemetry and the 2.45~GHz ISM band for wireless wake-up, which improves usability but introduces new electromagnetic and cyber-physical vulnerabilities. Passive and reconfigurable electromagnetic shields based on Frequency Selective Surfaces (FSSs) have therefore been proposed as hardware-level protection. This work quantitatively characterizes the wireless channel between an IMD and its external programmer to define the shielding requirements for such FSS-based systems. A full-wave analysis on a realistic voxel-based human model is performed in both MICS and ISM bands under regulatory power limits. The received power and communication margins are evaluated versus distance and incidence direction, identifying the worst-case exposure conditions.

17:55 Induced Resonance Variations Within PEC Imaging Chamber Due to Brain-Stroke Blood Volume

Wanting Zhang, Amir Attar, Colin Gilmore, Ian Jeffrey and Joe LoVetri (University of Manitoba, Canada)

In this work we explore the resonant signatures arising when a human-brain model is placed inside a quasi-resonant metallic chamber. The aim is to investigate how variations in blood volume, representative of ischemic or hemorrhagic stroke events, influence the complex-frequency poles and residues obtained from wide-band transfer functions between transmitter-receiver pairs positioned on the interior walls of the chamber. The frequency response between multiple transmitter-receiver pairs is analyzed using the Vector-Fitting algorithm to fit apparent resonant poles and residues, which are used to characterize the system's response. Although these parameters do not correspond to true eigenmodes, they provide meaningful insight into the spectral behavior of the chamber-head configuration. The paper highlights the sensitivity of the resonant signature to dielectric changes associated with blood-volume variation and motivates the development of future three-dimensional modal analysis for quantitative and diagnostic purposes.

Monday, April 20 16:15 - 18:15

CS26 Physics-compliant modeling and prototyping of reconfigurable metasurfaces

TO8 Fundamental research and emerging technologies/processes / Convened Session / Propagation
Chairs: Philipp del Hougne (CNRS, Univ Rennes, France), Marco Di Renzo (Paris-Saclay University / CNRS, France)

Room: Krakow

16:15 Scattering Synthesis for High-Efficiency Multi-Port Coupled RISs Using Passive-Loaded Patches

Sravan Kumar Reddy Vuyyuru, Francisco S. Cuesta and Viktar Asadchy (Aalto University, Finland); Do-Hoon Kwon (University of Massachusetts Amherst, USA); Sergei Tretyakov (Aalto University, Finland)

Realizing advanced functionalities of reconfigurable intelligent surfaces and reflectarrays demands fine subwavelength structuring of arrays, posing technical challenges in design and realization. This work proposes an alternative design and optimization framework based on non-local load and coupling networks. The method benefits from additional degrees of freedom, because the non-local coupling network model generalizes the conventional diagonal load impedance matrix to a non-diagonal form. Wide-angle anomalous reflectors based on fixed-period linear and periodic supercell arrays are designed and theoretically validated, demonstrating that the proposed non-local coupling network optimization achieves higher reflection efficiency than conventional diagonal load matrix synthesis.

16:35 Multiport Design of Non-Local Beamforming Metasurfaces

Malik Almunif (University of Michigan, USA); Faris Alsolamy (King Abdulaziz City for Science and Technology (KACST), Riyadh, Saudi Arabia); Anthony Grbic (University of Michigan, Ann Arbor, USA)

A framework for the accurate design of non-local beamforming metasurfaces is presented in this paper. The metasurface is modeled as an N-port network characterized by an admittance matrix, where one port is excited by a source and the remaining ports are terminated in reactive loads. Reactive nearest-neighbor interconnections are introduced, providing the degrees of freedom needed to control the amplitude and phase of the metasurface unit cells. In the framework, the target far-field pattern is projected onto the unit cell active element patterns to obtain the desired port voltage distribution. These port voltages are then mapped to the diagonal and off-diagonal elements of the termination network representing the shunt loads and nearest-neighbor interconnections. This approach eliminates the need for surface-wave power exchange that is typically synthesized through optimization to ensure a lossless and passive metasurface. The method is demonstrated using a one-dimensional metasurface designed to generate a flat-top radiation pattern.

16:55 Ultra Low-Profile Transmitarrays Using near-Field Illumination

Andrea Tummolo (Université de Rennes, France); Orestis Koutsos (CEA Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-Leti, France); Ronan Sauleau (Universite de Rennes, France)

This paper presents a synthesis strategy for low-profile transmitarrays excited by feed arrays, with particular emphasis on thinned configurations. The proposed model evaluates the incident field within the radiative near-field zone by superimposing far-field patterns of the feed elements, while also accounting for the scattering response of each transmitarray unit-cell. A parametric study of various feed configurations highlights the influence of array size and periodicity on spillover and aperture efficiencies, enabling identification of effective and simplified feed architectures. Based on this framework, two 3-bit transmitarrays with 20×20 unit-cells operating at 30 GHz are designed, one for broadside operation and one for beam-steering at 40°. Both designs feature an ultra-low profile (H/D=0.15) and are excited by a 4×4 array of open-ended waveguides with 2.5λ periodicity. Results show excellent agreement with full-wave simulations, demonstrating that near-field-fed thinned architectures can achieve high aperture efficiency (45% at broadside) using a limited number of sources.

17:15 Mutual Coupling in Programmable Metasurfaces as a Resource in Wireless Communications

Philipp del Hougne (CNRS, Univ Rennes, France); Marco Di Renzo (CentraleSupelec-University, France)

Technologies based on programmable metasurfaces emerge as key enabler of next-generation wireless systems. Notable embodiments include reconfigurable intelligent surfaces (RISs) and dynamic metasurface antennas (DMAs), as well as their beyond-diagonal (BD-RISs and BD-DMAs) and stacked (stacked intelligent metasurfaces, SIMs) counterparts. In this paper, we survey the role of mutual coupling (MC) in such programmable metasurfaces. First, we discuss how the importance of MC awareness emerged in the conception of physics-compliant system models for RIS to enable accurate optimization. Second, we explain how MC is now increasingly becoming a design resource: (i) we review evidence for the benefits of strong MC in programmable metasurfaces; (ii) we explain how MC is a fundamental ingredient providing ``structural non-linearity'' in recent demonstrations of wave-domain physical neural networks and related proposals. Third, we discuss the importance of experimentally estimating the MC parameters (to avoid vulnerability to fabrication inaccuracies) and summarize recent progress toward that goal.

17:35 A Dual-Polarized Hybrid Transmitting and Reflecting Beyond-Diagonal Reconfigurable Intelligent Surface Using Cell-Wise Group Connection with Continuous Control

Zhaoyang Ming (The Hong Kong University of Science and Technology, Hong Kong); Shanpu Shen (University of Macau, Macao); Junhui Rao (The Hong Kong University of Science and Technology, Hong Kong); Chi-Yuk Chiu (Hong Kong University of Science and Technology, Hong Kong); Ross Murch (HKUST, Hong Kong)

This paper presents a dual-polarized cell-wise group-connected hybrid transmitting and reflecting beyond-diagonal reconfigurable intelligent surface (BD-RIS) hardware design. The proposed design incorporates a four-port reconfigurable impedance network integrated with dual-polarized antennas, supporting reflection, transmission, and hybrid modes with continuous amplitude and phase control. Leveraging structural symmetry, the BR-RIS design enables four independent control paths for manipulating the dual-polarized wave from both sides, significantly enhancing beamforming flexibility and wave manipulation capability. A Thévenin equivalent model and an analytical calculation method are developed to efficiently optimize the beamforming performance. This work offers a practical and versatile solution for developing high-performance BD-RIS design for next-generation wireless communications.

17:55 Physically Consistent Modelling and Analysis of RIS Under Multipath Incidence

Gang Yu (University of Sheffield, United Kingdom (Great Britain)); Ashwin Thelappilly Thelappilly Joy (5GIC and 6GIC, University of Surrey, United Kingdom (Great Britain)); Wenji Xi (University of Sheffield, United Kingdom (Great Britain)); Jie Zhang (Ranplan Wireless Network Design Ltd, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

This paper presents an electromagnetics consistent model for the scattering behaviour of reconfigurable intelligent surfaces (RISs) illuminated by multiple incident waves in complex indoor environments. The proposed model addresses the fundamental gap between idealised analytical formulations and realistic multipath excitation conditions typically encountered in indoor propagation. By combining principles of physical optics and diffraction grating theory, closed-form expressions for the reflection coefficients of all Floquet-Bloch modes are derived as explicit functions of arbitrary incident angles, phases, and amplitudes. The formulation captures multimode re-radiation, parasitic scattering, and diffuse components in a computationally efficient manner, enabling seamless integration into large-scale ray-based simulators. Validation through full wave simulations demonstrates the accuracy and generality of the model across a wide range of excitation and configuration parameters. The proposed approach provides a practical yet physics-based framework for analysing, designing, and optimising RIS-assisted wireless systems in realistic indoor multipath environments.

Monday, April 20 16:15 - 18:15

CS27 Novel Antenna Measurement Techniques and Data Processing for Electromagnetic Applications

T04 RF sensing for automotive, security, IoT, and other applications / Convened Session / Measurements
Chairs: Dennis Lewis (Boeing, USA), Janet O'Neil (ETS-Lindgren, USA)

Room: Dusseldorf

16:15 Validation of a Free-Field Power Flux Density Calibration Chamber with a Novel Infrared Camera System

Adrien Laffont and Manon Bruneau (Anyfields, France); David Knight and Edward Goodall (National Physical Laboratory, United Kingdom (Great Britain))

This paper describes a comparison between the traceable electric field generated by a power flux density calibration range, and a novel infrared camera system. This represents a comparison between two independent types of measurement system. The comparison parameter is the peak field calculated from the power flux density system and the same measured by the response of thermosensitive film placed at a known distance in front of the transmit horn.

16:35 Toward Smarter Phase Retrieval in Antenna near-Field Measurements: A Machine Learning Approach for Seed Prediction

Yahya Rahmat-Samii (University of California Los Angeles (UCLA), USA); Vignesh Manohar (Delart, USA)

Phase retrieval algorithms are highly dependent on the choice of the initial phase seed-i.e., the assumed phase distribution at the aperture of the antenna under test (AUT). Unlike conventional optimization methods that must be re-executed for each new antenna measurement, a properly trained machine learning model can potentially generate an effective initial seed applicable to a broad range of antennas. In this work, a deep learning approach is employed to provide an optimal seed that effectively guides the phase retrieval algorithm toward faster convergence and improved accuracy. An infinitesimal dipole array model is used to generate the datasets for both training and evaluation. After training, the model is validated and tested on arrays with varying aperture sizes and geometries. A key contribution of this paper is the application of regression-based Artificial Neural Networks (ANNs) for seed prediction and their comparison with classification-based approaches previously reported in the literature.

16:55 A Plane Wave Generator Based on the Design Principles of a Compact Antenna Test Range

Clive Parini (Queen Mary University of London, United Kingdom (Great Britain)); Rostyslav Dubrovka and Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

The use of plane-wave generators (PWG) for antenna measurements in a production-line environment is becoming a popular choice, as they offer a highly compact solution to producing a pseudo plane-wave in the near-field (termed Quiet Zone) in which the Antenna Under Test (AUT) can be placed. However, they are costly to construct as they generally need a large number of digital amplitude and phase shifters to control the array of radiating elements that form the PWG. In this paper we design a PWG based on the design principles of a Compact Antenna Test Range (CATR) which requires only a few digital amplitude controllers and no digital phase shifters to achieve a performance compatible with that of a CATR.

17:15 Modeling of Surface Current Perturbations Induced by Water Drops on Antenna Radomes Utilizing Full-Wave Simulations

Jonas Tiede (Technical University of Munich, Germany); Christian Chwala (Karlsruhe Institute of Technology, Germany); Alexander H. Paulus and Uwe Siart (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

During rainfall events, but also afterwards, water drops and runlets can be present on weather-exposed antenna radomes, causing an increase of the measured propagation path attenuation. In the field of quantitative precipitation estimation (QPE) using commercial microwave links (CMLs), this so-called wet antenna attenuation (WAA) usually leads to rainfall overestimation. In order to develop models for WAA correction in CML time series, it is still highly desirable to better understand this effect and compensate for it to increase the CML-QPE accuracy.
Using full-wave simulation results of dry and wet antennas, a straightforward model for the electromagnetic drop impact is proposed. Locally observed, drop-induced perturbations of equivalent surface currents are replicated and undisturbed current distributions are manipulated accordingly. Consistency of obtained WAA values with results from simulations and measurements is demonstrated. The results significantly advance previous work and are a fundamental step towards the development of frequency-dependent WAA modeling techniques.

17:35 Novel Deembedding Method for Coaxial Reflectometer Measurements of RF Absorbers Using Time-Gated Fixture Characterization - Part 1: Theory

Zhong Chen, Yibo Wang and Kefeng Liu (ETS-Lindgren, USA)

RF absorbers are typically characterized using a coaxial reflectometer (CR) to assess reflectivity from VHF to 1 GHz. A CR uses a square coaxial fixture terminated with a short circuit, where reflections are measured with absorbers placed on the shorting plate. However, fixture imperfections and impedance mismatches can cause significant measurement errors. Conventional mitigation, such as time-domain gating, reduces some effects but often introduces artifacts and residual mismatches. We present a deembedding technique that estimates the fixture's effective S-parameters without direct access to the shorted port. The fixture is modeled as a two-port network, with parameters derived from gated responses under short-circuit and loaded conditions and refined through preprocessing. Unlike conventional gating, the method preserves broadband accuracy and minimizes spectral distortion. This first paper develops the theoretical formulation and demonstrates its accuracy using known networks and representative absorber data.

17:55 On the Fly Compensation of RF over Fiber Link Instability in UAV-Based near-Field Antenna Measurements

Jonathan Gundlach (Physikalisch-Technische Bundesanstalt, Germany & TU Braunschweig, Germany); David Ulm (Physikalisch-Technische Bundesanstalt, Germany); Thomas Kleine-Ostmann (Physikalisch-Technische Bundesanstalt (PTB), Germany)

To perform near field antenna measurements with uncrewed aerial vehicles (UAVs), the UAV mounted antenna is connected to the ground-based vector network analyzer via a radio frequency over fiber (RFoF) link, since coaxial cables tend to be too bulky. Utilizing bi-directional signal transmission, the actual measurement- and a feedback signal are transmitted through the same optical fiber so that the variability of both the attenuation and phase shift in the signal path due to environmental effects can be continuously compensated. Further, an extended approach to the VNA system error correction must be used to determine the static error parameters of the whole system, since standard methods cannot be applied due to the entire RFoF link being limited to unidirectional transmission. This article shows the compensation method, an extended system error correction method with a validation of both and an estimation of the remaining uncertainty.

Monday, April 20 16:15 - 18:15

CS51 AMTA Convened Session: New Measurement Methods for Reverberation Chambers

TO7 Electromagnetic modelling and simulation tools / Convened Session / Measurements
Chairs: Anouk Hubrechsen (Eindhoven University of Technology & AntenneX B. V., The Netherlands), Dennis Lewis (Boeing, USA)

Room: Madrid

16:15 Efficient RCS Estimation Using Discrete-Frequency Stirring in a Reverberation Chamber

Remco Heijs (Eindhoven University of Technology, The Netherlands); Antonius Johannes van den Biggelaar (ANTENNEX, The Netherlands); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

This paper presents a method for estimating the monostatic radar cross section of a target inside a reverberation chamber. Due to the large number of propagation paths, a significant number of undesired non-line-of-sight contributions must be removed in post-processing. Reflections are canceled by making use of phase correlation, allowing discrete-frequency stirring as the only stirring mechanism. Estimating the required bandwidth requires knowledge of the path length difference between the line-of-sight and the first-order reflection. Using this technique, a single measurement provides sufficient information to determine the target's normalized monostatic radar cross section, as long as a known measurement antenna is used. The method is described in detail and applied to estimate the radar cross section as a function of the incident angle of three square metallic plates with dimensions of four, five, and six wavelengths. The measurements are compared with results obtained by numerical modeling to validate the approach.

16:35 Practical OTA Testing of Drone Video Links in Dual Reverberation Chambers

Dani Tahan (Bluetest, Sweden); John Åsberg and John Kvarnstrand (Bluetest AB, Sweden)

Reliable video links are critical for drone operation, but are vulnerable in multipath and interference-rich environments. We present an over-the-air (OTA) test method using two interconnected reverberation chambers with a programmable attenuator to emulate distance and fading. The drone resides in one chamber and the pilot goggles in the other together with the controller. Continuous mode stirring was applied to provide time-varying multipath conditions. Video throughput is captured non-intrusively from the goggles' on-screen display via screen mirroring and optical character recognition (OCR). The approach enables repeatable throughput measurements and provides a foundation for extended studies under controlled interference and jamming conditions.

16:55 Early-Time Reverberation Chamber Modeling via Ray Tracing

Mingzheng Chen, Riccardo Musso and Siyao Li (KTH Royal Institute of Technology, Sweden); Pilar Castillo-Tapia (Eindhoven University of Technology, The Netherlands); Anouk Hubrechsen (Eindhoven University of Technology & AntenneX B. V., The Netherlands); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

The high unstirred energy level that occurs in the early time of reverberation chambers (RCs) has posed a critical problem for measurement accuracy, especially with the use of high-directivity antennas. Taking into account the large electric size of the RCs, modeling RCs in full-wave simulators is highly time-consuming. Here, we propose a raytracing method to evaluate unstirred energy in the early time of RCs by calculating the time-domain S-parameters of the used antenna. The numerical results show that the proposed RT method predicts with reasonable accuracy the occurrence of reflection peaks corresponding to a high level of unstirred energy, which can be used to optimize chamber design and antenna placement. Moreover, the computing time required for the RT method is less than 1/1000 that of the reference full-wave simulator.

17:15 Preliminary Results About Total Radiated Power Measurements of a Wireless Device in a VIRC

Guillaume Andrieu (XLIM, France); Anouk Hubrechsen (Eindhoven University of Technology & AntenneX B. V., The Netherlands); Robert Horansky (NIST, USA)

This paper presents preliminary results about the possibility to measure the total radiated power of a wireless device within a vibrating intrinsic reverberation chamber (VIRC), a reverberation chamber made of a metalized textile. Compared to the same tests performed in a classical RC, the VIRC allows a reduction of the measurement setup complexity (i.e. no need for several stirrers within the VIRC for instance), a simplified approach to define the stirring sequence and a significant reduction of the measurement time. Results obtained in a low cost and movable VIRC on a fourth-generation smartphone using an LTE protocol are shown.

17:35 Evaluation of Antenna Losses in a Reverberation Chamber Using Full-Wave Simulations

Francois Sarrazin (Université de Rennes & IETR, France); Ismail Ahmed Bouha (University of Rennes1 & IETR, France); Youssef Rammal (Institut Langevin, ESPCI Paris, Université PSL, CNRS & Xlim, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France)
Reverberation chambers (RCs) are increasingly employed for antenna characterization, notably for estimating radiation efficiency. Accurate evaluation of the antenna contribution to the chamber quality factor is essential for such measurements. Classical models from the literature neglect structural losses, limiting their accuracy for antennas with significant material dissipation. A recent model based on scattering matrix theory accounts for both radiation and structural losses, as well as their complex interactions. This paper validates that model through full-wave simulations using CST Studio Suite. Two dipole configurations are analyzed: a metallic dipole with varying conductivity and a dielectric-coated dipole. Results confirm the theoretical predictions and demonstrate the impact of structural losses on the RC quality factor, supporting the model's suitability for precise antenna loss characterization in reverberation chambers.

17:55 Effective Modulated Scattering Cross Section in Reverberation Chambers

Ion Kolkhuis Tanke (University of Wisconsin-Madison, USA & Eindhoven University of Technology, The Netherlands); Antonius Johannes van den Biggelaar (ANTENNEX, The Netherlands); Daniel van der Weide (University of Wisconsin - Madison, USA)
This paper introduces the reverberation chamber modulation depth as a quantitative metric for evaluating modulated scatterers in multipath environments. The method extends conventional scattering cross-section characterization to active, state-switching devices such as modulated scattering probes. Measurements from 6-40 GHz are compared with full-wave simulations that emulate chamber statistics through randomized plane-wave excitation.

Monday, April 20 16:15 - 18:15

CS55 Wireless Power Transfer System and the Roles of Antennas & Propagation

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Antennas
Chairs: Nuno Borges Carvalho (Universidade de Aveiro, Portugal & InstitutodeTelecomunicacoes, Portugal), Tadashi Takano (Nihon University & JAXA, Japan)

Room: Copenhagen

16:15 What Research on Antennas and Propagation are Required for a Solar Power Satellite System?

Tadashi Takano (Nihon University & JAXA, Japan)
This paper describes the configuration of a solar power satellite, its specialty relevant to antennas and propagation, and concrete research topics of A&P.

16:35 Liquid Oil Filled Ball Lens Antenna for Passive Beam Steering at MM Wave

Amit Kumar Baghel (Universidade de Aveiro, Portugal & IT AVEIRO, Portugal); Vinicius Magno Uchoa Lima Oliveira (University of Aveiro & IT - Instituto de Telecomunicações, Portugal); Pedro Pinho (UA - Universidade de Aveiro & IT - Instituto de Telecomunicações, Portugal); Nuno Borges Carvalho (Universidade de Aveiro, Portugal & InstitutodeTelecomunicacoes, Portugal)
In this paper, a lubricant oil (Loil)-filled ball-lens is designed and fabricated in the FR2 mm-wave band (26- 30 GHz). The simulated radiation pattern and beam-steering performance are presented. It is observed that, due to spherical symmetry, beam-steering of ±180 ◦ in both azimuth and elevation is achieved. By using Loil, a reduction of 14.6% in weight is obtained compared to a fully PLA ball-lens. Since Loil can be reused, the overall material consumption and production cost are also reduced. The fabricated ball-lens shows an average gain increase of 4.8 dBi across the band, with a maximum gain achieved at 28 GHz. Furthermore, a 1 dB bandwidth of 1.5 GHz is achieved.

16:55 Wideband Design of a 170-GHz Post-Wall Waveguide Corporate-Feed Array Antenna Based on Eigenmode Analysis

Takashi Tomura (Institute of Science Tokyo, Japan); Shohei Ogura (Tokyo Institute of Technology, Japan); Nobutaka Arai (Institute of Science Tokyo, Japan)
This paper reports a design approach for a 170-GHz post-wall waveguide corporate-feed array antenna achieving wideband performance through eigenmode-based optimization. A 2 × 2-element subarray was analyzed to design the radiating section, followed by combination with a feeding network. The proposed antenna achieved a reflection coefficient below -10 dB across 21.7 % fractional bandwidth (156-194 GHz). An 8 × 8-element array prototype provided over 20 dBi gain with a maximum of 24.3 dBi at 181.7 GHz and 46.1 % efficiency.

17:15 Design of Beam Ellipticity Compensation with Reflective Beam Expander and Deformable Mirror for Optical Wireless Power Transfer

Yuka Oshima (NTT, Japan); Sho Aonuki, Kazuto Kashiwakura, Yukiko Suzuki, Natsuha Ochiai and Masato Suzuki (NTT, Inc., Japan); Yohei Toriumi and Madoka Takahashi (Nippon Telegraph and Telephone Corporation, Japan)
Optical wireless power transfer (OWPT) is considered a promising approach for long-distance power transmission due to its small beam divergence. This technology can be widely applied in various fields, such as supplying power to mobile platforms. In this study, we focus on power transmission to high-altitude platform stations (HAPS) and show that the optimal emitted beam diameter is approximately 30 cm. Furthermore, to address the issue of beam ellipticity on the photovoltaic panel caused by oblique incidence, we propose a method to compensate the beam shape using a reflective beam expander incorporating a deformable mirror. Numerical analysis reveals that a deformable mirror stroke of a few micrometers is sufficient to achieve a beam ellipticity of 0.5, demonstrating the high feasibility of the proposed compensation method for practical implementation. These results broaden the potential and feasibility of OWPT systems for HAPS applications.

17:35 Numerical Estimation of Indoor Propagation Characteristics Considering Human-Safety for Beam-Type Wireless Power Transfer

Takashi Hikage, Shuhei Waki and Kohsuke Ushimaru (Hokkaido University, Japan)
The aim of this study is to develop an accurate and reliable method for estimating propagation channels and modeling propagation to advance the radio link design of a new generation of beam-type wireless power transfer systems . In the frequency bands used for beam-type WPT, shadow fading is not negligible, nor is the loss due to human bodies. We elucidates the effects of human body-absorption on beam-type WPT band propagation characteristics in an indoor environment.

Monday, April 20 16:15 - 18:15

E12 Materials and Waveguides

T07 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Michael J Havrilla (Air Force Institute of Technology, USA), Santi Concetto Pavone (Università degli Studi di Catania, Italy)

Room: Paris

16:15 Scattering Parameter Symmetries for a Bianisotropic Material with an Orthorhombic Lattice

Michael J Havrilla (Air Force Institute of Technology, USA)
The scattering parameters of a bianisotropic slab having an orthorhombic lattice of metallic split rings under normal incidence are derived. Eigenanalysis and group theory, including Curie and Neumann principles, are utilized to identify and explain the observed scattering parameter symmetries. The bianisotropic slab geometry is discussed and future work involving electromagnetic material characterization using a focused-beam measurement system is reported.

16:35 Electromagnetic Modeling of a Circular-Waveguide Fed Isotropic Plasma in a Cylindrical Metallic Cavity

Santi Concetto Pavone (Università degli Studi di Catania, Italy); Luigi Celona (INFN-LNS, Italy); Gino Sorbello (University of Catania, Italy)
This contribution deals with the analytical modeling of the electromagnetic interaction of a cylindrical-cavity-confined plasma and a feeding circular waveguide. The model is rigorous and allows, under specific assumptions, to find the field distribution inside the cavity in closed form, thus highlighting physics insights on wave superposition in the plasma region (thus also on energy transfer to plasma), and on most relevant parameters which play a role in efficient coupling between waveguide probes and confined plasmas.

16:55 An Approach to Realize Layered Dielectric Structures for Two-Dimensional Wave Propagation as Obtained via Transformation Optics

Nona Messhenas and Werner L. Schroeder (RheinMain University of Applied Sciences, Germany); Thomas Kaiser (Universität Duisburg-Essen, Germany)
Practical realization of two-dimensional guided-wave devices in layered dielectrics is addressed by simulation. A transformation-optics method directly realizes the required local variation of the propagation speed (modal index) of the fundamental TE slab mode, without reference to a bulk permittivity distribution. A Maxwell's fish-eye index profile is approximated by mirror-symmetric, two-material layer stacks of finite thickness selected from a lookup library. A 6-port waveguide crossing at 60 GHz serves as example. Results show smooth power guidance and low reflection over 55-65 GHz. Conclusions are drawn regarding achievable discretization accuracy, required layer thickness, and suitable material parameters for low-loss millimeter-wave interconnects in antenna arrays and beamforming networks.

17:15 Exact Solution of a PTD Waveguide Realized by Bed of Nails Metasurfaces

Xenofon Mitsalas (University of Siena, Italy); Nelson Castro (University Carlos III of Madrid, Spain); Stefano Maci (University of Siena, Italy)
In this paper, we present an analytical method capa- ble of capturing the propagation mechanisms in edge-line parity time-reversal duality (PTD) symmetric parallel-plate waveguides, realized using a "Bed of Nails" metasurface, as established in the existing literature. Building on our previous work, where the characteristic equations were derived using the Wiener- Hopf technique, we revisit and solve these equations within the framework dictated by the complex boundary conditions of the Bed of Nails structure. The Wiener-Hopf formulation is accordingly revised and modified, representing a significant step toward establishing a rigorous analytical solution for complex PTD-configured structures.

17:35 Tapered Hollow-Core Photonic Crystal Waveguide for Compact Particle Acceleration

Giuseppe Torrisi (INFN-LNS, Italy); Giorgio Mauro (INFN-LNL, Italy); Davide Guarnera (University of Catania, Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy); David Mascali (INFN-LNS, Italy); Andrea Locatelli (Università degli Studi di Brescia, Italy); Luca Vincetti (University of Modena and Reggio Emilia, Italy); Gino Sorbello (University of Catania, Italy)
This work presents the numerical design of a tapered hollow-core photonic crystal waveguide for novel Dielectric Laser Accelerators (DLAs). The proposed geometry, based on a triangular-lattice photonic crystal, supports a co-propagating acceleration scheme where the electromagnetic wave remains phase-matched with the particle bunch along the channel. As the particle velocity increases in the sub-relativistic regime, the waveguide is adiabatically tapered to preserve synchronism over a longer interaction length. Two-dimensional electromagnetic simulations performed with COMSOL Multiphysics show that the structure supports an accelerating mode characterized by a strong longitudinal electric field component and phase velocities matched to the target velocity range. These results confirm the effectiveness of the tapered design in supporting efficient acceleration in a compact, scalable photonic platform.

Monday, April 20 16:15 - 18:15

M07 Recent advances in near field measurement

T08 Fundamental research and emerging technologies/processes / / Measurements
Chairs: Francesco D'Agostino (University of Salerno, Italy), Marc Dirix (E&C Anechoic Chambers, Belgium & RWTH-Aachen University, Germany)

Room: London

16:15 A Direct near-Field-to-Far-Field Transformation Method for Single-Cut Pattern Measurements

Jiaqian Ding (Xian Jiaotong University, China); Xiaobo Liu and Xiaoming Chen (Xi'an Jiaotong University, China)
This paper proposes a single-cut near-field antenna measurement method. Unlike the existing spectral domain harmonics method and equivalent source method, the proposed near-field-to-far-field transformation method does not rely on any intermediate variables such as Fourier coefficients and equivalent sources. Starting from the representation of the radiation field using cylindrical Hankel harmonics, the method derives the asymptotic series expansion of the Hankel function. Thus, the single-cut radiated field can be rewritten as a series of spherical waves, where the far-field pattern as first-order expansion coefficient determines all higher-order expansion coefficients via mathematical derivative functions. Based on the difference form of these derivative functions, the far-field pattern can be directly solved and obtained from near-field data. Especially, this method outperforms the existing spectral domain harmonics method in the presence of spatial truncation. Simulation and measurement validate the proposed method.

16:35 Fast and Accurate Group Delay Antenna Measurements Based on Spherical near Field Multi-Probe Systems

Francesco Saccardi (Microwave Vision Italy, Italy); Andrea Giacomini (Microwave Vision Italy SRL, Italy); Jaydeep Singh (Microwave Vision Group, Italy); Nicolas Gross (MVG Industries, France); Ludovic Durand (SATIMO, France); Lars Foged (Microwave Vision Italy, Italy)
Group Delay (GD) is an important parameter in advanced antenna systems, especially for applications requiring timing precision and signal fidelity, such as GNSS, satellite communications, and modern 5G networks. This work presents, for the first time, the validation of absolute GD measurements using spherical near-field Multi-Probe Array (MPA) systems, enabling rapid and accurate antenna characterization. To ensure reliable GD measurements, a GD substitution method is employed to correct for the GD introduced by the measurement system itself. This is achieved by measuring a reference antenna with known GD under the same test conditions. Multi-purpose reference antennas are proposed to perform both gain and GD calibration simultaneously, simplifying the workflow. Experimental validation in the 5-6 GHz band using horn, dipole, and biconical antennas shows excellent agreement between measured and simulated GD values. The results confirm MPA systems as versatile tools for accurate characterization of both amplitude- and phase-related antenna parameters.

16:55 Microwave-Inspired Sample Design for near-Field Characterization of Plasmonic Antennas at Mid-Infrared Frequencies

Igor Getmanov and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)
Recent advances in near-field techniques, particularly electron energy loss spectroscopy (EELS), have expanded opportunities for quantitative characterization of plasmonic antennas at mid-infrared frequencies. However, the lack of a framework connecting EELS measurements to traditional microwave characteristics has limited their application in antenna evaluation and design. Here, we present a microwave-inspired model that links experimental EELS spectra to the S-parameters of plasmonic antennas, providing a direct analogy with conventional microwave analysis. Guided by this model, we propose optimized plasmonic antenna structures for near-field characterization and show that the nanorod/CPW/monopole configuration achieves significantly enhanced standing wave contrast compared to a conventional CPW-fed monopole. Analysis of samples with open, short, and thru loads further validates the approach, demonstrating good agreement between EELS-measured standing wave profiles and model predictions at 50-150 THz. This work lays the foundation for quantitative S-parameter extraction from near-field measurements, enabling more effective design of plasmonic antennas at mid-infrared frequencies.

17:15 Using MARS in Temperature Controlled OTA Measurements

Lieke AM Geubbels (Eindhoven University of Technology, The Netherlands); Justin Geerarts (technische universiteit Eindhoven, The Netherlands); A. B. (Bart) Smolders, Elmine Meyer and Ad Reniers (Eindhoven University of Technology, The Netherlands)
During temperature-controlled OTA measurements, it is important that the DUT temperature is accurately monitored. A thermal camera can produce a real-time temperature gradient of the DUT. However, this thermal camera has to be part of a temperature controlled chamber, and will thus act like a scattering object during the OTA measurement. The mathematical absorber reflection method is used as a post-processing technique to filter out the influence of the thermal camera on the measurement. The thermal camera is placed at different elevation angles θ of 0°, 22.5°, 45° and 67.5°, with the azimuthal angle $\phi = 45^\circ$ for all cases. The scenario in which the thermal camera is placed at $\theta = 45^\circ$ and $\phi = 45^\circ$ results in an absolute RMS error of 0.44 after post-processing, compared to an absolute RMS error of 7.10 before post-processing, while maintaining a sufficiently small spot size to create an accurate temperature gradient.

17:35 A Loaded Waveguide near-Field Probe Based on 3D-Printed Alumina for W-Band Applications

Zhenming Tian (University of Duisburg-Essen, Germany); Louis Delait (UCLouvain & ICTEAM, Belgium); Masoud Sakaki (University of Duisburg-Essen, Germany); Niels Benson (Institute for Nanostructures and Technology (NST), University of Duisburg-Essen, Germany); Dimitri Lederer and Jean-Pierre Raskin (Université Catholique de Louvain, Belgium); Daniel Erni and Andreas Rennings (University of Duisburg-Essen, Germany)
This paper presents a loaded-waveguide near-field probe based on 3D-printed Alumina for W-band applications. Conventionally, an air-filled waveguide is used to obtain information of RF devices. However, at mmWave frequencies, the waveguide's housing is bulky compared to the DUT, resulting in a distorted measurement field. Instead of an air-filled waveguide, we propose an Alumina-loaded waveguide probe based on 3D-printing technique. The high permittivity of Alumina down-scales the waveguide size, and its low loss tangent maintains an efficient signal transmission. Due to the smaller aperture size of the Alumina waveguide, it offers a higher spatial resolution. To employ this probe in a common measurement system that utilizes standard waveguide interfaces, a transition structure has been designed for the Alumina probe, which is integrated into a CNC-machined WR-10 adapter. It is shown that compared to a standard waveguide, our Alumina probe significantly enhances the spatial resolution of the measured field.

17:55 Polarization-Resolved Electro-Optic near-Field Measurement and Far-Field Evaluation of a 300 GHz Antenna

Wataru Kumazawa, Hokuto Isogai and Shintaro Hisatake (Gifu University, Japan)
This paper presents a polarization-resolved electro-optic (EO) measurement technique for high-frequency antenna characterization. The proposed method formulates complete coupling relations derived from the EO tensor of the crystal, including the polarity of each field component, and reconstructs arbitrary polarization states through multiple measurements with distinct EO-probe orientations. This approach overcomes the limitations of conventional EO measurements that assume a known polarization state. The technique is experimentally demonstrated through a 300 GHz near-field measurement of a horn antenna, successfully visualizing the spatial polarization distribution within the beam cross-section even when its polarization is misaligned with the sensitivity axis of the EO crystal. The capability to separate evanescent field components (e.g., Ez) enables precise visualization of the near-field behavior and improves the accuracy of far-field estimation. The proposed method provides a powerful framework for evaluating devices that generate vector beams in the sub-millimeter and terahertz regimes.

Monday, April 20 16:15 - 18:15

P12 **UWB, mm-wave and THz Propagation**

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Propagation
Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Vasilii Semkin (New York University Abu Dhabi, United Arab Emirates)

Room: Gothenburg

16:15 Angular and Delay Spread Characterization of RIS-Assisted Channels in an Industrial Environment at Low THz Frequencies

Varvara V. Elesina, Lorenz Helmut Wolfgang Löser and Thomas Kürner (Technische Universität Braunschweig, Germany)
This paper presents a double-directional measurement campaign conducted at 300 GHz in a realistic industrial workshop environment, utilizing two reconfigurable intelligent surface (RIS) prototypes. Two different scenarios were investigated, each with different transmitter (Tx), receiver (Rx), and RIS positions inside the same workshop environment. By performing full 360° azimuthal scanning at both the Tx and Rx, we extracted key channel metrics: power angular profile (PAP), angular spread (AS) at angle of departure (AoD) and angle of arrival (AoA), and root mean square (RMS) delay spread (DS) with the first and second RIS prototypes and without RIS. The results demonstrate that AS depends both on the RIS properties and on scenario specific conditions, in particular the relative strength of the RIS-assisted path compared to dominant environment-induced multipath component (MPC). Across all presented scenarios, the DS decreased with introduction of RIS, with reductions observed regardless of the specific environmental propagation conditions.

16:35 Rain Impact in 300 GHz Backhaul Planning Tool: Modelling and Network Performance Evaluation

Francesco Capelletti (Politecnico di Milano, Italy); Bo Kum Jung (Waseda University, Japan); Lorenzo Luini (Politecnico di Milano, Italy); Thomas Kürner (Technische Universität Braunschweig, Germany); Carlo Riva (Politecnico di Milano, Italy); Laura Resteghini (Huawei Technologies, European Research Center, Italy)
This work integrates MultiEXCELL, a cellular-based rain field model, into an in-house Simulator for Mobile Networks (SiMoNe) to support the planning of 300 GHz wireless backhaul links. By generating multiple and realistic rain events affecting the deployment site, the approach enables the evaluation of long-term rain attenuation statistics and overall network performance. Results for a study case scenario highlight the limitations of the ITU-R P.530-19 model, which tends to overestimate in predicting rain attenuation over short terrestrial links. Furthermore, system-level simulations at 300 GHz, consistent with the IEEE Std 802.15.3-2023, demonstrate capabilities to reliably support >100 Gbps, addressing the capacity gap in future backhaul services.

16:55 Measurement and Modeling of the Radio Channel for Warehouse Localization: UWB Technology

Pascal Pagani (CEA, LETI & Université Grenoble-Alpes, France); Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France)
Accurate localization is essential in warehouse environments, where knowledge of radio propagation conditions is critical. This paper presents an experimental and statistical characterization of ultra-wideband (UWB) channels in a typical warehouse building. Channel impulse responses were collected using a real-time channel sounder with a dual-polarized receiver, in the frequency range 6.75–7.75 GHz. Key parameters, including path loss, root-mean-square delay spread, and multipath clustering, were extracted. A statistical channel model Following the Saleh-Valenzuela formalism is proposed, capturing cluster arrivals, intra- and inter-cluster decay, and first-ray power excess. The model reproduces the observed channel behavior and can support system-level studies and the design of localization and communication solutions in warehouse scenarios.

17:15 Characterization of 300 GHz Power Delay Profiles in Corridor Environment

Hirokazu Sawada and Azril Haniz (National Institute of Information and Communications Technology, Japan); Takeshi Matsumura (National Institute of Information and Communications Technology (NICT), Japan & Kyoto University, Japan)
Sub-terahertz and terahertz frequency bands are being explored for next-generation wireless communication systems capable of achieving ultra-high data rates exceeding tens of Gbit/s. To design the physical layer of such systems, it is essential to characterize radio wave propagation in these bands. In our previous work, we measured the power delay profile using wireless signal bandwidths of 2.16 GHz and 5 GHz in both outdoor open areas and indoor data center environments. In this paper, we extend our measurements to a corridor environment to investigate the characteristics of the power delay profile and to construct corresponding channel models. Furthermore, we present an analysis of root mean square (RMS) delay spread comparing the results with previous measurements. These parameters are critical for the design and optimization of the physical layer in high-speed wireless systems.

17:35 Study and Modeling of Path Loss in Corridor Scenarios from 250 GHz to 330 GHz

Juan E. Galeote-Cazorla (University of Granada, Spain); Alejandro Ramírez-Arroyo (Aalborg University, Denmark); Cristian Gutiérrez (Pontificia Universidad Católica de Valparaíso, Chile); Manuel Almendra (Pontificia Universidad Católica de Valparaiso, Chile); Mauricio Rodríguez (Pontificia Universidad Católica de Valparaíso, Chile); Juan Valenzuela-Valdés (Universidad de Granada, Spain)
The future sixth-generation (6G) is expected to serve new cutting-edge applications such as extended reality or haptic systems. One of the key strategies is operating at the terahertz (THz) bands, where the available bandwidth is larger. However, deploying wireless systems at these frequencies is a technical challenge in terms of propagation. Path loss is notably high and the classical propagation mechanisms suffer of a great detriment. Therefore, current state-of-art envision these bands for short-range scenarios. In particular, this work presents measurements and modeling of the path loss within corridors at the ultra-wideband (UWB) frequency range from 250 GHz to 330 GHz. A noticeable multipath effect dependent on frequency is observed. Finally, path loss is modeled as a function of the link distance and frequency. A path loss exponent of 1.8 is obtained, which is attributed to the guiding phenomena also observed at mmWave bands.

17:55 Realistic Interference Simulation in a Conference Room Scenario at THz Frequencies

Steffen Kroos, Johannes M. Eckhardt, Christoph Herold and Thomas Kürner (Technische Universität Braunschweig, Germany)
This work documents the development, verification, and application of realistic interference simulations in THz communications with the SiMoNe simulation framework. Building on the structures already implemented in SiMoNe, a concept is developed and implemented which enables enables link-level simulations with several transmitters and receivers. The resulting interference at a receiver is automatically calculated as a superposition of time discrete waveforms within in a single simulation run. Within a realistic conference room scenario, simulations show that the influence of interference in THz communications using realistic antennas cannot be modelled by complex Gaussian noise distribution with an equivalent signal-to-interference-plus-noise ratio.

Monday, April 20 18:30 - 20:00

WC	Welcome Reception

Tuesday, April 21

Tuesday, April 21 8:00 - 9:40

A13a Array Antenna Feeds and Excitations 1

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)), Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

Room: Copenhagen

8:00 Multi-Material Inkjet-Printed Power Dividers for Antenna Array Feed Networks

Kevin Martin (University College Cork, Ireland & Tyndall National Institute, Ireland); Dimitra Psychogiou (University College Cork and Tyndall National Institute, Ireland)
This paper explores the potential of a two-material piezo drop-on-demand process for the realization of monolithic four-way power dividers. Integration concepts using grounded coplanar waveguide transmission lines with different geometrical profiles, i.e. solid- and dielectric-filled conductors, are examined to observe their suitability for the power divider realization. For proof-of-concept validation purposes a prototype of the four-way power divider was manufactured and tested at Ku-band. It demonstrated a reflection coefficient |S11| ≤ -10 dB from 11 GHz to 14.9 GHz that corresponds to a fractional bandwidth of 30.46%. The proposed solution has an average insertion loss of 5.2 dB that includes the loss of the coaxial connectors.

8:20 An Ultra-Wideband Circularly Polarized Phased Array with Large-Angle Scanning Based on Novel Phase Shifter

Han-Jie Xu and Shi-Wei Qu (University of Electronic Science and Technology of China, China); Shiwen Yang (University of Electronic Science and Technology of China (UESTC), China)
In this paper, an ultra-wideband wide-angle scanning circularly polarized phased array is proposed based on a novel phase shifter. To avoid the occurrence of grating lobes, the element spacing in wide-scanning phased arrays is typically close to 0.5 λh, where λh is the free-space wavelength at the highest operating frequency. Consequently, conventional circularly polarized phased arrays rarely utilize phase-shifted multi-feed networks to achieve circular polarization, which typically exhibits a relatively narrow operating bandwidth. To address this issue, a novel 90° miniaturized phase shifter based on a modified Π-type network is introduced, featuring a compact size of only 0.406 λh * 0.368 λh. Finally, the antenna achieves VSWRs of less than 2.5 across the 2 ~ 6 GHz range during ±60° beam scanning in both the xoz- and yoz-planes. Additionally, the axial ratio (AR) remains below 3 dB, and the radiation efficiency exceeds 89% within the operating bandwidth.

8:40 Design and Validation of Ultra-Wideband Multi-Layer PCB Patch Arrays for 57-71 GHz

Mohamed Räsänen (Aalto University, Finland); Afroza Khatun (Arctic Instruments, Finland); Juha Ala-Laurinaho and Vili Kuosmanen (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)
This work presents two novel, experimentally validated 4 × 4 wideband antenna arrays operating at 57-71 GHz, realized using multi-layer PCB technology. The first array employs a cavity-backed grounded circular patch antenna (CB-GCPA) with an L-probe feed, while the second uses a cavity-backed stacked patch antenna (CB-SPA) with a direct feed. Both arrays are fed through a grounded coplanar waveguide power divider, which distributes the input signal to the antenna elements. The CB-GCPA array achieves a -10-dB impedance bandwidth exceeding 40%, surpassing the 21.9% required by the 802.11ay standard. The CB-SPA array provides a -9.5-dB impedance bandwidth greater than 34%. The CB-GCPA array attains a maximum gain of 20.1 dBi after transmission-line loss compensation, compared to 19 dBi for the CB-SPA array. Gain variation is 2.1 dB for the CB-GCPA array over a 34% fractional bandwidth and 4.4 dB for the CB-SPA array across the target band.

9:00 Performance Enhancement of Circularly Polarized Phased Array Based on Cavity-Backed Antenna Elements for Multilayer PCB Design

Samuel Lottin (University of Limoge, France & ISL, France); Edson Martinod and Joel Andrieu (University of Limoges, France); Loic Bernard (ISL & IETR, France); Ronan Adam (French-German Research Institute of Saint-Louis, France); Paul Karmann (DGA, France)
In this paper, a low-cost solution to improve the performance of a circularly polarized (CP) cavity-backed antenna and phased array antenna based on multilayer PCB technology is described. In practice, a lot of antennas are manufactured on PCB, but go from metallic walls of a cavity-backed antenna element to metallic vias on PCB technology degrades the CP performance of the element. The objective is to restore the performance of the antenna by using the constraint of PCB technology. First, the characteristic mode analysis (CMA) is performed to improve the antenna. By understanding the flow of surface currents, a solution is provided and the axial ratio bandwidth (ARBW) of the cavity-backed element is improved from 6.4% to 8.87%. Then, the benefits on the performance of a CP phased array will be shown. The proposed solution improved the operating bandwidth from 4.87% to 10.44% for a ±45° scanning angle.

9:20 Enhancement of Phased Array Scan Range via WAIM for High Power Applications

Chrysovalantis Stefopoulos (Netherlands Organization for Applied Scientific Research (TNO), The Netherlands); Alessandro Garufo (TNO Defense Safety and Security, The Netherlands); Stefania Monni (TNO Defence Security and Safety, The Netherlands)
This paper presents a technique for enhancing the scan range of phased array antenna systems through the implementation of wide-angle impedance matching (WAIM) layers. A computationally efficient circuit model is used, enabling dynamic impedance matching through a scan-dependent shunt capacitor. The design parameters of the WAIM are optimised to improve the impedance performance across a range of scan angles. The analysis of a finite array, via full-wave simulation, validates the effectiveness of the WAIM structure, demonstrating improved wide-angle scanning performance with realised gain enhancements up to 1.4 dB at θ = 60 ◦ , while maintaining impedance matching below -10 dB for all the scanning angles up to θ = 50 ◦ , across the full operational bandwidth. The proposed approach offers a robust and efficient method for designing WAIM layers.

Tuesday, April 21 8:00 - 9:40

A18a Hybrid Lens Antenna Solutions 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Nuria LLombart (Delft University of Technology, The Netherlands), Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

Room: Gothenburg

8:00 Design of 30-60 GHz Continuous Transverse Stub Array for Feeding Flat Lenses

Marick Vermeulen, Caspar M Coco Martin and Daniele Cavallo (Delft University of Technology, The Netherlands)
The design of a feed for millimeter-wave wideband flat lenses is presented. The feed is based on a continuous transverse stub (CTS) array, with a one-to-four parallel-plate-waveguide power divider that implements a quadratic phase profile and an amplitude taper on the array aperture. The design aims at reducing the frequency dispersion of the patterns for stable illumination of the lens across the wide bandwidth from 30 to 60 GHz. The CTS array is fed with a printed circuit board that hosts two grounded coplanar waveguides (GCPWs), a junction, and a transition to a coaxial connector. The feed is manufactured and tested in combination with a previously developed flat lens prototype. The experimental results confirm the wideband properties of the feed, which can operate with stable performance across the entire bandwidth from 30 to 60 GHz.

8:20 Optimization of Spherically Conformal Fly-Eye's Lens Antenna Arrays

Nick van Rooijen, Alexandros Bechrakis Triantafyllos, Maria Alonso-delPino and Nuria LLombart (Delft University of Technology, The Netherlands)
This work introduces a method for the optimization of spherically conformal antenna arrays based on core-shell lens antennas as array elements. First, the spherically antenna is optimized using using Goldberg polyhedron topologies for directivity and beam overlap. This first step derives the number of unique antennas and their optimal aperture current distribution. Second, the optimal current distributions are synthesized via a core-shell lens antenna whose geometry is derived using a field-matching technique.

8:40 Design of a Densely Packed PCB Dual-Pol. Array for a Wide FoV mm-Wave Lens Antenna

Dunja Lončarević, Huasheng Zhang, Andrea Neto and Nuria LLombart (Delft University of Technology, The Netherlands)
A dual-polarized leaky-wave feed is optimized for an extended hemispherical low-permittivity lens antenna enabling wide-angle beam scanning of 60 deg. in the U-plane and 20 deg. in the V-plane. The compact PCB feed achieves impedance matching better than -15dB and inter-polarization coupling below -40dB over the 24.75-27.5GHz band. Radiation pattern symmetry, degraded by the microstrip and coaxial transitions, is restored through a revised transition and via layout. The resulting feed maintains balanced performance across both polarizations and supports dense focal array integration with 0.87 wavelength spacing, suitable for wide-FoV mm-wave lens antennas in 5G applications.

9:00 Design of a 2D Array Based on the Combination of Geodesic Lenses

Sergio Garcia-Martinez (Universidad Politécnica de Madrid, Spain); Pilar Castillo-Tapia (Eindhoven University of Technology, The Netherlands); Jose Rico-Fernandez (Northern Waves AB, Sweden); Pablo Sanchez-Olivares and Adrián Tamayo-Domínguez (Universidad Politecnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
We present a 2D lens array antenna based on geodesic lenses as a highly efficient solution that can scan in two planes. The two-step beamforming network generates 83 independent beams in a steering range of 100 degrees in the horizontal plane and 70 degrees in the vertical plane. Scanning in the horizontal plane is achieved by an array of generalized geodesic Luneburg lenses, whereas scanning in the vertical plane is achieved by a beamformer composed of a geodesic half Maxwell fish-eye lenses. Both geodesic lenses are designed with an efficient in-house ray-tracing and physical-optics model, prioritizing a high level of crossover between adjacent beams. The resulting antenna is fully metallic and can be manufactured monolithically using additive manufacturing.

9:20 A Reflector - Lens Hybrid Antenna System for Backhaul Links at 300 GHz

Alexandros Bechrakis Triantafyllos, Huasheng Zhang, Maria Alonso-delPino and Nuria LLombart (Delft University of Technology, The Netherlands)
This work presents a Quasi-Optical antenna for energy efficient backhaul/fronthaul links at 300GHz. The proposed antenna concept consists of an offset Gregorian reflector configuration illuminated by a lens-based subsystem. The overall structure is fed by an antenna on-chip (AoC) implemented in a 90nm SiGe-BiCMOS process. The diameter of the primary reflector is 45cm, featuring a directivity of 62dBi and a half-power beamwidth of 0.15degrees. By operating in the radiative near-field, the proposed antenna system achieves power spreading loss of 0.8dB for a point-to-point link of 100m. To satisfy the tight alignment requirements of the envisioned scenario, scanning capability is included through the lens-based subsystem. This is done by rotating a lightweight free-standing silicon lens and allows correction for misalignment of 2degrees (14 beams) with a scan loss lower than 1.1dB over a 90GHz frequency range. The overall loss, considering the AoC as well as spillover and reflection losses, is 3.5-4dB.

Tuesday, April 21 8:00 - 9:40

CS10a Recent Advances on Propagation Research and Its Impact on Localizations 1

T05 Positioning, localization, identification & tracking / Convened Session / Propagation
Chairs: Christian Gentner (German Aerospace Center (DLR), Germany), Wei Wang (Chang'an University, China)

Room: Dusseldorf

8:00 RIS-Enabled Indoor Mapping Experiments with mmWave Channel Measurements

Benoit Denis (CEA-Leti & Université Grenoble Alpes, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France)
Considering a Millimeter Wave (mmWave) single-Base Station (BS) Non-line-of-Sight (NLoS) scenario, this paper explores the possibility to map scattering points in the vicinity of a presumed known mobile user's location, with the assistance of a reflective Reconfigurable Intelligent Surface (RIS). The approach

relies on multipath parameters (i.e., delays and angles) extracted at the user while the RIS is beam scanning the environment, as well as on basic geometric heuristics for identifying and selecting the best scattering point candidates after channel calibration. The qualitative analysis of first experimental results based on real mmWave channel measurements at 28 GHz confirms the interest of leveraging standard RIS beam scanning protocols and multi-RIS cooperation, as well as multi-site user sensing strategies (e.g., along a trajectory or in a group of spatially distributed nodes). They also point out a few limitations, such as the presence of significant grating lobes in RIS beam patterns.

8:20 Measurement and Modeling of the Radio Channel for Warehouse Localization: RFID Technology

Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France); Pascal Pagani (CEA, LETI & Université Grenoble-Alpes, France)
Reliable localisation of assets in industrial warehouses is critical for automated logistics, yet the electromagnetic environment of such facilities characterised by extensive metallic racks, conveyor belts, and high-density storage systems poses severe challenges for back-scattered RFID links. In this work we present a comprehensive polarimetric measurement campaign of a RFID channel in a real warehouse, focusing on the demanding carousel for bin handling. A dual-polarised dipole/Vivaldi antenna pair, fed by a 4-port vectornetwork-analyzer based channel sounder, measured the full 2x2 S-parameter matrix over a 200 MHz band centered at 864 MHz. The data were processed with a high-resolution SAGE algorithm to extract multipath components, yielding path-loss exponents, shadowfading statistics, delay spreads, angular spreads, and cross-polarisation ratios for all four polarisation configurations. The derived statistical and extracted small scale parameters provide realistic inputs for simulation and localisation algorithm design in industrial

8:40 Channel Modeling and Connectivity Analysis Based on UAV Air-to-Ground Channel Measurement

Chen Liang and Yue Lyu (Chang'an University, China); Ji Zihao (ChangAn University, China); Wei Wang (Chang'an University, China)
In recent years, unmanned aerial vehicles (UAVs) have been widely used as aerial base stations in emergency rescue and environmental monitoring. However, air-to-ground (A2G) links are susceptible to large-scale fading. This paper investigates channel characteristics through measurements of fixed-wing UAVs at 300-800 meters altitudes in suburban scenarios, focusing on shadow fading and connectivity. Based on measurement data, the Gamma distribution is selected to model shadow fading via hypothesis tests and information criterion. A connectivity probability model incorporating path loss exponent and Gamma parameters is derived. Simulations show the effects of key parameters and altitude on connectivity, revealing that higher altitudes accelerate the decline in link

9:00 Impact of Typhoon Gaemi (202403) on Evaporation Duct Distribution and Radio Signal over-the-Horizon Propagation in the Taiwan Strait

Zikang Zhang, Shuwen Wang, Hao Zhao, Yihang Shu and Kunde Yang (Northwestern Polytechnical University, China)
Evaporation ducts, formed by oceanic evaporation, significantly affect electromagnetic (EM) propagation. Typhoons notably alter evaporation duct height (EDH) and path loss (PL), yet research on over-the-horizon (OTH) communication across the Taiwan Strait under typhoon conditions remains scarce. Using Typhoon Gaemi (202403) as a case study, this study examines EDH's spatial distribution and PL's variations over the strait via coastal small cell base station signal analysis. The typhoon's high-wind-speed (high-WS) zone and eye triggered substantial meteorological variations, lowering EDH from 15 m to 12 m. Consequently, PL rose from 162 dB (high-WS zone) to 209.2 dB (eye). Wind speed (WS) and relative humidity (RH) dominated EDH/PL changes during the typhoon, though RH gained greater dominance over the link as the low-WS eye passed.

9:20 Dualband OFDM Delay Estimation for Multi-Target Localization

Jialun Kou (KU Leuven, Belgium); Achiel Colpaert (IMEC, Belgium & KU Leuven, Belgium); Zhuangzhuang Cui and Sofie Pollin (KU Leuven, Belgium)
Integrated localization and communication (ILC) systems aim to reuses communication waveforms for simultaneous data transmission and localization, but delay resolution is fundamentally limited by available bandwidth. In practice, large contiguous bandwidths are difficult to obtain due to hardware constraints and fragmented spectrum. Aggregating non-contiguous narrow bands can increase the effective aperture, but it is not equivalent to a contiguous band: missing spectral components distort the delay profile, broadening the mainlobe and elevating sidelobes.
This paper introduces a point-spread-function (PSF)-centric framework for dual-band OFDM delay estimation. We model the observed delay profile as the convolution of the true target response with a PSF determined by the dual-band subcarrier selection pattern, explicitly linking band configuration to resolution and ambiguity. To suppress PSF-induced artifacts, we adapt the RELAX algorithm for the dualband multi-target delay estimation. Simulations demonstrate improved robustness and accuracy in dual-band scenarios, supporting ILC under fragmented spectrum.

Tuesday, April 21 8:00 - 9:40

CS25a Electromagnetic medical imaging: inversion algorithms and novel data processing strategies 1

T06 Biomedical and health / Convened Session / Electromagnetics
Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)

Room: Prague

8:00 Enhanced Electromagnetic Torso Imaging Using Body-Matched Cavity-Backed Antenna

Seyed Mohammad Hadi Mousavi and Lei Guo (The University of Queensland, Australia); Christophe Fumeaux (University of Queensland, Australia); Amin Abbosh and Sasan Ahdi Rezaeieh (The University of Queensland, Australia)
A body-matched cavity-backed antenna is proposed for electromagnetic torso imaging platforms. To address the strong reflections caused by the mismatch between the antenna and the skin surface, it is designed using a high-permittivity substrate with a thickness of 10 mm. To enhance operating bandwidth and signal penetration, the antenna is developed in three stages: starting from a sleeved coax-fed square patch on the top layer, followed by metallization of the substrate edges and placement of a radiator on the back layer, and addition of four triangular corners at the top layer. The designed antenna excites three resonant frequencies at 0.73, 1.02, and 1.35 GHz, resulting in a wide fractional bandwidth of 73% at 0.65–1.4 GHz with a compact size of 60 × 60 × 10 mm³, corresponding to 0.13 × 0.13 × 0.02 λ_0^3, with respect to the wavelength at 0.65 GHz.

8:20 Detection of Hotspots During Domestic Composting by Direct Microwave Imaging Algorithms: A Numerical Assessment

David O.Rodriguez-Duarte and Alex Ramiro Masaquiza-Caiza (Politecnico di Torino, Italy); Shreesal Shrestha (Constructor University, Bremen,Germany); Francesca Vipiana (Politecnico di Torino, Italy)

Having homogeneous temperature profiles is desirable in composting, especially in low-volume-mass production, a less self-regulated and unstable scenario, where the biomass maturation cycle is more sensitive to the detrimental effects of hotspot disruptions that could annihilate the process. This study numerically assesses the performance of microwave imaging (MWI) as an alternative for detecting these hotspots by using four non-iterative algorithms: truncated singular value decomposition (TSVD) with a Born approximation, delay-and-sum (DAS), multiple signal classification imaging (MUSIC-I), and multifrequency bifocusing (MFBF), and two non-invasive multi-view operation setups, partial and full, to map temperature related dielectric contrasts within a domestic composter. Overall, the study demonstrates that direct MWI is a feasible approach for compost hotspot detection.

8:40 A New 3D Breast Dataset, Randomly and Auto Generated for Microwave Imaging

Ambroise Dièss (Sorbonne Université, Laboratoire de Génie Electrique et Electronique de Paris, France); Hélène Roussel (Sorbonne Université, CNRS, Laboratoire de Génie Electrique et Electronique de Paris, France); Nadine Joachimowicz (Sorbonne Université, CNRS Laboratoire de Génie Electrique et Electronique de Paris, France & Université Paris Cité, France)

This paper introduces a new dataset of anthropomorphic breast models designed for machine learning applications in microwave imaging. The purpose is to automate the development of a database of 3D breast models designed for tumor detection. A software capable of automatically and randomly generating realistic breast models, including internal structures such as tumors and glandular tissue, is developed. This enables the production of various and complex models ready for 3D printing and electromagnetic simulations, each in just a few minutes on a standard PC. In this work, the 3D breast models set is devoted to train a U-NET architecture dedicated to microwave breast imaging. However, its design also allows for broader applications in supplying neural networks for general breast imaging tasks.

9:00 2D Microwave Imaging for Pleural Effusion: Towards a Safer Alternative to X-Ray Scans

Adarsh Singh (Indian Institute of Engineering Science and Technology, Shibpur, India); Bappaditya Mandal (Uppsala University, Sweden); Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India); Robin Augustine (Uppsala University, Sweden)

Pleural effusion and other high-water lung abnormalities often need to be monitored continuously or repeatedly. However, traditional techniques like chest X-rays and CT scans can be hazardous because they use ionizing radiation. This study presents a microwavebased imaging method that uses a high-gain, wideband directional antenna and a raster scanning method to identify these anomalies. The antenna operates in the 1.5–3.1 GHz range, including the 2.45 GHz ISM band, giving it broad-spectrum coverage. The image reconstruction technique was modified and subsequently compared to assess the accuracy and potential for clinical application. The proposed approach is demonstrated on a realistic human body model, and a comparison with conventional X-ray imaging highlights its potential as a safe, non-invasive, and effective alternative for detecting lung conditions characterized by high water content.

9:20 Hybrid Processing in Electromagnetic Imaging for Steatotic Liver Diagnosis

Azin Janani (The University of Queensland, Australia); Kamel Sultan (University of Queensland, Australia); Sasan Ahdi Rezaeieh and Amin Abbosh (The University of Queensland, Australia)

A hybrid processing method for electromagnetic torso imaging aimed at detecting hepatic steatosis is presented. The method employs blind source separation and independent component analysis combined with correlation-based filtering to suppress strong reflections from outer torso layers that obscure weak liver responses. The artifact-reduced signals are then processed using a two-stage delay-multiply-and-sum imaging algorithm to reconstruct the target region. This approach removes the need for precise and symmetric antenna placement on both sides of the torso, a major practical limitation of differential electromagnetic signal processing techniques. The proposed method is evaluated in a full-wave simulation environment using a realistic torso model and a twelveelement antenna array. Quantitative analysis demonstrates its effectiveness in detecting hepatic steatosis while reducing dependency on symmetric antenna positioning.

Tuesday, April 21 8:00 - 9:40

CS31a Antennas and Arrays for Radio Astronomy 1

T03 Aerospace, space and non-terrestrial networks / Convened Session / Measurements
Chairs: Sean V Hum (University of Toronto, Canada), David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

Room: Krakow

8:00 Efficient Analytical Estimation of Mutual Coupling in Murchison Widefield Array Antennas

Maria Kovaleva (Curtin University, Australia); Rob Maaskant (CHALMERS, Sweden); Karl Warnick (BYU, USA); David B Davidson (Curtin University, Australia & Stellenbosch University, South Africa)

Australia & Stellenbosch University, South Africa) Mutual coupling between antenna elements can significantly affect array performance, yet full-wave simulations of large-scale phased arrays of hundreds of elements are computationally expensive. This work aims to verify that recently proposed analytical methods to estimate mutual coupling between antenna elements can be used to predict the coupling coefficients in phased array antennas even for infinite ground planes. We estimated mutual coupling between the arrays of half-wavelength dipoles and the Murchison Widefield Array dipoles using the plane-wave approximation and a modified pattern overlap integral. Our approach predict the coupling directly from the complex electric field of an isolated element, avoiding the need for embedded element pattern simulations. The analytical results have an excellent agree with FEKO-MoM simulations for both half-wave and MWA bow-tie dipoles, in free space and above an infinite ground plane, while significantly reducing computational cost.

8:20 Optimising Array Layouts with Aperiodic Tiling to Reduce Beam Spectral Variations Caused by Mutual Coupling

Ashish Mhaske, Quentin Gueuning, Eloy De Lera Acedo, Oscar OHara, Dominic Anstey and John Cumner (University of Cambridge, United Kingdom (Great Britain)); Anthony Keith Brown (University of Manchester, United Kingdom (Great Britain)); Andrew Faulkner and Fred Dulwich (University of Cambridge, United Kingdom (Great Britain))

The embedded element patterns (EEPs) of wideband antenna arrays can exhibit sharp spectral variations caused by mutual coupling between antennas. This, in turn, increases the time-delay spread of the impulse response, a critical performance metric in modern radio astronomy. To minimise this chromaticity, we propose an optimisation of the array layout using aperiodic tiling, specifically the hat polykite pattern. Two in-house methods are combined: a fast electromagnetic solver for rapid generation of EEPs for a given layout, and an optimisation scheme based on PolyChord's nested-sampling algorithm to efficiently explore the antenna position parameter space and determine the optimal configuration. Results show that aperiodic tiling yields EEPs with improved spectral smoothness compared to existing layouts.

8:40 Differential Active Planar Antenna and Frequency-Division Multiplexing with Commercial Electronics for CHARTS Interferometer

Albert Wai Kit Lau (University of Toronto, Canada); Gonzalo Burgos (Universidad de Concepcion, Chile); Bruno Pollarolo and Sebastian Manosalva (Universidad de Chile, Chile); Frederik Brecht (University of Toronto, Canada); Tomas Cassanelli (Universidad de Chile, Chile); Juan Mena-Parra and Keith Vanderlinde (University of Toronto, Canada); Ricardo Finger (University of Chile, Chile)

The Canadian-Chilean array for radio transient studies (CHARTS) is a wide-field, low-frequency interferometer (300--500 MHz) designed to detect and localize astronomical transients in the southern sky. We present the CHARTS antenna and analog front-end architecture, highlighting key constraints including noise budget, interference robustness, manufacturability, and cost. To maximize digitizer utilization, we implement frequency-division multiplexing that combines eight antennas per digitizer input while preserving per-sub-band gain and phase calibration. We validate the design with a two-element interferometer built from the CHARTS hardware, and solar observations yield clear interferometric fringes with the expected minute-scale wrapping. These results demonstrated endto-end functionality and inform the path to initial station deployment and the full array.

9:00 Spinning Array Antenna Radio Telescope Targeting Low Cost and Low Mutual Coupling

Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Quentin Gueuning and Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain))

Radio telescopes are typically based on reflector or aperture array antennas. These face challenges such as high cost, slow survey speed, and/or high mutual coupling. This paper proposes an antenna concept based on a spinning interferometer to overcome these challenges. In the proposed system, a small number of antennas are sparsely placed on a revolving platform. The received signal at the different antennas is pair-wise correlated, and the platform is rotated to suppress grating lobes. An example system consisting of 18 dual-polarized Vivaldi antenna elements with a minimum antenna spacing of 4 wavelengths is studied demonstrating attractive imaging properties such as narrow beam and low side lobes in the point-spread function. The proposed concept is applicable to science cases with slowly varying sky signals that require wide fields-of-views.

9:20 A Suite of Wideband Receivers for Murriyang, CSIRO's Parkes Radio Telescope

Stephanie Smith (CSIRO Space and Astronomy)

This paper presents the scientific benefits and main system design of the ultra-wideband receiver being developed for Murriyang, the CSIRO Parkes Radio Telescope, covering 704 MHz to 33 GHz. It outlines the project's progress, key system designs, and anticipated scientific outcomes. The main RF subsystems and signal flow are also briefly described.

Tuesday, April 21 8:00 - 9:40

CS37a Advances in Dynamic Metasurface Antennas/Reconfigurable Holographic Surfaces for Next-Generation Wireless Applications: Design, Development and Applications 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Aakash Bansal (Loughborough University, United Kingdom (Great Britain)), Abdul Jabbar (Loughborough University, United Kingdom (Great Britain))

Room: Rome

8:00 2D Waveguide-Fed Metasurface Antenna Arrays: Modeling and Optimization for Bistatic Sensing

Ioannis Gavras (National and Kapodistrian University of Athens, Greece); Panagiotis Gavriilidis (University of Athens, Greece); George C. Alexandropoulos (University of Athens & University of Illinois Chicago, Greece)

This paper presents a physics-consistent framework for bistatic sensing incorporating a 2-Dimensional (2D) waveguide-fed metasurface antenna array capable of realizing eXtremely-Large Multiple-Input Multiple-Output (XL MIMO) apertures. A coupled-dipole model is presented that captures the array's mutual coupling due to both waveguide and free-space interactions, and a novel passivity constraint on the corresponding magnetic polarizabilities is proposed. Focusing on a bistatic sensing setup, we leverage a Neumann-series approximation of the array response model and derive the Cramer-Rao bound for multi-target parameter estimation, which is then incorporated into a sensing optimization formulation with respect to the metasurface's per-element resonance strength configuration. Simulation results on the position error bound in the radiative near field with the proposed design quantify the critical role of metamaterial placement in strongly coupled metasurface-based XL MIMO bistatic sensing systems.

8:20 Analysis of Frequency-Diverse and Dispersion Effects in Dynamic Metasurface Antenna for Holographic Sensing and Imaging

Abdul Jabbar, Aakash Bansal and William Whittow (Loughborough University, United Kingdom (Great Britain))

Dynamic metasurface antennas (DMAs) represent a novel approach to programmable and affordable electromagnetic wave manipulation for enhanced wireless communications, sensing, and imaging applications. Nevertheless, current DMA designs and models are usually quasi-narrowband, neglecting the versatile frequency-diverse manifestation and its utilization. This work demonstrates the frequency-diversity and dispersion operations of a representative DMA structure at the millimeter-wave band. We demonstrate flexible dispersion manipulation through dynamic holographic reconfigurability of the meta-atoms in a DMA. This effect can create distinct radiation patterns across the operating frequency band, achieving flexible frequency diversity with enhanced scanning range within a compact, reconfigurable platform. It eliminates the need for wideband systems or complex phase-shifting networks while offering an alternative to frequency-scanned static beams of traditional leaky-wave antennas. The results establish fundamental insights into modelling and utilization of dispersive effects of DMAs in next-generation near-field and far-field holographic sensing and computational holographic imaging applications.

8:40 A State-of-the-Art Review on Additively Manufactured Electromagnetic Metasurface Research at Loughborough University

Aakash Bansal and William Whittow (Loughborough University, United Kingdom (Great Britain))
This paper presents a general overview of different 3D printed metamaterials and metasurfaces developed by the Wireless Communications Research Group at Loughborough University, UK. This condensed review highlights some of the major contributions in additively manufactured two and three-dimensional electromagnetic devices such as reflectarrays, transmitarrays, lenses, and antennas.

9:00 Design Optimization of Dynamic Metasurface Antenna Elements for Beamforming Capabilities

Joseph Carlson (University of California, San Diego, USA); Sajedeh Keshmiri (ASU, USA); Mohammadreza F. Imani (Arizona State University, USA); Robert Heath (University of California, San Diego, USA)
Dynamic metasurface antennas (DMAs) are a type of reconfigurable antenna aperture that offers low-power, electronically steerable beamforming capabilities. While prior studies have demonstrated successful beam steering using p-i-n- and varactor-diode-based DMA architectures, limited attention has been given to the underlying element-level design and its influence on efficiency and tunability. In this paper, we study the optimization of DMA meta-atom geometries with an emphasis on radiation efficiency, tuning sensitivity, and frequency response characteristics. Using full-wave HFSS simulations, we extract key design parameters to reveal a fundamental tradeoff in the meta-atom design, where high radiation resistance designs lead to a lower tuning sensitivity. We also find that the radiation resistance for the optimal meta-atom design that maximizes beamforming gain is proportional to the resistance of the selected varactor diode. This highlights an important design consideration for DMA meta-atoms, where the meta-atom radiation resistance should be tailored towards the integrated varactor diode.

9:20 Physical Implementation of a Three-Layer Metasurface Enabling Reflectionless Anomalous Transmission

Kioumars Pedram, Federico Giusti, Enrica Martini, Stefano Maci and Matteo Albani (University of Siena, Italy)
A highly efficient metasurface (MTS) engineered to deflect a normally incident plane wave toward an oblique angle of 50° is proposed. The surface is composed of three macroperiodic homogenized layers, each designed such that their overall spatial modulation enforces the cancellation of undesired Floquet modes over a macroperiod. The homogenized impedance profiles of these layers are derived using the Floquet-Mode Optimization (FM-OPT) method and subsequently mapped onto subwavelength unit cells for realistic implementation. This design ensures high-efficiency wave redirection with minimal reflection and scattering losses. Full-wave simulations of both the homogenized model and the discretized metasurface confirm excellent agreement in electric-field distributions, scattering parameters, and radiation patterns, validating the proposed macroperiodic MTS design approach.

Tuesday, April 21 8:00 - 9:40

CS42a AMTA Post Processing Techniques in Antenna Measurements 1

TO8 Fundamental research and emerging technologies/processes / Convened Session / Measurements
Chairs: Joshua Gordon (US National Institute of Standards and Technology, USA), Francesco Saccardi (Microwave Vision Italy, Italy)

Room: London

8:00 A Combined Spherical Wave Correction and Iterative Approach to Manage 3D Positioning Errors in a Non-Redundant NFFF Transformation for Long AUTs

Francesco D'Agostino, Flaminio Ferrara, Claudio Gennarelli, Rocco Guerriero and Massimo Migliozzi (University of Salerno, Italy); Luigi Pascarella (Università di Salerno, Italy)
In this work, we address the issue of compensating for known 3D position errors which affect the data in a non-redundant (NR) spherical near-field to far-field (NFFF) transformation for long antennas. A novel and compelling method, built upon two steps, is here developed. The first step involves a phase correction procedure, the spherical wave correction, which corrects the phase shift affecting the collected samples caused by their radial displacements from the scanning sphere. In the second step, an iterative algorithm is employed to retrieve the samples at their correct positions set by the NR representation from those, now lying on the correct scan sphere, got as result of the first step. Finally, an optimal sampling interpolation expansion allows one to get the input data required to execute the traditional spherical NFFF transformation. Numerical tests show the validity of the approach.

8:20 Wideband Antenna Deconvolution for Bistatic Millimeter Wave Radar Reflectivity Measurements

Carsten Andrich, Isabella B. Varga, Tobias Nowack, Alexander Ihlow, Sebastian Giehl, Michael Schubert, Reiner S. Thomä and Matthias Hein (Technische Universität Ilmenau, Germany)
Bistatic radar measurements offer unique spatial diversity and enhanced target characterization capabilities, rendering them increasingly vital for contemporary sensing application research. The reliability of such measurements is contingent upon precise system and antenna calibration. The prevailing technique is the substitution method, which involves the use of known reference objects. We propose an over-the-air calibration algorithm for spherical bistatic measurement systems. Our method is both significantly simpler and twice as fast as existing algorithms. The application of our technique to reflectivity measurements of a metal sphere from 76 to 81 GHz demonstrates a dynamic range enhancement of up to 40 dB when compared with uncalibrated data. A comparison with simulation data demonstrates a high degree of agreement between measurement and simulation.

8:40 Handling Redundancy in Optimized Sampling of Fields in the near-Zone: The 2D Case

Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy)
In Near-Field (NF) antenna measurements, reducing sampling redundancy has traditionally been pursued to minimize the number of acquired samples. However, redundancy can also play a beneficial role by mitigating the impact of measurement noise. To enable a degree of sampling redundancy, a constrained Singular Value Optimization (SVO) technique is introduced which additionally enforces a lower bound on the largest singular value, set according to a target Signal-to-Noise Ratio (SNR) on the data. Numerical results demonstrate that constrained SVO achieves the requested SNR levels and that redundancy has a spatial averaging, and thus noise filtering, effect.

9:00 Implementation of Spherical Mode Filtering Based Reflection Suppression Through the Use of the Generalized Vector Addition Theorem for Antenna Position Translation

Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Marc Dirix (E&C Anechoic Chambers, Belgium & RWTH-Aachen University, Germany); Florian Reher (RWTH Aachen University, Germany)

Reflections within antenna test ranges can be the most significant single source of measurement uncertainty within the range assessment budget. Frequency domain, mode-filtering based techniques have become an indispensable tool providing a very effective method for supressing range multi-path effects resulting from parasitically coupled re-radiation in all forms of free-field antenna measurements. These techniques rely upon the acquisition of the test antenna when offset from the origin of the measurement coordinate system. During the post-processing, it is required that the antenna be translated to the origin of the measurement coordinate system. This paper provides further validation of an alternative strategy involving the generalized vector addition theorem for applying the antenna position translation which is especially convenient for spherical near-field measurements as several domain transformations are negated. This paper extends the authors prior studies by comparing the traditional and revised algorithms using empirically data taken in a scattering rich environment.

9:20 Analysis of Flush-Mounted Antenna Placement via Huygens Source Reconstruction from VHF Measurements

Zain Haider (MVG Industries, France); Francesco Saccardi and Lars Foged (Microwave Vision Italy, Italy)

The Huygens Box (HB) technique offers an accurate and computationally efficient approach for antenna placement within computational electromagnetic solvers. This paper presents an experimental validation of the HB method for low-frequency, flush-mounted antennas using measured radiation patterns of a monocone antenna mounted on a 4-meter ground plane, acquired with a multi-probe system. The Infinite Plane Boundary Condition (IPBC) pre-processing is applied to minimize edge diffraction effects from the finite ground plane. The HB model is integrated onto an aircraft geometry and evaluated using full-wave simulations across the 100-200MHz band. Results show strong agreement with reference data, confirming findings from a recent parametric study on HB dimensioning for low-frequency measured sources. Repeating the analysis with the known CAD model of the source shows minimal deviation from measured data, demonstrating robustness against typical low-frequency measurement errors. These results confirm the HB method as a reliable tool for low-frequency antenna modeling.

Tuesday, April 21 8:00 - 9:40

CS4a Challenges in assessing human RF exposure to existing and emerging mobile radio technologies up to 6G 1

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Wout Joseph (Ghent University/IMEC, Belgium), Lisa-Marie Schilling (Technische Universität Ilmenau, Germany)

Room: Paris

8:00 EMF Exposure Assessment in Spatial and Temporal Scale with Uncertainty Quantification

Yukun Liu (Telecom Paris - IP Paris, France); Shanshan Wang (Polytechnic Institute of Paris, France); Yarui Zhang (University Paris-Saclay, France); Joe Wiart (Télécom Paris, France)

The rapid expansion of wireless communication technologies, particularly with the deployment of 5G and beyond networks, has heightened public concerns regarding radio frequency electromagnetic field (RF-EMF) exposure. Measurement based assessments, however, are often affected by uncertainties arising from device noise, spatial environmental variability, and temporal fluctuations in base station activity. This paper presents a framework on spatial and temporal prediction of RF-EMF exposure with quantified uncertainty. Electric field measurements were collected over 11 months from 12 sensors deployed in an urban environment. On the spatial scale, Polynomial Chaos Expansion combined with Bootstrap resampling is used to model and predict exposure levels along with spatial uncertainty. On the temporal scale, a Long Short-Term Memory network is utilized for multi-step forecasting, and conformal prediction is employed to provide statistically valid confidence intervals. The proposed framework demonstrates improved reliability in exposure prediction and uncertainty estimation for continuous EMF monitoring in complex real-world environments.

8:20 Importance of Diffraction for Improved RF Exposure Planning and Measurements for 5G and Beyond

Emrah Tas and Frederic Pythoud (Swiss Federal Institute of Metrology METAS, Switzerland)

With new emerging wireless standards, the planning of RF exposure from base station and its compliance measurements are becoming more difficult tasks due to the introduction of new techniques. The consistence of the exposure measurements with planned RF exposure values could be harder to reach. This issue was experienced during a recent RF exposure measurement campaign. There, the effective electric field strength was found to be significantly higher than the calculations for some locations. The reason was found out to be the diffraction of the electromagnetic radiation through an open window, which resulted in the amplification of the electric field at a focus point behind the window opening. In this publication, this phenomenon is presented in terms of theory, simulations and measurements in the context of RF exposure from base stations. Moreover, the effect of diffraction and its implications for the RF exposure planning for 5G and beyond are discussed.

8:40 Investigation of 5G Massive MIMO Beam Management by Synchronous Multiprobe Exposure Measurement

Christian Bornkessel and Lisa-Marie Schilling (Technische Universität Ilmenau, Germany); Anna-Malin Schiffarth, Thanh Tam Julian Ta and Dirk Heberling (RWTH Aachen University, Germany); Matthias Hein (Technische Universität Ilmenau, Germany)

A network of synchronized measurement probes was used to study the beam management on a 5G massive MIMO antenna system over the air. The measurements were supported by a second-by-second operational monitoring. A beam walk crosswise to a fixed user provoking maximal data traffic showed 12° azimuth 3 dB beam width confirming that it exceeds the dimensions of an exposed person many times at typical user distances. Outside the beam, the exposure is much less, resulting in an exposure decrease compared to fixed-beam antennas. In a second scenario, the user moved along the measurement probes, and the adjustment of the beam could be tracked. In case of two locally separated users in the same cell forcing maximal traffic, the transmit power of the station was divided between both, resulting in an exposure decrease compared to a single user. The results support risk communication and the development of measurement methods.

9:00 SAR-Based Assessment of the EMF Exposure Behind a Massive MIMO Base Station

Stanislav Stefanov Zhekov, Bo Xu, Carla Di Paola, Davide Colombi, Paramananda Joshi, Jens Eilers Bischoff, Christer Törnevik and Björn Flach (Ericsson AB, Sweden)

Radio frequency (RF) electromagnetic field (EMF) exposure is assessed before a base station (BS) is delivered to the market. In this paper, the RF EMF exposure behind a massive multiple-input multiple-output (mMIMO) BS having a dual-polarized 64-element antenna array is numerically assessed. The used exposure metrics are local 1-g and 10-g specific absorption rate (SAR), and whole-body average SAR. The assessment is performed at 3.5 GHz for 400 W output power from the radio for any transmit beam. The results show that the EMF exposure is below the limit values for both local and whole-body average SAR already on the back surface of the BS and therefore it is possible to work behind similar BS without reduction of the output power. It is also demonstrated that using the reference levels to assess EMF compliance in the back direction of a mMIMO BS may lead to overestimation of the compliance distance.

9:20 Initial 5G mmWave EMF Exposure Assessment on Outdoor Private Networks

Alvaro Villaescusa-Tebar, Sandra Garcia-Ubeda and Mauro Gonzalo Tarazona Levano (Universitat Politècnica de València, Spain); Concepcion Garcia-Pardo (Universitat Politècnica de València & Institute of Telecommunications and Multimedia Applications

The introduction of 5G communications at the millimeter-wave (mmWave) spectrum has enabled gigabit data rates but also introduced new challenges for electromagnetic-field (EMF) exposure assessment. At these frequencies, active-antenna systems with dynamic beamforming produce highly variable radiation patterns, making realistic evaluation of exposure particularly complex. Recent studies have mainly focused on some scenarios, but outdoor private networks remain unexplored. This paper presents an initial experimental assessment of EMF exposure in a 5G mmWave private network operating at 26 GHz. Two simultaneous measurement approaches were employed-frequency-selective and code-selective-to evaluate exposure values under idle and traffic-loaded conditions and using both omnidirectional and directive antennas. Results show that traffic activity significantly increases exposure levels and that type of antenna can strongly affect the measured values, underlining the need for harmonized methodologies for 5G mmWave EMF

Tuesday, April 21 8:00 - 9:40

EO8a Electromagnetic theory: New Material Design 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Electromagnetics
Chairs: Ana Díaz-Rubio (Universitat Politècnica de València, Spain), Piero Triverio (University of Toronto, Canada)

Room: Barcelona

8:00 Near-Field Coupled Metamaterial Absorber for Wearable Strain Sensing with Enhanced Shielding

Tauseef Hussain (Universitat Politècnica de Catalunya (UPC), Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat Politecnica de Catalunya, Spain)

This paper presents a novel wireless strain sensing approach based on a near-field coupled metamaterial absorber (MMA). The proposed system exploits near-field interaction between a dipole antenna and a stretchable MMA, where strain-induced resonance shifts are translated into variations in the antenna gain. Full-wave simulation results indicate that a 10% strain produces a gain variation of approximately 5.5 dBi. Furthermore, a prototype MMA was fabricated by direct ink writing on a TPU film integrated with an elastic cotton waist belt. Experimental validation demonstrates wireless respiration monitoring, where RSSI variations of approximately 2-3 dBm were observed during breathing, and the corresponding respiration cycles were successfully identified by a Z-score based peak detection algorithm. In addition, specific absorption rate (SAR) analysis verified that the MMA also serves as an effective shielding layer, ensuring enhanced user safety by reducing electromagnetic exposure.

8:20 Advancing Periodic Surface Solutions for Wearable Antenna Protection in ETA Radar Systems

María Elena de Cos Gómez (Universidad de Oviedo, Spain); Alicia Flórez Berdasco (University of Oviedo, Spain); Jaime Laviada (Universidad de Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)

A comparative analysis of three metallization geometries-cross, hexagonal, and circular-for a metaradome designed to protect and preserve the performance of a 24 GHz wearable antenna for Synthetic Aperture Radar (SAR) based Electronic Travel Aid (ETA) applications is presented. A previously developed Grid Array Antenna (GAA), operating within the 24.05 GHz to 24.25 GHz band, is used as the reference radiator to assess the electromagnetic behavior of each configuration. All metaradomes are fabricated using ecofriendly aluminum-cladded polypropylene (Al-cladded PP) and are evaluated in terms of transmission, reflection, angular stability, and their impact on the antenna's radiation characteristics. Special attention is given not only to amplitude but also to phase variations introduced by the radomes, as phase integrity is critical for SAR image quality.

8:40 Absorbers Used as Multi- Frequency Tags at Millimeter Wave

Atefeh Kordzadeh (Silicon Austria Labs GmbH, Austria); Saeid Karamzadeh (Silicon Austria Labs, Austria); Wagner Christoph (Silicon Austria Labs (SAL), Austria); Walter Hartner (Infineon Technologies, Austria)

This paper reports on the design, numerical simulation, and experimental realization of chipless frequency selective surface (FSS) tags operating in the millimeter-wave regime. The proposed tags are composed of periodic arrays of unit cells patterned on a lossy dielectric substrate, working as an absorber at a designated frequency. Information encoding is achieved through the selective presence or absence of resonance frequencies within the interrogation bandwidth, corresponding to binary states "1" and "O," respectively. The operational frequencies is 77 GHz. In the next step, a dual frequency tag is designed and fabricated. The adoption of a cost-effective FR4 substrate underscores the practicality of the proposed approach, rendering the tags suitable for secure identification and authentication applications.

9:00 Inverse Design for Broadband All-Dielectric 3D-Printed Absorbers

Teresa Mengual Chuliá, Marcos Alberto Molina Obrien Molina Obrien, David Zurita Herranz and Luis Manuel Mánez-Espina (Universitat Politècnica de València, Spain); Daniel Rodriguez Del Rosario (Aimplas, Spain); Ana Díaz-Rubio (Universitat Politècnica de València, Spain)

This paper investigates the potential of thermoplastics for electromagnetic applications, with a particular focus on high-permittivity materials. A comprehensive characterization of the dielectric properties of several polymers is carried out, highlighting their suitability for radio-frequency and microwave devices. Building on these results, we explore the design and implementation of all-dielectric metasurfaces for efficient microwave absorption. More specifically, a multiband absorber is developed using inverse design techniques and experimentally validated, demonstrating the feasibility of additive-manufactured thermoplastics as functional building blocks for next-generation of all-dielectric electromagnetic devices at microwaves.

9:20 Isotropic Low-Loss Artificial Dielectrics with 3D Metallic Inclusions for mm-Wave Lens Applications

Dunja Lončarević, Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

High-directivity mm-wave lens antennas increasingly require materials that combine low loss, isotropic behavior, and scalability. This work aims to exploit artificial dialectics with metallic inclusions engineered to achieve isotropy and reduced dissipation. Based on Lewin's analytical formulation from 1946, the dependence of the effective parameters on inclusion size is revisited, identifying distinct nano- and micro-inclusion regions. Building on that, full-wave simulations demonstrate that while canonical cubic inclusions provide limited magnetic response, a modified "rubic" shape proposed in this paper restores permeability and maintains low loss. The resulting artificial dielectric achieves an isotropic refractive index of 2 with attenuation below 0.25 dB per wavelength, making it suitable for compact, high-gain mm-wave lens antennas.

Tuesday, April 21 8:00 - 9:40

PO8a Propagation models for Non-Terrestrial Networks 1

TO3 Aerospace, space and non-terrestrial networks / / Propagation
Chairs: Joonas Kokkoniemi (University of Oulu, Finland), Lorenzo Luini (Politecnico di Milano, Italy)

Room: Firenze

8:00 Impact of Doppler Shift in Terahertz Band Non-Terrestrial Network Applications

Bushra Khan and Joonas Kokkoniemi (University of Oulu, Finland)
In today's world, high-speed and reliable internet access is essential, yet users in airplanes and remote regions often face limited connectivity. Conventional microwave bands provide long-range coverage but suffer from bandwidth constraints, limiting data rates and reliability. To address these shortcomings, non-terrestrial networks (NTNs) using millimeter-wave (mmWave) and terahertz (THz) frequencies enable multi-gigabit links but are highly sensitive to mobility-induced impairments. This work investigates the Doppler effects for ground-to-satellite (G2S), ground-to-aircraft (G2A), and satellite-to-aircraft (S2A) links and evaluates the performance of the orthogonal time-frequency space (OTFS) modulation. Results show that the G2A link experiences the lowest Doppler shift, while G2S and S2A face more severe impairments. OTFS with pilot-based Minimum Mean Square Error (MMSE) equalization effectively mitigates Doppler distortions across all NTN links under realistic channel conditions.

8:20 Development of a New Cloud Attenuation Model and Estimation of Cloud Attenuation Based on CPS Sonde Observations

Takahiro Ohno (NTT, Japan & Kyoto University, Japan); Munehiro Matsui (NTT Access Network Service System Laboratories, Japan); Kiyohiko Itokawa and Tomohiro Tokuyasu (NTT Access Network Service Systems Laboratories, Japan); Kosuke Ito and Tetsuya Takemi (Kyoto University, Japan)
Recently, satellite communications have attracted increasing attention as a key technology for next-generation mobile systems. To achieve ultra-high-speed communications and meet the growing demand for higher data rates in satellite communications, sub-THz communications are essential. However, unlike conventional Ku- and Ka-band communications, cloud attenuation becomes significant. Cloud attenuation models are therefore crucial for link budget design and network deployment in satellite communications. Conventional cloud attenuation models, such as those recommended by ITU-R, treat all cloud particles as water droplets. In reality, however, clouds consist of both water droplets and ice crystals, making it difficult for conventional models to accurately reproduce actual cloud attenuation. In this study, a new cloud attenuation estimation model incorporating ice crystals was developed. Using this model, we estimated cloud attenuation based on cloud data observed in Okinawa, Japan during the baiu (Japanese rainy season) of 2025 with the cloud particle sensor (CPS) sondes.

8:40 Cross-Polarization Discrimination of Signal in Earth-Alphasat Satellite Propagation at Ka and Q Bands

Arsim Kelmendi (The French Aerospace Lab - ONERA, France); Valentin Vaissiere (ONERA, France); Jean-Pascal Monvoisin and Laurent Féral (Office national d'études et de recherches aérospatiales, France); Laurent Castanet (ONERA, France)
To meet the demand for ultra-high data rates, the next-generation satellite communication systems are expected to extensively use the abundant bandwidth available in high frequency bands, such as Ka-band, Q-band, and beyond. In addition, the spectral efficiency can be improved by employing dual orthogonal polarization, enabling simultaneous transmission on the same frequency band. At high frequencies, signal propagation is significantly affected by tropospheric phenomena, with rain-induced attenuation emerging as a critical factor limiting the availability and continuity of Earth-to-satellite communication links. Depolarization interference caused by raindrops and ice particles further degrades dual-polarized systems by inducing a partial transfer of signal power from one polarization component to the orthogonal polarization. This paper investigates cross-polarization discrimination (XPD), which evaluates the ratio of co-polarized to cross-polarized induced electric fields of the signals transmitted by Alphasat satellite at 19.7 GHz and 39.4 GHz based on measurements in Salon-de-Provence, southern France.

9:00 Water Vapor Attenuation for Millimeter-Wave Satellite Communications Using GNSS Tropospheric Delay in a South American Tropical Climate

Gustavo Siles and Monserrat Urcullo (Universidad Privada Boliviana, Bolivia)
This paper addresses the estimation of water vapor attenuation for forthcoming millimeter-wave satellite communication links (40-110 GHz) in high-humidity tropical climates, a region typically underrepresented in propagation studies. By utilizing a seven-year time series of Zenith Tropospheric Delay from the unique IGS GNSS station in the Bolivian Amazon, instantaneous water vapor attenuation values were estimated by combining the GNSS meteorology technique with the latest ITU-R Recommendation P.676-13 model. The resulting long-term statistics were compared against the statistical characterization provided by the ITU global model, showing good agreement with maximum absolute mean errors below 2.2% and a maximum RMS error below 7.55% at 110 GHz; these metrics decrease with frequency. The results confirm that tropospheric GNSS products are a cost-effective tool for deriving water vapor attenuation time series at millimeter frequencies.

9:20 Selecting the Optimal Modulation and Coding per Elevation Sector on a Ka Band LEO Downlink Using Synthetic Attenuation Time Series

Laurent Quibus and Mohamad Younes (Académie Militaire de Saint-Cyr Coëtquidan, France); Eric Plouhinec (Ecoles de St-Cyr Coëtquidan, France)
While their number grows, Low-Earth Orbit (LEO) satellite systems remain challenging in many ways. The use of higher frequencies in conjunction with more advanced designs and protocols is one of the main driving force behind technological improvements in the domain. This holds particularly for specialized Earth Observation (EO) systems which cannot be so easily multiplied. This paper investigates a straightforward algorithm to select the Modulation and Coding (MODCOD) on a Ka band LEO downlink simulated based on a military EO satellite. The simulations rely on the synthesis of tropospheric attenuation time series in LEO according to a recent proposal. The results indicate an increase in transferred daily data volumes with respect to a similar link in X band. However, maintaining a quasi error-free availability of the data beyond 99:9% of the time prove difficult with this method alone.

Tuesday, April 21 8:00 - 9:40

SW7a 4-CAD: Advancing Over-The-Air Testing in Vehicular Communications and Automotive Radar Sensing

/ / Antennas

Room: Madrid

Thomas Dallmann
Vittorio Degli Esposti
Ainur Ziganshin
Thomas Kürner
Maik Weber
Renato Zea Vintimilla
Matthias Hein
Isabella Varga
Sonakshi Gupta
Muhammad Luqman Nazar
Lukas Ostendorf

Today, safe operation of road traffic relies solely on humans. At the advent of Connected and Automated Driving (CAD), as technology takes over control of vehicles and traffic, testing plays a central role to ensure safety and reliability of such systems. Suitable verification and validation methods have to go beyond software by providing in-the-loop and over-the-air testing on component and system level. In recent years, researchers from TU Braunschweig, TU Ilmenau and RWTH Aachen have worked on these procedures for V2X communications and automotive radars. Within this workshop, we demonstrate results and draw our vision of a unified CAD testbed.
Workshop outline: The workshop will present the results of a DFG package application project consisting of two sub-projects. It is divided into topical blocks addressing EM simulations, OTA channel emulation, and OTA radar target emulation. We will explain our emulation workflows as well as the software and hardware systems developed for this purpose. We will also report on the validation of our systems via measurements. The collaboration between the two subprojects has revealed interesting connections between communications and sensor testing, which we will highlight. Finally, we will present our ideas for combining the two validation methods in a single testbed.

08:00 - 08:15 Thomas Dallmann 4CAD - What for?
08:15 - 08:35 Vittorio Degli Esposti Advanced ray tracing modelling and applications
08:35 - 08:50 Ainur Ziganshin Ray-Based Simulation of Scattering from Discretized Curved Bodies
08:50 - 09:05 Thomas Kürner Multi-stage Over-the-Air Testbed for dynamic V2X scenarios
09:05 - 09:15 Maik Weber Realistic Performance Evaluation of NR-V2X in Urban Scenario Using Ray Tracing and ns-3
09:15 - 09:25 Maik Weber Insights into Software Defined Radio-Based Channel Emulation
09:25 - 09:40 Renato Zea Vintimilla Emulation of a V2X communication link using Over-the-Air (OTA) Testing
10:10 - 10:25 Matthias Hein Over-the-air vehicle-in-the-loop testing: Method and its application to automotive radar
10:25 - 10:35 Isabella Varga Data-driven radar target modelling
10:35 - 10:50 Sonakshi Gupta Environmental Modeling for Radar Verification and Validation
10:50 - 11:00 Muhammad Luqman Nazar Ground reference benchmarking for scenario-based virtual verification and validation
11:00 - 11:15 Lukas Ostendorf Automotive Data Collection for Development and Testing
11:15 - 11:25 Lukas Ostendorf Joint Scenarios for V2X and Radar
11:25 - 11:50 Thomas Dallmann 4CAD - What next?

Thomas Dallmann received the Dipl.-Ing. degree in electrical engineering from RWTH Aachen University, Germany in 2010 and the Dr.-Ing. degree from RWTH Aachen University in 2017. From 2016 to 2022, he was with the Fraunhofer-Institute for High Frequency Physics and Radar Techniques FHR, Wachtberg, Germany and lead the Research Group Aachen in Aachen. He is currently Junior Professor at Technische Universität Ilmenau, Germany and responsible for the Radio Technologies for Automated and Connected Vehicles Research Group and Electronic Measurements and Signal Processing Group. His research is concerned with joint communication and radar sensing networks and virtual validation of automotive radars.

Thomas Kürner (Fellow IEEE) received his Dipl.-Ing. degree in Electrical Engineering in 1990, and his Dr.-Ing. degree in 1993, from University of Karlsruhe (Germany). From 1994 to 2003, he was with the radio network planning department at the headquarters of the cellular operator EPlus Mobilfunk GmbH & Co KG, Düsseldorf. Since 2003, he is Full University Professor for Mobile Radio Systems at Technische Universität Braunschweig. In 2012, he was a guest lecturer at Dublin City University within the Telecommunications Graduate Initiative in Ireland. Currently he is chairing the IEEE 802.15 Standing Committee THz and the ETSI Industrial Specification Group THz.

Vittorio Degli-Esposti is Full Professor with the Department of Electrical, Electronic and Information Engineering "G. Marconi" (DEI) of the University of Bologna. He teaches courses on Electromagnetic Fields, Propagation for Wireless Systems and Vehicular Radio Propagation. He is IEEE Senior Member and Editor of the IEEE Transactions on Vehicular Technology. He has been Vice Chair of EuCAP2010 and EuCAP2011, Chair of URSI EMTS2025 and Director of Research in 2015 and 2016 of Polaris Wireless Inc., California, USA. He received the "EurAAP Propagation Award 2023" and is author or co-author of 7 patents and more than 160 peer-reviewed technical papers.

Prof. Dr. Matthias A. Hein joined the TU Ilmenau in 2002 as head of the RF and Microwave Research Laboratory. He has founded the multi-purpose automotive antenna test range "VISTA - Virtual road simulation and test area" at the Thuringian Center of Innovation in Mobility. His research focuses on antennas and microwaves, wave propagation, and over-the-air testing. He has co/authored over 700 publications and talks, supervised 48 doctoral and 102 Master projects. His research has attracted a cumulative funding of nearly 25 MEUR. Since 2021, Matthias Hein is the Director of the Thuringian Center of Innovation in Mobility at TU Ilmenau.

Ainur Ziganshin received the B.E. degree from the Kazan National Research Technical University in 2020, the M.Sc. degree from the Technische Universität Ilmenau in 2023. He is currently pursuing his Ph.D. degree at the Technische Universität Ilmenau. His research interests include channel measurement data analysis, stochastic and deterministic channel modeling for ISAC, ray tracing for radiowave propagation, and object scattering.

Maik Weber was born in Vechta, Germany, in 2001. He received the B.Sc. and M.Sc. degrees in Computer and Communication Systems Engineering from Technische Universität Braunschweig, Braunschweig, Germany, in 2023 and 2025, respectively. In February 2025, he joined the Institute for Communications Technology at Technische Universität Braunschweig, where he is currently working toward the Ph.D. degree. His research interests include software defined radio-based wireless channel measurements and characterization with focus on sub-6 GHz applications.

Tuesday, April 21 8:00 - 9:40

SW3a Recent Advancements and Applications for Antenna Arrays and Systems (IEEE AP-S Technical Committee 2 "Array")

/ / Electromagnetics

Room: The Hague

Dr. Diane Titz (Université Côte d'Azur)
Prof. Yong-Mei Pan (South China University of Technology)
Prof. Mauro Ettorre (Michigan State University)
Prof. Takashi Tomura (Institute of Science Tokyo)
Prof. Tian Hong Loh (UK National Physical Laboratory)
Dr. Martijn de Kok (Eindhoven University of Technology)
Prof. Zhi-Hao Jiang (Southeast University, China)
Prof. Oscar Quevedo-Teruel (KTH Royal Institute of Technology)

In the scope of the IEEE Antennas and Propagation Society (AP-S) Technical Committee 2: "Arrays" (TC-2) is responsible for monitoring and advancing the latest developments and trends in antenna array and system technologies. This scientific workshop aims at sharing and discussing the latest advancements and applications for antennas arrays and systems for enabling emerging radio technologies for 5G and beyond. The workshop will serve as a valuable platform for knowledge exchange and networking and is envisaged to gather experts and researchers in the proposed field from all around the world to present, discuss and showcase their latest innovative research in antenna arrays, and next-generation antenna systems. In the scope of the IEEE Antennas and Propagation Society (AP-S) Technical Committee 2: "Arrays" (TC-2) is responsible for monitoring and advancing the latest developments and trends in antenna array and system technologies. This scientific workshop aims at sharing and discussing the latest advancements and applications for antennas arrays and systems for enabling emerging radio technologies for 5G and beyond. The workshop will serve as a valuable platform for knowledge exchange and networking and is envisaged to gather experts and researchers in the proposed field from all around the world to present, discuss and showcase their latest innovative research in antenna arrays, and next-generation antenna systems.

08:00 - 08:05 Dr. Diane Titz (Université Côte d'Azur) / Prof. Tian Hong Loh (National Physical Laboratory) Welcome and Workshop Scope

08:05 - 08:35 Prof. Yong-Mei Pan (South China University of Technology) Design of Wide-Angle Beam-Scanning Millimeter-Wave Dielectric Resonator Antenna Arrays
ABSTRACT: Dielectric Resonator Antennas (DRAs), composed primarily of dielectric material, offer high radiation efficiency in the mm-Wave band by eliminating conductor loss, making them ideal for mm-Wave systems. Complementing this, phased array technology enables rapid electronic beam steering, flexible shaping, and precise pointing through accurate amplitude and phase control, serving as a key enabler to overcome mm-Wave propagation bottlenecks. This report highlights our group's progress in wide-angle scanning DRA phased arrays. We propose a strategy that leverages dielectric resonant modes, ground plane image effects, and inter-element near-field coupling to broaden the element active pattern. This approach significantly expands the array's scanning range without introducing additional structural complexity.

08:35 - 08:55 Prof. Mauro Ettorre (Michigan State University) Non-dispersive Radiation: Concepts and Future Directions from Communications to High-Power Applications
ABSTRACT: The dispersive behavior of radiating systems significantly impacts the radiation of short pulses used in communication, sensing, and power transmission. This presentation will introduce fundamental concepts, outline limitations, and provide the metrics necessary for analyzing radiating systems. The aim is to clarify the scientific questions and obstacles related to the radiation of short pulses. Following this introduction, the presentation will discuss recent advancements addressing these challenges and offer innovative solutions for effectively radiating extremely short pulses with minimal dispersion.

08:55 - 09:15 Prof. Takashi Tomura (Institute of Science Tokyo) Origami Deployable Reflectarray Antennas for Small Satellites
ABSTRACT: 6G requires extended coverage over the air, sea, and space, in addition to ultra-high-speed communications and low latency. This talk presents origami deployable reflectarray antennas for small satellites. The antennas can be compactly stowed by origami fold patterns when onboard a rocket and deployed large in space. To further increase the functionality of the antennas, reconfigurable reflectarrays enable non-flatness compensation and beam steering.

09:15 - 09:35 Prof. Tian Hong Loh (UK National Physical Laboratory) A Metrological Millimetre-Wave Over-The-Air Test Platform Incorporating a Fully-Connected Hybrid Beamformer with a Large Antenna Array
ABSTRACT: Current efforts to develop cost-effective, energy-efficient wireless systems operating at millimeter-wave (mm-wave) frequencies with large-scale phased array antennas-driven by the high data-rate demands of future sixth-generation (6G) networks-have highlighted the need to explore the use of hybrid beamforming technologies. This talk presents a novel metrological mm-wave 5G new-radio MIMO testbed for radiated-two-stage (RTS) over-the-air (OTA) testing. The testbed features a highly reconfigurable fully connected hybrid beamformer with a large antenna array, a base station emulator, a channel emulator, and a user-programmable software-defined radio (SDR) platform. The evaluation of the RTS method is presented.

10:10 - 10:30 Dr. Martijn de Kok (Eindhoven University of Technology) Power Amplifier (PA)-Antenna Co-Design in Active Phased Array Antennas:
ABSTRACT: This presentation outlines a holistic co-design workflow for active phased arrays, integrating Power Amplifier (PA) load-pull modeling with antenna design using a custom simulation framework. The approach supports early stage design decisions and enables rapid optimization of the PA-antenna interface while accounting for finite-array effects and varying active reflection coefficients. A 16-element X-band array comprising Vivaldi antennas directly matched to gallium nitride (GaN)-based PAs is developed and realized to demonstrate the methodology. The presented co-design strategy offers a practical foundation for efficiently scalable and high-performance active array systems.

10:30 - 10:50 Prof. Zhi-Hao Jiang (Southeast University, China) Development of Reconfigurable Reflect-Arrays and Their Application for Beam-Steering Cassegrain Reflector Antennas
ABSTRACT: Reconfigurable arrays, realized by integrating RF switches into radiating or scattering elements, offer a new low-cost beamforming solution for communication and sensing applications. The first part of this report will focus on the design and experimental validation of Kaband reconfigurable reflect-arrays and transmit-arrays, including large-scale high-bit reconfigurable reflect-arrays, wideband dual-polarization reconfigurable reflect-arrays, and wideband dual-polarization reconfigurable transmit-arrays. In addition, the report will present the use of a reconfigurable reflect-array as the sub-reflector in an electrically large Cassegrain antenna to achieve two-dimensional electronic beam steering of its high-gain beam.

10:50 - 11:10 Prof. Oscar Quevedo-Teruel (KTH Royal Institute of Technology) Design Considerations for Array Radomes
ABSTRACT: Most of the practical implementations of arrays make use of a radome to protect the antennas from the environment. Consequently

radomes can have a negative influence in the performance of the array. Therefore, its analysis and design are crucial for the final implementation of most of the commercial arrays. In this talk, we will explain the practical considerations to take into account when an array is integrated with a radome. In addition, we will show how to fast simulate these radomes with ray-tracing techniques and physical optics. Finally, we will discuss on how to take advantage of the radome in our own benefit.

11:10 - 11:30 Dr. Diane Titz (Université Côte d'Azur) Antenna Systems for E-Band and Future Telecom Applications
ABSTRACT: 5GNR (Beyond 5G) and 6G wireless network access and backhaul as well as satellite telecommunications are targeting E-band (71 to 76 GHz and 81 to 86 GHz) and D-band (150 GHz) radio systems due to the wide available bandwidth the offer. This presentation will show several antenna and antenna-array designs within these bands manufactured using Digital Additive Manufacturing (DAM) techniques as well as High Density Interconnect (HDI) Planar Circuit Board (PCB). Part of this work has been done with the support of the European SHIFT (Sustainable, Technologies Enabling Future Telecom Applications) project.

11:30 - 11:50 Dr. Diane Titz / Prof. Tian Hong Loh / Prof. Yong-Mei Pan / Prof. Mauro Ettorre / Prof. Takashi Tomura / Prof. Zhi-Hao Jiang Panel Discussion

Yong-Mei Pan (IEEE Fellow) is a full professor at the School of Electronics and Information, South China University of Technology, China. Her research focuses on dielectric resonator antennas, filtering antennas, MIMO antennas, and antenna-in-package, with over 150 SCI-indexed papers published and 12 US patents granted. Dr. Pan was awarded the IEEE Antennas and Propagation Society's Lot Shafai Mid-Career Distinguished Achievement Award in 2022, the Guangdong Province Science and Technology Award for Technological Invention (First Class) in 2020, and the Ministry of Education's Higher Education Scientific Research Outstanding Achievement Award for Natural Science (First Class) in 2016. Dr. Pan served as an Associate Editor for the IEEE Transactions on Antennas and Propagation (TAP) from August 2016 to October 2022, and she is currently a Track Editor of TAP.
Mauro Ettorre received a Laurea degree "summa cum laude" in Electrical Engineering and a Ph.D. degree in Electromagnetics from the University of Siena, Italy, in 2004 and 2008, respectively. Part of his Ph.D. work was developed at the TNO, the Netherlands. Since 2023, he has been a Professor at Michigan State University, East Lansing, USA. Previously, he was a Research Scientist at the CNRS, IETR laboratory in France. From 2014 until 2020, he co-led the multi-beam antenna activity for satellite applications in the joint laboratory between IETR and Thales Alenia Space, France. From 2016 until 2021, he led the mm and sub-mm waves team at IETR, and co-chaired from 2021 to 2023 the department ADH (Antennas and Microwave Devices Department) at IETR. Dr. Ettorre's research interests include the analysis and design of quasi-optical systems, periodic structures, wideband arrays, millimeter-wave antennas, non-diffractive radiation, and localized waves. He has authored over 97 journal papers and 250 conference communications and holds 14 patents (2 licensed) on millimeter-wave antenna technology. Dr. Ettorre is a Fellow of IEEE. From 2017 until 2023, he served as Associate Editor for the IEEE Transactions on Antennas and Propagation. Since 2023, he has served as Track Editor for the same journal. He currently serves as the Editor-in-Chief of the IEEE Antennas and Propagation Magazine. Dr. Ettorre is the 2024 IEEE MTT-S and AP-S Inter-Society Distinguished Lecturer. The research activities of Dr. Ettorre have been recognized with several prizes, including the 2009 French Ministry of Research award for the most innovative project in all natural sciences, the Young Investigator Award from the French National Research Agency in 2014, the Innovation Award at the 2018 ESA Antenna Workshop in the Netherlands, the Best Paper Award in Electromagnetics and Antenna Theory at EuCAP 2018, UK, the Best Antennas Paper Award at EuCAP 2021, Germany and Best Paper Award at the iWAT 2023, Denmark.
Takashi Tomura received his Ph.D. degree from Tokyo Institute of Technology, Japan. His doctoral research focused on the hybrid analysis of millimeter-wave broadband waveguide slot array antennas using the Method of Moments and the Finite Element Method. He previously worked at Mitsubishi Electric Corporation, where he was engaged in the research and development of reflector antennas for satellite payloads and ground station antennas for satellite communications. Since 2017, he has been with Tokyo Institute of Technology (now Institute of Science Tokyo), where he works on deployable origami-inspired antennas for small satellites and high-gain antennas and modules in the sub-terahertz frequency bands.
Tian Hong Loh (IEEE Fellow) is a Principal Scientist at the UK National Physical Laboratory (NPL) and the Science Area Leader for NPL's Electromagnetic Technologies Group. He leads a team of scientists undertaking ground-breaking measurement science research in support of the emerging electromagnetic technologies developments. He has edited one book, holds seven patents, authored, and co-authored over 240 refereed publications. He is currently President of the URSI UK Board, Chair of the EurAAP Measurement Working Group, Visiting Professor at the University of Surrey, UK, Representative of the IEEE APS at the IEEE FNTC, member of IEEE APS Standards Committee, IEEE TCAM and the IET, and senior member of IEEE and AMTA. His research interests include 5G/6G communications, MIMO antennas, smart antennas, small antennas, metamaterials, body-centric communications, wireless sensor networks, electromagnetic compatibility, and computational electromagnetics.
Martijn de Kok obtained his Bachelor, Master and PhD degrees Electrical Engineering (all cum laude) from Eindhoven University of Technology in The Netherlands. His PhD thesis, defended in 2025, was titled 'Active Phased Array Antenna Systems for Next-Generation Radars: Co-design, Integration, and Scalability.' In 2019 he was a visiting student at the Advanced RF & Optical Technologies group of the NASA Jet Propulsion Laboratory. In 2021 he became a guest researcher at the Radar Technology department of TNO Defense, Safety and Security in The Hague. In 2025 he joined TNO as a Scientist focusing on phased-arrays and high-power antenna systems for applications including large-scale radars and space. Dr. de Kok received the Best Antenna Theory and Design Paper Award at the 2025 EuCAP conference, and the 2025 Veder-prize for his contributions to Dutch radio science in that year.
Zhi Hao Jiang received the Ph.D. degree from The Pennsylvania State University, in 2013, and is currently a Professor with the State Key Laboratory of Millimeter Waves, Southeast University. He has published 3 books and more than 150 papers in peer-reviewed journals, and holds 12 granted U.S. patents and 30 granted Chinese patents. He was a committee member of the IEEE AP-S NTDC (2022 - 2024), serves as the Associate Editor of IEEE Transactions on Antennas and Propagation and as a committee member of IEEE AP-S TC-2 and IEEE MTT-S CEC, and has served as the TPC Co-Chair for multiple international conferences. He was a recipient of the Outstanding Youth Scholar of NSFC in 2021, the IEEE Microwave Prize in 2021, the Young Scientist Award at URSI-GASS 2020 and ACES-China 2019. His current research interests include millimeter-wave antennas and circuits, impedance surfaces, and analytical methods.
Oscar Quevedo-Teruel received his Telecommunication Engineering and Ph.D. Degrees from Carlos III University of Madrid, Spain in 2005 and 2010. In 2014, he joined the KTH Royal Institute of Technology (Stockholm, Sweden), where he is presently a Full Professor in the Department of Communication Systems in the School of Electrical Engineering and Computer Science. He is also the responsible for the Antenna Laboratory and Director of the Master Programme in Electromagnetics Fusion and Space Engineering. He was a distinguished lecturer of the IEEE Antennas and Propagation Society for the period of 2019-2022. He is an IEEE Fellow for his contributions to glide symmetry based metasurfaces and lens antennas. He has been a member of the EurAAP Board of Directors since January 2021. Since January 2022, he is presently the EurAAP vicechair. He was an Associate Editor of the IEEE Transactions on Antennas and Propagation since 2018-2022, and he acts as Track Editor in IEEE TAP since 2022. He is the founder and editor-in-chief of the EurAAP journal Reviews of Electromagnetics since 2020. He has made scientific contributions to periodic structures with higher symmetries, lens antennas, metasurfaces, physical optics and ray tracing. He is the co-author of more than 160 papers in international journals and more than 250 at international conferences.
Diane Titz (SMIEEE) received her Master degree from Paris-Saclay University in 2009 and her Ph.D degree from University of Côte d'Azur, France, in 2012. Since then, she is been as associate researcher with the Polytech'Lab at the University of Côte d'Azur, while teaching physics and chemistry to future engineering students. Her research interest include millimeter-wave to terahertz applications through the design of antennas, lens and their measurement. She has coauthored three book chapters and more than 80 publications. She was the recipient of the 2018 Lot Shafai mid-career distinguished achievement award. She also serves as an associate editor for the IEEE TAP and is a committee member of AP-S TC2.

Tuesday, April 21 8:00 - 9:40

SW8a From RFID to Wireless Sensing and IoT: Antenna Innovations for Nonlinear Transpoder Systems

/ / Electromagnetics

Room: Glasgow

A. Lavrenko (UTwente)
M. Polivka (Czech Technical University in Prague)
A. Austin (University of Bristol)
V. Palazzi (University of Perugia)
C. Li (Texas Tech University)
G. Marrocco (University of Rome Tor Vergata)

Nonlinear mechanisms are reshaping the landscape of passive wireless technologies from classical RFID to emerging harmonic and intermodulation backscatter-based sensors that operate without batteries or active components. These systems underpin a new generation of wireless sensing and IoT applications, enabling identification, localization, and environmental monitoring with ultra-low-power hardware. Antenna design is central to their performance: it governs energy transfer, harmonic generation, polarization behavior, impedance interaction, and system efficiency under varying, and sometimes extreme, constraints of size, bandwidth, and operating conditions. This workshop gathers researchers from antennas, microwave engineering, and applied sensing to discuss design, modeling, and integration challenges for antennas in nonlinear and passive wireless systems bridging communities in RFID, harmonic radar, chipless sensing, and sustainable IoT.

Workshop outline: The half-day workshop will comprise two 1h40 sessions combining invited technical presentations, a keynote talk, and a concluding round-table discussion. The first session will address the fundamentals of modeling and design of antennas for nonlinear passive wireless systems, featuring invited speakers from leading research groups. The second session will highlight integration, fabrication, and application examples across RFID, wireless sensing, and IoT domains. The workshop will conclude with an interactive round-table inviting end-users from applied fields to share their perspectives on current challenges, practical constraints, and emerging opportunities for antenna design for nonlinear technologies.

Session 1: Foundations and Antenna Design Perspectives
08:00 - 08:10 A. Lavrenko (UTwente) Welcome and Workshop Scope
08:10 - 08:35 M. Polivka (Czech Technical University in Prague) Wearable Patch-Type Harmonic Tags: Step-by-Step Design Considerations
08:35 - 09:00 A. Austin (University of Bristol) Conversion Efficiency Is Not a Number: 3D Pattern Measurements for Harmonic Tags
09:00 - 09:25 A. Lavrenko (UTwente) To Match or Not to Match: Antenna Design Requirements and Constraints in Compact Harmonic Transponders
09:25 - 09:40 All Discussion / Q&A

Session 2: Materials, Fabrication, and System-Level Perspective 10:10 - 10:35 V. Palazzi (University of Perugia) Design of Passive Wireless Sensors Using Harmonic Transponders: Architectures, Challenges and Technological Outlook
10:35 - 10:55 C. Li (Texas Tech University) Printable Nonlinear Tags and Handheld Devices for Clutter-Resilient Contactless Monitoring and Tracking
10:55 - 11:20 G. Marrocco (University of Rome Tor Vergata) The Laser-Induced Graphene Technology for Sustainable Radiofrequency Identification and Sensing
11:20 - 11:40 All Round-Table Discussion: What's Next for Antenna Design in Nonlinear Transponder Systems?
11:40 - 11:50 A. Lavrenko (UTwente) Wrap-Up and Outlook

Dr. Milan Polivka is an Associate Professor at the Czech Technical University in Prague, specializing in advanced antenna systems, nonlinear backscatter transponders, and RF measurement techniques. He is internationally recognized for his contributions to harmonic and intermodulation tag design, including dual-band antenna architectures, characterization of nonlinear scattering mechanisms, and precision link-budget modelling for passive transponder systems. Dr. Polivka leads several research activities on nonlinear tag metrology, compact sensing antennas, and EMC-related measurements, and has co-authored numerous journal and conference papers in these areas. His group is among the leading European teams advancing nonlinear tag antennas and their practical evaluation.

Prof. Valentina Palazzi is an Associate Professor at the University of Perugia, Italy, with research interests spanning RFID systems, chipless and harmonic transponders, and passive wireless sensors. She is widely recognized for her work on antenna-circuit co-design, dual-band and nonlinear tag architectures, and electromagnetic modelling of passive sensing platforms. Her contributions include innovative chipless sensing schemes, compact tag antennas for low-power applications, and analytical methods for characterising nonlinear backscatter mechanisms. Prof. Palazzi has published extensively in leading RF and antenna journals and plays an active role in the European RFID and wireless sensing research community.

Prof. Changzhi Li is a Professor of Electrical and Computer Engineering at Texas Tech University, internationally recognized for pioneering contributions to noncontact RF sensing, nonlinear radar, and harmonic signal processing. His research focuses on Doppler and harmonic radar architectures, nonlinear transceiver design, and high-sensitivity motion and vital-sign detection using low-power microwave systems. Prof. Li has published extensively in IEEE Transactions, delivered numerous invited talks and tutorials, and his work has strongly influenced emerging applications in biomedical sensing, smart environments, and low-power IoT. He is a Fellow of the IEEE and a leading figure in advanced nonlinear RF sensing technologies.
ABSTRACTS: Wearable Patch-Type Harmonic Tags: Step-by-Step Design Considerations: This contribution presents a step-by-step methodology for designing wearable patch-type harmonic tags, with an emphasis on efficient harmonic generation, and a compact design. The choice of diode is determined based on the selected operating frequencies. An analytical model is used to identify the level of incident power at which these losses are minimal. A dual-band, differentially fed, dual-quarter-wave patch antenna topology is selected, which provides broadside radiation, and self-resonant operation without the need for external matching circuits. Impedance matching is further improved by the use of tuning slots, whose effect on resonance tuning is investigated. Finally, selected prototypes are experimentally characterized, demonstrating achievable performance in terms of conversion efficiency, and robustness in wearable scenarios. Conversion Efficiency Is Not a Number: 3D Pattern Measurements for Harmonic Tags The radiation efficiency of harmonic radar tags is typically measured and reported at a single incidence angle. However, the radiation efficiency is a three dimensional (re-)radiation pattern. In this presentation, the setup for three dimensional measurements of harmonic radar tags operating at 9/18 GHz will be presented, along with experimental results, interpretation, and future improvements.

To Match or Not to Match: Antenna Design Requirements and Constraints in Compact Harmonic Transponders The design of compact harmonic transponders introduces unique challenges that go beyond conventional antenna matching paradigms. In these systems, the antenna must be co-designed with the nonlinear element, where impedance matching, radiation efficiency, and conversion efficiency are tightly interdependent. This talk revisits the role of matching in harmonic transponders, questioning when traditional approaches remain valid and when they become limiting. Emphasis is placed on practical design constraints arising from miniaturization, low-power operation, and integration. Through representative examples, the talk highlights key trade-offs and proposes guidelines for antenna-nonlinearity co-design in next-generation passive sensing systems.

Design of Passive Wireless Sensors Using Harmonic Transponders: Architectures, Challenges and Technological Outlook This talk will describe some of the most recent design strategies both at component and system level to develop energy-autonomous harmonic transponders with sensing capabilities, while maximizing the read range of the transponders. Practical examples with a case study related to automotive applications will be shown as well. This talk will also focus on the open challenges of this field and will highlight some promising technologies for future advancements in the field.

Printable Nonlinear Tags and Handheld Devices for Clutter-Resilient Contactless Monitoring and Tracking This talk presents printable, battery-free nonlinear tags and compact harmonic radar systems for clutter-resilient, contactless sensing and tracking. Operating at 4-8 GHz and 8-16 GHz, the systems exploit second-harmonic generation from diode-based printed tags to suppress linear reflections and enable reliable detection in complex environments. Scalable fabrication methods, including inkjet printing on flexible substrates, produce lightweight, conformal tags. Two compact high-linearity radar platforms ensure strong harmonic isolation and sensitivity. Demonstrations include accurate, noninvasive respiratory monitoring and object localization, establishing a scalable approach for healthcare, tracking, and nonlinear IoT sensing applications.

The Laser-Induced Graphene Technology for Sustainable Radiofrequency Identification and Sensing This talk discusses nonlinear RFID transponders as a new frontier in antenna-enabled wireless systems, where the backscattered response is governed not only by tag geometry, but also by chip dynamics, mutual coupling, interrogation power, and material imperfections. Within this perspective, self-tuning chips enable environment-aware sensing, interacting transponders reveal equilibrium phenomena, and power-dependent responses generate distinctive electromagnetic signatures for physical unclonable functions. Additional nonlinear features may arise from imperfect graphene-based materials, further enriching the transponder behavior. The overall picture shows how nonlinear backscatter can extend RFID well beyond identification, opening new directions toward sensing, authentication, and physics-inspired IoT devices.

Round-Table Discussion: What's Next for Antenna Design in Nonlinear Transponder Systems? This round-table will explore emerging directions and open challenges in antenna design for nonlinear and passive transponder systems. Moving beyond conventional matching and efficiencydriven approaches, the discussion will address how antennas can be co-designed with nonlinear elements, materials, and system architectures to enable robust operation in realistic environments. Topics include compact and wearable implementations, advanced fabrication techniques, measurement methodologies, and the role of antennas in shaping system-level performance. By bringing together perspectives from design, materials, and applications, the session aims to identify key research priorities and opportunities for the next generation of RFID, sensing, and IoT systems.

Tuesday, April 21 8:00 - 9:40

IW8 Industrial Workshop - IEEE Antennas and Propagation Society - Advancing Careers

/ / Electromagnetics

Room: Stockholm

Dr. C. J. Reddy 2026 IEEE AP-S President
Prof. George Shaker Chair, IEEE AP-S Membership Benefits Committee
Prof. Qammer Abbasi Chair, IEEE AP-S Young Professionals Committee

With the technological advances in wireless technology, this is a great time to be an antenna engineer, with expertise in antennas, propagation and electromagnetics. Core mission of IEEE Antennas and Propagation Society (AP-S) is to foster antennas, propagation and electromagnetics theory, technology, applications innovation and excellence for the benefit of humanity. Career is more than a job-it's a journey. AP-S provides the support and resources you need to thrive providing opportunities to share ideas at conferences, publish papers in leading journals, and develop leadership skills with volunteer opportunities. AP-S offers various opportunities to increase your technical skills offering various student paper/design contests, research grants as well as travel grants to attend various conferences. AP-S is bringing these opportunities to students and researchers providing opportunities to attend AP-S Sponsored conferences to present papers and exchange ideas along with opportunities for establishing and growing AP-S Chapters and Student Branch Chapters. Students can get involved with a student branch, network with peers and industry professionals, and gain experience that can help the first job.

Tuesday, April 21 10:10 - 11:50

A13b Array Antenna Feeds and Excitations 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)), Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

Room: Copenhagen

10:10 Compact and Scalable Feed Architecture Based on Quasi-TEM Ridge Gap Horn to Reduce Power Dividers for Excitation of Large Arrays

Usman Shehryar, Jian Yang and Ashraf Uz Zaman (Chalmers University of Technology, Sweden); Ahmed A Kishk (Concordia University, Canada)

A compact, efficiency-enhanced feed architecture is proposed for 140-150 GHz for CTS arrays. The design cascades four hard-wall feed channels, each realized with artificial magnetic conductor (AMC) boundaries to produce a uniform aperture distribution (magnitude and phase) across a center-fed aperture, thereby eliminating need for a large corporate divider network. This architecture can reduce number of power dividers in the feeding network resulting in a reduction of insertion loss and gain improvement. The proposed feed has amplitude and phase balance of ±1.5 dB and ±12°. When the proposed feeding is used to excite the CTS subarray, a realized gain of 27.8 dBi with radiation efficiency above 82% is achieved for gold plated structure with surface roughness of 0.9µm. The fully metallic AMC structure ensures low ohmic loss and simple fabrication without dielectric loading or precision alignment. The proposed compact, low-loss feed is scalable to realize high-gain antennas for sub-THz band.

10:30 Multi-Port Antenna Designs for Doherty Amplifier-Antenna System

Guo Wei, Genedyn Gems S Mendoza, Anu Lehtovuori and Kari Stadius (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

This paper introduces a novel approach to designing a Doherty amplifier-antenna system using a two-port antenna to replace the traditional matching circuit and power combiner. The proposed two-port antenna is designed to meet impedance and coupling requirements of the power amplifier. Our approach employs an asymmetrical patch antenna to achieve distinct port impedances and incorporates metal via-holes to regulate the coupling between the ports. The study demonstrates that the entire system can achieve a competitive gain compared to the reference design, with a power-added efficiency exceeding 60%.

10:50 Design of Reflection-Type Phase Shifters: Concepts and Applications to RC-Loads

Dilaawaiz Fazal (ESIGELEC University, France & IRSEEM, France); Constant M. A. Niamien (University of Rouen Normandy, ESIGELEC, IRSEEM, France); Rania Khalifeh (IRSEEM ESIGELEC, France)

This paper formulates the reflection coefficient of a standard reflection-type phase shifter (RTPS) to derive a systematic design methodology applied to RC-loaded RTPS. The proposed approach analytically relates the key design parameters to anticipate the phase range and insertion loss. Under design criteria that maximize the phase range, typically $\Delta\theta \geq 175^\circ$, and almost cancel insertion loss with $|\Gamma| \geq 0.95$, two optimum RC-loaded RTPS are derived. The series RC-loaded circuit require low series resistance, typically $R \leq 0.03|Z_0|$, and are suitable for narrowband applications with limited capacitance ranges. In contrast, shunt RC-loaded circuits offer wideband operation with large parallel resistances, typically $R \geq 40|Z_0|$, coping with large capacitances.

11:10 Low-Loss Analog Phase Shifter Using a Tunable Bulk High-Permittivity Ferroelectric Ceramic

Zahra Rahimian Omam and Theo Saunders (Queen Mary University of London, United Kingdom (Great Britain)); Hangfeng Zhang (Queen Mary University London, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain))

A low-loss analog phase shifter using a tunable highpermittivity $CaSrTiO_7$ (CST) ferroelectric ceramic is presented in a loaded-line configuration on a standard printed circuit board (PCB). A bulk 0.7mm CST slab serves as a voltagecontrolled shunt capacitor above the transmission line. Material characterization confirms stable microwave permittivity ($\varepsilon_r \approx 150$, tunable to 110) and a low loss tangent ($\tan\delta \approx 0.009$), enabling efficient phase control. Full-wave simulations at ~7.5 GHz demonstrate continuous, monotonic phase tuning over 200°, while maintaining sub-dB insertion loss (0.2-0.7 dB) and return loss better than -10 dB. Compared with BST thick film, and varactorbased approaches, the bulk CST design reduces fabrication complexity, improves insertion loss, and enables cost-effective PCB integration. These advantages make it a promising candidate for reconfigurable microwave devices and phased array antenna systems.

11:30 Self-Impedance Tuning of a Dipole Antenna Using an Auxiliary Feed Signal

Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)); Saleem Shahid (Graz University of Technology, Austria); Gabriel G. Machado (Ulster University, United Kingdom (Great Britain)); Wolfgang Bosch (Graz University of Technology & Institute of Microwave and Photonic Engineering, Austria); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain))

This study investigates self-impedance tuning for antennas, a novel approach with the potential for dynamic impedance adjustments. Using half-wave dipoles as an example, the work capitalizes on a hybrid coupler system and a feed signal's power to adapt the antenna's impedance in real time by injecting an auxiliary control signal into the antenna feed terminals in order to adjust its input impedance. The study investigates how simultaneous impinging and auxiliary signals, along with varying phases between them, influence the antenna's input impedance. Additionally, it examines practical challenges related to impedance tuning. This study proposes a robust solution that is applicable to any one-port antenna type, for optimal power transfer in ever-evolving wireless environments.

Tuesday, April 21 10:10 - 11:50

A18b Hybrid Lens Antenna Solutions 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden), Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

Room: Gothenburg

10:10 Lens Loaded Phased Array Antennas for Ground Station Terminals Offering Wide Beam-Steering for Connected and Autonomous Vehicles

Aakash Bansal (Loughborough University, United Kingdom (Great Britain))

This paper presents a new architecture for a Luneburg lens loaded phased array antenna. The proposed architecture is aimed at compensating scan loss of the phased array systems and offers a fast beam-steerability. The proposed antenna is shown to operate at 11.7 to 12.7 GHz while maintaining a right hand circularly polarized beam of gain approx. 20 dBi and a 110 deg field of view in both azimuth and elevation planes. The proposed antenna is validated in simulations and measurements and has potential applications as a ground station antenna for fast moving autonomous vehicles to connect with Low Earth Orbit satellite constellations.

10:30 High-Gain mmWave Antenna with Enhanced 3-dB Gain Bandwidth Using Director Loaded Vivaldi and Parabolic PRS Radome

Ahmed Khairy (King Fahd University of Petroleum and Minerals, Saudi Arabia); Md Ahsan Halimi (King Fahd University of Petroleum & Minerals, Saudi Arabia); Ans Rehman (King Fahd University of Petroleum and Mineral, Saudi Arabia); Abdulrahman Alqadami (King Fahd University of Petroleum and Minerals, Saudi Arabia); Hussein Attia (King Fahd University of Petroleum and Minerals (KFUPM) & Interdisciplinary Research Center for Communication Systems and Sensing, Saudi Arabia)

This paper introduces a parabolic partially reflect- ing surface (PRS) radome integrated with a wideband Vivaldi antenna, delivering high gain and a broad 3-dB gain bandwidth for millimeter-wave (mmWave) systems. The antenna employs (i) a parabolic PRS that forms a Fabry-P´erot (FP) cavity above the Vivaldi antenna aperture, (ii) an elliptical-slot transition for broadband impedance matching, and (iii) tiled rectangular directors to enhance realized gain. The PRS consists of periodic air cavities and circular copper patches. The configuration achieves an impedance bandwidth of 28-68 GHz and a 3- dB gain fractional bandwidth exceeding 70%. A maximum realized gain of 16.2 dBi is obtained-6 dB higher than a standalone Vivaldi-while maintaining radiation efficiency above 91%. The compact, lightweight architecture is well-suited to high- performance mmWave communications and sensing.

10:50 Optimizing mmWave Radar Coverage via Dielectric-Lens Radome Pattern Shaping

Coen van de Ven (University of Twente & Gapwaves AB, The Netherlands); Carlos Biurrun Quel (Gapwaves AB, Sweden); Andrés Alayón Glazunov (Linköping University, Sweden)

We integrate a gradient-index (GRIN) lens into a millimeter-wave corner-radar radome to reshape array radiation for automated emergency braking and vulnerable road-user detection. A radar-equation coverage mask-assuming a -5.5 dBsm pedestrian, 50 km/h approach, and ≥ 15 m minimum range-drives optimization of the radome's dielectric gradient, producing asymmetric left/right tapers without modifying the feed. Two additively manufactured radomes are characterized at 76, 78.5, and 81 GHz. Measurements show energy redirected into sidewalk/braking regions with S11 similar to the bare array and ~ 4 dB peak-to-peak ripple at some angles. System-level analysis indicates extended frontal detection range with AoA performance on par with typical corner-radar baselines.

11:10 3D-Printed Two-Dimensional Mikaelian Dielectric Lens Antenna with Low-Loss Beam Scanning at V-Band

Jose-Manuel Poyanco (Universidad Técnica Federico Santa María, Chile); Dubravko Tomić (University of Zagreb, Croatia); Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Zvonimir Sipus (University of Zagreb, Croatia); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

(A 3D-printed Mikaelian metasurface lens antenna for V-band operation (57-66 GHz) is presented. The designemploys a glide-symmetric dielectric unit cell within a parallel-plate waveguide to achieve a wide effective-index range with low dispersion. The resulting geometry is synthesized using the Multimodal Transfer Matrix Method (MMTMM) to realize the Mikaelian refractive-index profile. An optimized exponential flare minimizes scan losses, while a redesigned feeding network with metallic walls suppresses leakage between plates. Full-wave simulations show wide-angle beam scanning of ±50° with a maximum scan loss below 2 dB and return losses better than -10 dB. The proposed antenna offers a compact, low-loss, and easily manufacturable solution for millimeter-wave systems.

11:30 Feeding Array with Optimized Amplitude and Phase Coefficients for Planar Lens Antennas for Conical Scanning Instruments

Aurélien Neuhart (European Space Agency (ESA-ESTEC), The Netherlands); Alexandra Mavropoulou (Delft University of Technology, The Netherlands); Erio Gandini (ESA - European Space Agency, The Netherlands)

Conical scanning instruments on-board Earth observation satellites typically rely on mechanical spinning of the entire radiating architecture to acquire the conical beam sweep, significantly increasing their mass and risk of failure. As an alternative, in a previous paper, a circular planar lens with conical scanning towards θ = 25deg at Ka-band (35.5GHz) was proposed, along with a corresponding feeding array with complex amplitude and phase coefficients. This paper presents design simplifications and methods used to build the array, in the scope of manufacturing and testing the antenna.

Tuesday, April 21 10:10 - 11:50

CS10b Recent Advances on Propagation Research and Its Impact on Localizations 2

T05 Positioning, localization, identification & tracking / Convened Session / Propagation
Chairs: Christian Gentner (German Aerospace Center (DLR), Germany), Wei Wang (Chang'an University, China)

Room: Dusseldorf

10:10 Gaussian Process-Based Extended Object Estimation for 6G ISAC at Millimeter-Wave Frequencies

Mehmet Ertug Pihtili and Ossi Kaltiokallio (Tampere University, Finland); Julia Equi (Ericsson Research, Finland); Jukka Talvitie (Tampere University, Finland); Elena Simona Lohan (Tampere University, Finland & Universitat Autonoma de Barcelona, Spain); Ertugrul Basar (Tampere University, Finland & Koc University, Turkey); Mikko Valkama (Tampere University, Finland)
This paper introduces a Gaussian process (GP)-based method for extended object estimation (EOE) in integrated sensing and communication (ISAC) scenarios, representing a promising approach to enhance environmental awareness beyond the conventional point-scatterer assumption. The suitability of the proposed GP-based method for EOE is investigated through a practical measurement setup compliant with the fifth-generation (5G) New Radio (NR) standard and employing bistatic sensing, with results evaluated for both mapping and simultaneous localization and mapping (SLAM) cases at millimeter-wave (mmWave) frequencies. The findings reveal that the enhanced capabilities of communication networks, when combined with bistatic sensing and GP-based EOE, enable improved environmental awareness in future wireless systems. Importantly, the results demonstrate that, under practical conditions, GP effectively performs EOE in both mmWave mapping and SLAM scenarios.

10:30 Device-Free Localization with Reconfigurable Intelligent Surfaces: A Body Fading Model

Martin Schmidhammer, MichaelWalter, ChristianGentner and Stephan Sand (German AerospaceCenter (DLR), Germany)
Device-free localization (DFL) systems exploit variations in the received strength of signals exchanged between static radio nodes to infer presence and position of a person. With the deployment of reconfigurable intelligent surfaces (RISs), additional programmable reflection paths can be established between nodes. To exploit these paths for DFL, this work introduces a deterministic body-fading model based on scalar theory of diffraction. The human body is represented as a two-dimensional knife-edge object, and its influence on the received electric field is analytically derived. A closed-form expression for the body-induced attenuation is obtained as a function of RIS aperture, geometry, and body position. Simulations are conducted for sub-6 GHz and mmWave frequencies, showing qualitatively similar attenuation patterns but stronger spatial confinement at higher frequency. The analysis further reveals a diminishing attenuation with increasing RIS aperture, providing a physically grounded basis for RIS-assisted DFL design and other RIS-enabled radio applications in dynamic environments.

10:50 Performance Assessment of DOA and Doppler Positioning Under Erroneous Starlink and OneWeb LEO Satellites Ephemerides

Zaher M Kassas, Paul El-Kouba and Sharbel Kozhaya (The Ohio State University, USA)
The performance of direction-of-arrival (DOA) and Doppler-based positioning with Starlink and OneWeb low Earth orbit (LEO) satellites under erroneous ephemerides is assessed. First, an extended Kalman filter (EKF) and an unscented Kalman filter (UKF) are formulated to estimate the position of a stationary receiver with (i) DOA-only, (ii) Doppler-only, and (iii) DOA+Doppler measurements. Second, Monte Carlo (MC) simulations are conducted to compare the filters and study the effect of different erroneous ephemerides on the positioning solution, namely (a) no errors, (b) small errors, and (c) large errors in the ephemerides. Finally, MC-based experimental results are presented of stationary receiver positioning with (i) DOA-only, (ii) Doppler-only, and (iii) DOA+Doppler from 4 Starlink and 4 OneWeb LEO satellites. Starting with an average initial two-dimensional (2D) position error of 2,611 m, it is shown that despite using erroneous LEO ephemerides (obtained by propagating two-line element (TLE) data with SGP4), the average final positioning error was (i) 38 m, (ii) 1,228 m, (iii) 915m, respectively, which demonstrates that positioning with DOA measurements is less sensitive to ephemeris errors.

11:10 Measurement-Based Human Blockage Modeling for mmWave Body-to-Body Communications

Amedeo Morat, An Lin and José Rodríguez-Piñeiro (Tongji University, China); Luis M Correia (IST / INESC INOV-Lab, University of Lisbon, Portugal); Guangzheng Jing, Jingxiang Hong and Xuefeng Yin (Tongji University, China)
This paper quantifies the System Loss (SL) for millimeter-wave (mmWave) Body-to-Body (B2B) communication channels in crowded indoor environments. A model simplifying the B2B complex link geometries by means of the concept of visibility was first proposed. Later on, a comprehensive measurement campaign was conducted in a corridor to validate the proposal. The measurements systematically evaluated the impact of different antenna placements for typical B2B applications, users' relative orientations and various levels of human crowd density within the transmitter (Tx) and receiver (Rx) on the SL. Two key phenomena were observed: (1) a crowd saturation effect, exhibiting that the growth of the crowd density from a certain threshold will not increase the SL; and (2) negligible impact on the SL by the on-body antenna heights for random user orientations. One concludes that the SL can be modeled by using two dominant factors: link visibility and a binary state of crowd presence.

11:30 Accurate Radio Map Estimation from Sparse Measurements with U-Nets

Wilfried Wiedner (Institute of Telecommunications, TU Wien, Vienna, Austria & Christian Doppler Laboratory for Digital Twin Assisted AI for Sustainable Radio Access Networks, Austria); Viet Dung Thomas Tran (Institute of Telecommunications, TU Wien, Vienna, Austria); Lukas Eller (Vienna University of Technology, Austria); Philipp Svoboda and Markus Rupp (TU Wien, Austria)
This paper presents a deep learning approach for predicting cellular signal strength maps in urban environments using a U-Net architecture. The network processes building and antenna configuration data as images and optionally integrates sparse measurements through an additional calibration channel. Using only 5% of available ground-truth data reduces the root-mean-square error (RMSE) by 1.2 dB compared to predictions without measurements. The model remains robust under measurement noise up to 12.9 dB and consistently outperforms interpolation and k-nearest-neighbor regression. The proposed approach offers a scalable, accurate, and computationally efficient solution for radio map estimation and network planning.

Tuesday, April 21 10:10 - 11:50

CS25b Electromagnetic medical imaging: inversion algorithms and novel data processing strategies 2

T06 Biomedical and health / Convened Session / Electromagnetics
Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)
Room: Prague

10:10 Attenuation Compensation with Wave Operator Model for Inhomogeneous Dissipative Media

Tianchen Shao (Tsinghua University, China); Zekui Jia (Purdue University, USA); Maokun Li, Fan Yang and Shenheng Xu (Tsinghua University, China)

Wave attenuation in dissipative media poses challenges to solving inverse scattering problems. In this paper, we study an attenuation compensation method based on the wave operator model, which restores the measured data by reversing the dominant exponential decay term in the wave solution. The effectiveness and robustness of the method are validated through numerical experiments on a model with inhomogeneous loss distributions, including a performance boundary analysis.

10:30 Head Tissue Segmentation Using Qualitative Microwave Imaging Results Obtained with Parametric Models

Anja Kovačević and Darko Ninković (University of Belgrade, Serbia); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Branko Kolundzija and Marija Stevanovic (University of Belgrade, Serbia)

Microwave imaging of head tissues constitutes a challenging endeavor due to the inherent nonlinearity of the inverse scattering problem and the complex heterogeneity of cerebral structures. This complexity can be mitigated by providing an informed initial guess to inversion algorithms. In this paper, we propose an approach for qualitative reconstruction of head tissue boundaries. The approach employs spherical harmonic basis functions to represent the permittivity distribution within the framework of the first-order Born approximation, coupled with Tikhonov regularization to stabilize the inversion process. To demonstrate the feasibility of the approach, we apply it to a realistic head phantom comprising eight distinct tissues. Preliminary results indicate that the proposed approach reliably identifies two major scattering interfaces: skull-soft tissue and skull-brain boundary.

10:50 An Innovative Two-Step Method for MR-Based Electrical Properties Tomography

Fabiana Capitanio (Sapienza, University of Rome, Italy); Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy)

Magnetic resonance electrical properties tomography is a noninvasive imaging technique aimed at estimating the electromagnetic properties of biological tissues from magnetic resonance data. The underlying task involves a nonlinear and ill-posed inverse problem. In this work, a two-step method is proposed to reformulate the problem as a cascade of linear subproblems. In the first step, a linear ill-posed inverse problem is solved to estimate the distribution of contrast sources and the internal electric field within the region of interest. In the second step, the electrical properties are retrieved through a least-squares fitting based on the quantities estimated in the first step. A numerical example involving a simple phantom is presented to provide an initial validation of the proposed approach.

11:10 A Comparison of Attention-Based Multi-Frequency 2-D and 3-D Microwave Imaging Deep Learning Models

Haylee Janz, Ben J Martin, Keeley Narendra, Colin Gilmore and Ian Jeffrey (University of Manitoba, Canada)

Time-harmonic microwave imaging algorithms benefit from the additional information present in multi-frequency data, yet limited work has addressed how multi-frequency data should be incorporated into deep learning schemes aimed at solving the microwave imaging problem. In this work we compare deep learning architectures for multi-frequency imaging. Our primary focus is on a data-to-image workflow applied to both 2-D and 3-D imaging scenarios. We also consider input sequence options (over frequencies or transmitters) for select 3-D architectures. Results highlight the performance benefits of attention-based models over traditional U-Net and recent LSTM-based approaches.

11:30 Magnetic Resonance-Based Electric Properties Tomography Based on Green's Identity

Alessandro Arduino, Oriano Bottauscio, Adriano Troia, Umberto Zanovello and Luca Zilberti (INRIM, Italy)

Magnetic resonance-based electric properties tomography is a quantitative imaging modality that non-invasively measures the distribution of the electric properties of a human subject by processing the results of magnetic resonance imaging. This imaging modality is still not consolidated and research on an effective processing algorithm is ongoing. Recently, an implementation based on the Green's identity and relying on the assumption of locally homogeneous electrical properties has been proposed. Here, this implementation is further developed to overcome the local homogeneity assumption and improve the quality of the recovered images in presence of discontinuities in the electrical properties, like at the interface between different biological tissues.

Tuesday, April 21 10:10 - 11:50

CS31b Antennas and Arrays for Radio Astronomy 2

T03 Aerospace, space and non-terrestrial networks / Convened Session / Measurements
Chairs: Sean V Hum (University of Toronto, Canada), David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

Room: Krakow

10:10 Ambient L-Band Feed for the Westerbork Synthesis Radio Telescope

Paulus Kruger, Mark Ruiter and Geert Vastenhoud (ASTRON, The Netherlands); Michel Arts (ASTRON, the Netherlands Institute for Radio Astronomy, The Netherlands); David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

A new ambient L-band feed is being developed for the Westerbork Synthesis Radio Telescope (WSRT). The goal is to replace the cryogenically cooled feed with an ambient temperature feed that has the same sensitivity while improving the bandwidth. This will replace the complex cryogenic feeds which are expensive to operate and maintain. The upgrade is made possible by modern low-noise transistors and a new co-design technique for the feed and low-noise amplifier. The co-design makes it possible to noise match the lownoise transistor directly inside the feed, thereby minimising loss. The first ambient L-band prototype achieves a sensitivity of 9 m^2/K at 1.4 GHz, which is similar to the cryogenically cooled frontend. It also has an improved bandwidth of 1.3 - 2.1 GHz.

10:30 On the Performance of a Generic Phased Array Feed for the European VLBI Network

Saba Aslam (Ericsson AB, Sweden & Eindhoven University of Technology, The Netherlands); Lars Manholm (Ericsson Research, Sweden); Ulf Johannsen (Eindhoven University of Technology, The Netherlands); David S Prinsloo (ASTRON & Netherlands

Institute for Radio Astronomy, The Netherlands) This paper demonstrates the simulated performance of a generic phased array feed (PAF) that can be used for the prime-focus radio telescopes present in the European Very Long Baseline Interferometry Network (EVN). To this extent, for a given array size (1.5λ by 1.5λ) and a selected low-noise amplifier, a parametric study is carried out to analyse the performance of the array feed as a function of the reflector geometry and beamforming algorithms. The overall performance of the system is discussed in terms of achievable aperture efficiency, beam dependent system temperature, and sensitivity as a function of the focal length-to-diameter ratio f/D of the reflector with three different beamforming schemes. Based on this initial study, the challenges in the generic PAF design are identified and recommendations are made for the final system.

10:50 DSA-2000 Antenna System Noise Temperature Measurements

Jonas Flygare and Kiran A. Shila (Caltech, USA)

The Deep Synoptic Array (DSA-2000) will revolutionize radio astronomy with unprecedented sensitivity and survey speed. It will consist of 1650 reflector antennas, each with 6.15 m diameter and cover the frequency range of 0.7-2 GHz. It is based on a highly sensitive, low-cost antenna system with ambient-temperature receiver electronics that include a low-noise amplifier with 11 K noise temperature. In this paper, we present initial system noise temperature measurements of less than 25 K near the proposed site for the

11:10 Towards an Alignment Model for the ngVLA Reflector System

Robert Lehmensiek (National Radio Astronomy Observatory, USA & Stellenbosch University, South Africa); Dirk de Villiers (Stellenbosch University, South Africa)

During the commissioning of a new radio astronomy reflector system, precise characterization and adjustment of the reflector surfaces are critical to meeting the specified mechanical tolerances. The surface accuracy is typically derived from holographically measured far-field radiation patterns. We present a machine learning-based regression model for estimating large-scale alignment errors caused by translational and rotational misalignments of the sub-reflector and feed. The model is implemented as a feedforward neural network that takes a pre-processed far-field pattern as input and outputs a vector quantifying the corresponding alignment errors. This approach enables rapid inference of misalignment states from field measurements and has potential utility in closed-loop surface tuning and system diagnostics.

11:30 Q-Band Beam Measurement of the QUIJOTE CMB Telescope Using a UAV

Fabio Paonessa (Consiglio Nazionale Delle Ricerche (CNR-IEIIT), Italy); Lorenzo Ciorba (University of Bern & Institute of Applied Physics, Switzerland); Marco Bersanelli (Università degli Studi di Milano, Italy); Cristian Franceschet (Università degli studi di Milano, Italy); Ricardo Tanausú Génova Santos, Roger Hoyland, Carlos Hugo López-Caraballo and José Alberto Rubiño-Martín (Institute of Astrophysics of the Canary Islands, Spain); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

The Large Scale Polarization Explorer (LSPE), supported by the Italian Space Agency, encompasses the LSPE-Strip telescope, a ground-based facility designed to probe Cosmic Microwave Background (CMB) anisotropies. Operating from the Teide Observatory, it will employ 49 polarimeters at 43 GHz and auxiliary channels at 95 GHz for atmospheric monitoring. Accurate on-site testing is required to mitigate systematic effects, including beam distortions and pointing errors. To this end, a UAV-borne Q-band source was developed and validated through a measurement campaign on a similar instrument, i.e., the QUIJOTE-CMB telescope developed by the Institute of Astrophysics of the Canary Islands. Results confirmed the effectiveness of drone-based beam characterization, paving the way for LSPE-Strip's deployment.

Tuesday, April 21 10:10 - 11:50

CS37b Advances in Dynamic Metasurface Antennas/Reconfigurable Holographic Surfaces for Next-Generation Wireless Applications: Design, Development and Applications 2

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Aakash Bansal (Loughborough University, United Kingdom (Great Britain)), Abdul Jabbar (Loughborough University, United Kingdom (Great Britain))

Room: Rome

10:10 Reconfigurable Metasurface Aperture for Integrated Compressive Electromagnetic Sensing and Imaging

Mengran Zhao (Queen's University Belfast, United Kingdom (Great Britain) & Xi'an Jiaotong University, China); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Insang Yoo (Yonsei University, Korea (South)); Trung Q. Duong (Memorial University of Newfoundland, Canada); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

In this paper, a reconfigurable metasurface aperture (RMA) is proposed for integrated compressive electromagnetic sensing and imaging (ISAI) applications. The proposed RMA consists of randomly distributed switchable meta-atoms with two orthogonal orientations to enable dual-polarized radiation. The meta-atoms are loaded with PIN diodes, and by reconfiguring their operating states, the meta-atoms are selectively deactivated or activated. This dynamic mechanism is used to generate spatially low-correlated radiation patterns. These patterns serve as measurement modes for ISAI implementation. The performance of RMA is characterized using the reflection coefficient to assess the antenna behavior, and the correlation coefficient and the singular value spectrum to evaluate the spatial orthogonality of its measurement modes. An RMA-based ISAI study is conducted to validate the proposed design, in which the incident angles of far-field sources are accurately estimated and both the image and orientation of a target are successfully retrieved, confirming the effectiveness of the approach.

10:30 Multi-Port Dynamic Metasurface Antenna: Prototype and Preliminary SVD-Based Examination

Jean Tapie (CNRS, France); Philipp del Hougne (CNRS, Univ Rennes, France)

Dynamic metasurface antennas (DMAs) emerge as ultra-thin, low-power, low-cost, hybrid-MIMO technology. Numerically extracting the MC between the meta-elements is computationally too costly (DMAs are electrically large) and risks mismatching the experimental reality (fabrication inaccuracies). We report an important preliminary step toward experimentally calibrating an MC-aware DMA model based on multi-port network theory (MNT). First, we fabricated a multi-port chaotic-cavity-backed DMA operating at 18 GHz. Second, we measured the reflection matrix of the DMA's feed ports and the transmission matrix from the feeds to a virtual antenna array, for a specific series of DMA configurations. Third, we verified experimentally that the rank of the change of these matrices upon reconfiguring a single meta-element is approximately one. Besides validating a fundamental assumption of the MNT model for our multi-port DMA, our approach also turns out to be a good diagnostic tool to identify malfunctioning meta-elements.

10:50 A Dual Function Metasurface for RIS Applications

Irsat Gulen (University of Birmingham, United Kingdom (Great Britain) & University of Huddersfield, United Kingdom (Great Britain)); Evangelos Vassos (Steatite Antennas, United Kingdom (Great Britain)); Venkat Reddy Kandregula (University of Huddersfield, United Kingdom (Great Britain)); Savvas Chalkidis (University of Birmingham, United Kingdom (Great Britain)); Stamatia Rizou (Singular Logic, Greece); Pavlos Lazaridis (University of Huddersfield, United Kingdom (Great Britain)); Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain))

A dual function metasurface based on two flip-chip Aluminium Gallium Arsenide (AlGaAs) PIN
diodes is presented. Depending on the biasing state of the PIN diodes, the metasurface exhibits either a 1-bit reflection phase response or a transmission response. The design was optimized using the full 3D model of the PIN diodes. Additionally, a study of the integrated biasing lines, which were carefully designed to minimise unwanted coupling and ensure negligible degradation of the reflection and transmission responses, is also presented. Simulations have been carried out using CST microwave studio to evaluate the performance of the dual function metasurface. The optimized metasurface demonstrates an average reflection loss of 0.52 dB and a transmission loss of 1.15 dB at 29 GHz.

11:10 Bowtie Metasurface Reflectarray for Wideband Beamforming Applications in K and Ka Band

Mirza Shujaat Ali, Zaid Akram, Jalil ur Rehman Kazim, Hasan Abbas, Farooq A Tahir, Muhammad Ali Imran and Qammer Abbasi (University of Glasgow, United Kingdom (Great Britain))

This paper presents the design of a wideband metasurface-based reflectarray for an operational frequency range from 25 GHz to 36 GHz. The proposed metasurface employs a bow-tie shaped element which achieves a 1-bit phase phase quantization in reflection mode by variation of geometric parameters. achieving a 180° phase difference between its two states. The metasurface exhibits a reflection loss of less than 1 dB and is angularly stable up to 20° for transverse electric (TE) incident wave. To validate the beam-forming capability, two 32 × 32 reflectarray prototypes were synthesized to produce highly directional reflected beams at 20\textdegree and 30°, respectively. Full-wave simulations demonstrate broadband phase continuity and stable high gain radiation over the wide frequency range. The proposed design highlights the potential of bow-tie metasurfaces for high-gain, reconfigurable, and wideband beam-steering applications in mm-wave communication systems, particularly for 5G/6G front-end and satellite link implementations.

11:30 Development of an Anisotropic Holographic Metasurface Antenna on a Flexible Printed Circuit Board: Challenges and Solutions

Ville Lundén, Mayank Mayank, Mostafa Movahediqomi, Viktar Asadchy and Jaan Praks (Aalto University, Finland)

Holographic metasurface antennas (HMAs) provide excellent radiation pattern control, making them an attractive option for many applications requiring high-performance antennas. This work presents the integration of a high-performance anisotropic HMA on a flexible printed circuit board (flex-PCB) to enable implementing curved or deployable HMAs that can further unlock new opportunities for example for small satellites. In addition to demonstrating the design process of a circularly polarized flexible HMA prototype, this work discusses practical challenges, trade-offs, and solutions. The prototype for lower K-band is implemented on a 0.314 mm thin multilayer polyethylene terephthalate (PET) substrate. A discrepancy observed between simulated and measured radiation patterns is, through systematic analysis, attributed to inaccuracy in substrate permittivity. Measurements show, nevertheless, that the antenna provides excellent performance with 22 dBi realized gain and better than -25 dB cross-polarization level at 20 GHz while enabling a less than 10 mm antenna bending radius for compact stowage.

Tuesday, April 21 10:10 - 11:50

CS42b AMTA Post Processing Techniques in Antenna Measurements 2

TO8 Fundamental research and emerging technologies/processes / Convened Session / Measurements
Chairs: Joshua Gordon (US National Institute of Standards and Technology, USA), Francesco Saccardi (Microwave Vision Italy, Italy)

Room: London

10:10 Evaluation of Parameter Sensitivity in Autonomous Robotic Measurements

Celia Fontá Romero (Universidad Politécnica de Madrid); Ana Arboleya (Universidad Rey Juan Carlos, Spain); Manuel Sierra Castañer (Universidad Politécnica de Madrid, Spain)

This paper presents an in-depth analysis of several optimization strategies applied to the autonomous antenna measurement process using a robotic arm. A methodology is proposed for grid-reduced, fully automated measurements requiring minimal human intervention and leveraging prior information about the antenna under test (AUT). The approach is based on maximizing the variability of the projected coefficients of the reconstructed aperture field. However, this process involves two particularly sensitive aspects: the choice of the optimization algorithm and the definition of the reduced grids at each iteration. This work analyzes different alternatives for both and provides a comprehensive study of their impact on the overall performance of the measurement process.

10:30 Extraction of the Electric Field Vector with SDR Equipment for Phaseless Nearfield Measurement

Myssipsa Mehraz (IMT Atlantique & LabSticc Laboratory, France); Francois Gallée (IMT Atlantique, France)

This work presents a V band measurement setup combining an orthomode transducer and a software-defined radio to simultaneously acquire orthogonal field components and their phase shift. Used alongside the Iterative Fourier Transform algorithm, this setup enables efficient and accurate polarization characterization while reducing measurement complexity and time. The algorithm reconstructs the near-field phase of each component independently, and, combined with the measured phase shift, allows complete far-field polarization retrieval.

10:50 Reduced-Order Model with Domain-Decomposition for Electrically Large Antenna Characterization

Samuel Corre (IETR, France); Benjamin Fuchs (Federal Office of Communications, Switzerland); Nicolas Mezieres (Centre National d'Etudes Spatiales, France); Laurent Le Coq (University of Rennes 1 & IETR, France)

The characterization of electrically large antennas is time consuming as it requires the acquisition of a large amount of field samples. One solution to accelerate antenna measurements is to compute the Reduced-Order Model (ROM) of the antenna characterization problem. To achieve this, the application of the Singular Value Decomposition (SVD) of the discretized radiation operator, allows the construction of a field expansion basis tailored to the Antenna Under Test (AUT), leading to a drastic reduction of the number of required field samples as compared to standard approaches. However, the SVD operation becomes computationally prohibitive in terms of time and memory, as the electrical size of the AUT and consequently the dimensions of the radiation matrix increase. To yield more tractable computations, a Domain Decomposition for Reduced-Order Model (DD-ROM) is proposed. The radiation operator is separated into interconnected regions to replace the single large SVD by several smaller ones.

11:10 Compensation of Mechanical Alignment Errors Using a Non-Uniform Fast Fourier Transform

Javier Fernández Álvarez, Jeppe Nielsen and Samel Arslanagić (Technical University of Denmark, Denmark); Michael Mattes (DTU Space, Germany)

A method based on a non-uniform 2D FFT was developed and validated to compensate for the effects in near-field measurements of the bending of heavy antennas under gravity. This results in an incorrect sampling of the measurement sphere, in a set of irregularly distributed directions of observation, different from the nominal sampling directions. The method could, in principle, compensate other measurement errors which result from improper alignment of the measurement setup and where the effect is an incorrect sampling of the measurement sphere, e.g. errors of pointing, axis intersection, or probe position. The aforementioned method is adapted to compensate two of such errors, tested with experimental and simulated measurements of a real antenna under controlled conditions of error. By comparing the compensated patterns with reference data, performance can be studied in a more systematic way than in previous work where the goal was the compensation of an unwanted, unavoidable effect.

11:30 Phase-Corrected near-Field Microwave Imaging via Inverse Source Reconstruction with Modulated Signals

Quanfeng Wang and Alexander H. Paulus (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

An inverse source reconstruction (ISR) based 3-D near-field (NF) passive radar microwave imaging method utilizing modulated signals is presented. The modulated signals from a non-cooperative transmitter are scattered by the targets of interest and captured by a fixed reference antenna together with an NF scanning probe at different positions. By normalizing with the reference signals, spatial coherence of the NF observations is obtained, and a single-frequency inverse source solver is subsequently utilized for ISR and image generation. A corresponding phase correction method is proposed for the coherent superposition of multi-frequency images and verified through simulations. In addition, it is shown that for realistic narrowband signals, an incoherent imaging approach is sufficient. The presented technical scheme is validated using a planar scanning system in a typical office room, where software-defined radios are employed for the transmitting and receiving of narrowband orthogonal frequency-division multiplexing signals at Wi-Fi operating

Tuesday, April 21 10:10 - 11:50

CS4b Challenges in assessing human RF exposure to existing and emerging mobile radio technologies up to 6G 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Wout Joseph (Ghent University/IMEC, Belgium), Lisa-Marie Schilling (Technische Universität Ilmenau, Germany)

Room: Paris

10:10 Impact of Reconfigurable Intelligent Surfaces Aided Networks on the Electromagnetic Exposure

Thanh Tam Julian Ta and Anna-Malin Schiffarth (RWTH Aachen University, Germany); Christian Bornkessel, Lisa-Marie Schilling and Matthias Hein (Technische Universität Ilmenau, Germany); Dirk Heberling (RWTH Aachen University, Germany)

Passive reconfigurable intelligent surfaces have been proposed as a potential enabler for extending millimeter-wave coverage in forthcoming 6G networks, although their influence on electromagnetic exposure requires further investigation. A deterministic link-level simulation framework that integrates ray tracing, a standards-compliant physical layer and a clustered delay-line channel model is presented for the joint evaluation of spectral efficiency and electromagnetic exposure. The framework is applied to a scenario in which a conventional base-station-to-user link is compared with a cascaded base-station-surface-user topology. The surface establishes a line of sight path which enables reliable decoding even with significantly reduced resource allocation. While the local field strength increases along the new path, achieving the same capacity by merely boosting the base-station power in the conventional link would increase the overall exposure even more. These findings demonstrate the potential of intelligent surfaces as an exposure-efficient solution for expanding millimeter-wave coverage.

10:30 RIS-Enhanced Propagation and Exposure Evaluation in Modern Greenhouses

Felipe Oliveira Ribas and Gunter Vermeeren (Ghent University, Belgium); Thomas Zemen (AIT Austrian Institute of Technology GmbH, Austria); Milica Djordjevic and Hamed Radpour (AIT Austrian Institute of Technology, Austria); Wout Joseph (Ghent University/IMEC, Belgium)

Modern agriculture increasingly relies on high-capacity wireless links, motivating the use of millimeter-wave (mmWave) frequencies. However, in greenhouse environments, dense vegetation creates non-line-of-sight (NLoS) conditions that block mmWave signals and reduce reliability. Reconfigurable intelligent surfaces (RIS) can restore coverage by redirecting energy around obstacles, but their beamforming also changes the exposure environment. In this work, a realistic 3D greenhouse model is combined with Sionna ray-tracing at 26 GHz and FDTD dosimetry on a human model and a bumblebee, a widely used for insect pollination in commercial tomato cultivation. Results show that RIS restores blocked links with more than 40 dB SNR improvement, while human exposure remains well below ICNIRP 2020 limits and insect absorption increases by about four times. These findings highlight both the communication benefits and the altered exposure patterns associated with RIS deployment in smart horticulture.

10:50 Evaluating the Accuracy of the Huygens Source Model in RF Exposure Assessment

Zain Haider (MVG Industries, France); Francesco Saccardi (Microwave Vision Italy, Italy); Ludovic Durand (SATIMO, France); Lars Foged (Microwave Vision Italy, Italy)

Assessing human exposure to radiofrequency emissions is critical for ensuring compliance with international safety standards. While conventional direct measurements of Specific Absorption Rate (SAR) offer high accuracy, they typically require time-consuming experimental setups. Recently, non-invasive SAR estimation based on Huygens source modeling of the Device Under Test have gained attention as more time-efficient alternatives. This study presents a comprehensive analysis of the theoretical limitations and practical considerations for accurate non-invasive SAR estimation. Full-wave simulations were conducted to investigate how key parameters, like Huygens source size, mesh density, and near-field model delta, affect reconstruction accuracy. Further analysis of electromagnetic coupling between a smartphone and a homogeneous phantom revealed that incorporating a simplified internal model of the phone within the Huygens source significantly improves SAR prediction accuracy. These findings establish practical lower bounds for Huygens source dimensions and provide implementation guidelines for fast, reliable, and measurement-based non-invasive SAR characterization of wireless devices.

11:10 Current Approaches for RF-EMF-Monitoring in Europe

Marco Zahner (Fields at Work GmbH, Switzerland); Dominik Haas and Toni Ziegler (Grolimund & Partner AG, Switzerland); Martin Röösli (Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Italy); Jürg Fröhlich (Fields at Work GmbH, Switzerland)

Current approaches in exposure assessment on the public and the personal level are evaluated regarding accuracy, representativity and suitability for categorization into subpopulations. We discuss novel approaches such as field strength monitoring via a smartphone-based exposure app in a citizen science project and the introduction of a low-cost sensor network for visualizing and quantifying the spatial and temporal dynamics of adaptive transmission technologies. Together with already established population-level monitoring, these methods provide a toolkit enabling multi-layered monitoring.

11:30 A Comparison of EMF Exposure Prediction in mmWave to Sub-THz Using XGBoost with SHAP and Deep Feedforward Neural Networks

Ming Yao and Gert Frølund Pedersen (Aalborg University, Denmark); Kun Li (The University of Electro-Communications, Japan); Shuai Zhang (Aalborg University, Denmark)

Assessing human EMF exposure at millimeter-wave to sub-THz frequencies for 6G is time-consuming and resource-intensive. Learning-based surrogates can accelerate exposure estimation by replacing full-wave simulations with fast predictors. In this study, we compare XGBoost with SHAP explanations against a deep feedforward neural network for predicting skin temperature rise and absorbed power density, and measure both training and prediction time. SHAP attributions quantify the relative influence of features (e.g., frequency, incidence angle, air gap, polarization), providing transparency not available from the deep feedforward neural network baseline. Finally, we will provide a concise decision guideline indicating when XGBoost with SHAP or a deep feedforward neural network is preferable, given the balance among accuracy, latency, and interpretability.

Tuesday, April 21 10:10 - 11:50

EO8b Electromagnetic theory: New Material Design 2

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Electromagnetics
Chairs: Ana Díaz-Rubio (Universitat Politècnica de València, Spain), Piero Triverio (University of Toronto, Canada)

Room: Barcelona

10:10 Electromagnetically Induced Transparency Using Dispersive Plasma Media

Krushna Kanth Varikuntla (Queen's University Belfast, United Kingdom (Great Britain) & Queens's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))
In this work, a combination of gaseous plasma media and metamaterials is employed to achieve active control of electromagnetic waves in the microwave regime for realizing an electromagnetically induced transparency (EIT) response. A reconfigurable plasma device integrated with metallic resonators is investigated, wherein the ionization state of the enclosed gas is controlled to actively modulate the coupling conditions. A strong reflection is observed in the frequency range of 2.17-2.61 GHz (at -1 dB), while a high-Q, sharp transmission band is obtained at 2.45 GHz with a bandwidth of 33 MHz (fractional bandwidth of 1.35%), corresponding to a quality factor of approximately 74.2. This approach demonstrates a promising pathway toward the development of real-time, and tunable devices based on EIT principles.

10:30 The Effect of the Modulating Waveform on Time-Modulated Metasurfaces

Tomas Lira-Valdes (Universidad de Malaga, Spain); Elena Abdo-Sánchez (University of Málaga & E. T. S. I. Telecomunicación, Spain)
This paper investigates the influence of the modu- lation waveform on the frequency translation of time-modulated metasurfaces. Using an analytical Floquet model and FDTD simulations, several temporal waveforms are analyzed. Results show that sinusoidal, square, and triangular modulations produce symmetric multi-harmonic spectra, while the sawtooth waveform enables nearly single-harmonic translation following the Serrodyne principle. The modulation phase controls the translation direction, and the strong correlation between analyti- cal and numerical results confirms the model's accuracy and the potential of waveform engineering for reconfigurable frequency translation.

10:50 Metasurface-Enhanced Textiles for Passive Antenna Aperture Extension in Mobile Devices

Shuai S. A. Yuan (Aalto University, Finland); Xianghui Qiu (Harbin Engineering University, China); Mohammadmahdi Asgari, Francisco S. Cuesta and Sergei Tretyakov (Aalto University, Finland); Xuchen Wang (Harbin Engineering University, China & XYZ Company, China); Viktar Asadchy (Aalto University, Finland)
Millimeter-wave links suffer from severe path loss, non-line-of-sight blockage, and the intrinsically small apertures of handheld and wearable devices. We propose metasurface-enhanced smart textiles that passively capture incident fields on clothing, convert them to guided surface waves along the body, and funnel energy to a nearby device's electrically small antenna. This approach leverages the textile area to enlarge the device's aperture for both downlink and uplink, requiring neither batteries nor infrastructure modifications. The wearable metasurface can be realized via screen-printed conductive patterns on standard fabrics, enabling low-cost, unobtrusive integration. A complete design framework for the metasurface is developed, including theoretical modeling of a loaded-wire metasurface, impedance matrix retrieval using numerical Green's function, and optimization via a multi-population genetic algorithm. Full-wave simulations in COMSOL and CST demonstrate efficient conversion of incident waves into guided surface waves, resulting in enhanced power delivery to the receiving small antenna.

11:10 An Original Technique for the Experimental Characterization of THz Metasurfaces

Edoardo Negri (Consiglio Nazionale delle Ricerche, Italy); Dimitrios Zografopoulos (CNR-IMM, Italy); Francesco Maita (IMM-CNR, Italy); Luca Maiolo (CNR-IMM, Italy); Romeo Beccherelli (Consiglio Nazionale delle Ricerche, Italy); Walter Fuscaldo (National Research Council (CNR), Italy)
Research Council (CNR), Italy) We present an original technique for the experimental characterization of homogenized metasurfaces at THz frequencies. Specifically, both inductive- and capacitive-like metasurfaces placed on top of a metal-backed silica substrate are measured through THz timedomain spectroscopy (TDS) in reflection mode. Their response is originally characterized depending on the resonance-frequency shift with respect to that of an ideal parallel-plate cavity resonator. As a consequence, the sensitivity figure of merit of the proposed technique is determined exclusively by the frequency resolution of the instrument and is almost independent of the system noise floor, thereby making this approach highly robust to the amplitude uncertainties that commonly affect THz spectroscopic measurements.

Tuesday, April 21 10:10 - 11:50

PO8b Propagation models for Non-Terrestrial Networks 2

TO3 Aerospace, space and non-terrestrial networks / / Propagation
Chairs: Joonas Kokkoniemi (University of Oulu, Finland), Lorenzo Luini (Politecnico di Milano, Italy)

Room: Firenze

10:10 Site Diversity Switching Strategies for Q-Band SatCom Systems Using Conditional Probability Fields

Miles A. Turner, Alef Comisso, Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy)
Satellite links above 20 GHz suffer severe rain fades, making site diversity essential to guarantee the target availability and performance levels. This paper evaluates reactive and conditional probability-based switching strategies using long-term Q-band data collected in two Italian sites in the framework of the Alphasat Aldo Paraboni propagation experiment. Results show that all strategies outperform single-site operation. Specifically, the simple reactive method maximizes fade protection but incurs frequent outages, while conditional based approaches prove to reduce switching overhead and provide more stable performance with only minor efficiency loss.

10:30 Insights on Earth-to-Satellite Cross-Polarization Discrimination at Ka-Band Using a New Experimental Database

Armando Rocha (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal); Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); José E. Silva (Universidade de Aveiro, Portugal)
Depolarization in the troposphere gives rise to interference in Earth-Satellite communication systems employing polarization reuse. This work presents generic results of the depolarization phenomenon based on a database of nearly 10 years in the Ka band. Statistical data of the depolarization ratio are analyzed from three perspectives: in the form of the complex vector depolarization ratio and its Cartesian components as a function of attenuation, with the aim of identifying the presence of ice, rain, or both populations and their relationship with attenuation. An evaluation is also conducted on the performance of ITU-R Recommendation P.618-14 with respect to the XPD-CPA equal probability relationship.

10:50 Using Deep Learning for Outlier and Precipitation Detection in Satellite Propagation Data Processing

Karin Plimon (Joanneum Research, Austria); Martin Winter (JOANNEUM RESEARCH Forschungsgesellschaft mbH, Austria); Mirela Fetescu (Joanneum Research, Austria & Graz University of Technology, Austria); Michael Schmidt (JOANNEUM RESEARCH, Austria); Martin Rytir (Norwegian Defence Research Establishment (FFI), Norway); Raul Orus Perez (European Space Agency (ESA) / ESTEC, The Netherlands)
This activity investigates the applicability of deep learning methods on specific tasks for satellite propagation data processing such as outlier and precipitation event detection. We trained separate models for outlier detection and precipitation detection on several years of measurement data covering three climate zones and the three frequency bands Ka-, Q- and V-band. The performance of the trained models is evaluated on a test set comparing the model output with reference labels. The deep learning-based precipitation flags are as well compared to reference data in terms of excess attenuation statistics using an ITU-R model as performance baseline.

11:10 A Microphysical Model to Investigate Cloud-Induced Hydrometeor Scattering Intersystem Interference

Enrico Polo, Michele D'Amico and Carlo Riva (Politecnico di Milano, Italy); Antonio Martellucci (European Space Agency, The Netherlands); Lorenzo Luini (Politecnico di Milano, Italy)
This paper presents a study on the contribution of water and ice clouds in the framework of hydrometeor scattering interference analysis. A microphysical model has been developed to account for the scattering effect induced by populations of water droplets in lowheight clouds and ice crystals in clouds at higher altitude. Rayleigh scattering theory has been implemented and applied to these particles populations, described through appropriate Particle Size Distributions (PSD) for both the water and ice cases. Following, a comparison between cloud and rain scattering contributions is presented to quantify their relative impact, providing a comprehensive characterization of hydrometeor scattering interference from different atmospheric phenomena.

11:30 Application for Secure, Real-Time Astronauts' Health Monitoring over Delay Tolerant Networks

Nadia Kortas and Shaun McKeehan (NASA Glenn Research Center, USA); Pradnyan Khodke (University of Illinois Urbana-Champaign, USA); Timothy Recker (NASA Glenn Research Center, USA)
NASA's Artemis missions require resilient communication systems for real-time astronaut health monitoring during deep space operations. This work presents a DTN-enabled Electrocardiogram (EKG) sensor application that transmits over 600 secure readings per second via a free-space optical link. The system integrates a graphical user interface for real time monitoring and remote sensor tuning, enabling adaptability to harsh environments. Validation was conducted both in laboratory conditions and during flight tests on NASA's PC-12 aircraft, demonstrating reliable performance under disrupted and delayed communication links. Designed for integration into space suits as a portable DTN node, the platform supports future expansion to multi-sensor physiological monitoring. This approach combines biomedical telemetry, DTN, and optical communication to advance astronaut safety and space missions success.

Tuesday, April 21 10:10 - 11:50

SW7b 4-CAD: Advancing Over-The-Air Testing in Vehicular Communications and Automotive Radar Sensing

/ / Antennas
Room: Madrid

Thomas Dallmann
Vittorio Degli Esposti
Ainur Ziganshin
Thomas Kürner
Maik Weber
Renato Zea Vintimilla
Matthias Hein
Isabella Varga
Sonakshi Gupta
Muhammad Luqman Nazar
Lukas Ostendorf

Today, safe operation of road traffic relies solely on humans. At the advent of Connected and Automated Driving (CAD), as technology takes over control of vehicles and traffic, testing plays a central role to ensure safety and reliability of such systems. Suitable verification and validation methods have to go beyond software by providing in-the-loop and over-the-air testing on component and system level. In recent years, researchers from TU Braunschweig, TU Ilmenau and RWTH Aachen have worked on these procedures for V2X communications and automotive radars. Within this workshop, we demonstrate results and draw our vision of a unified CAD testbed.

Workshop outline: The workshop will present the results of a DFG package application project consisting of two sub-projects. It is divided into topical blocks addressing EM simulations, OTA channel emulation, and OTA radar target emulation. We will explain our emulation workflows as well as the software and hardware systems developed for this purpose. We will also report on the validation of our systems via measurements. The collaboration between the two subprojects has revealed interesting connections between communications and sensor testing, which we will highlight. Finally, we will present our ideas for combining the two validation methods in a single testbed.

08:00 - 08:15 Thomas Dallmann 4CAD - What for?
08:15 - 08:35 Vittorio Degli Esposti Advanced ray tracing modelling and applications
08:35 - 08:50 Ainur Ziganshin Ray-Based Simulation of Scattering from Discretized Curved Bodies
08:50 - 09:05 Thomas Kürner Multi-stage Over-the-Air Testbed for dynamic V2X scenarios
09:05 - 09:15 Maik Weber Realistic Performance Evaluation of NR-V2X in Urban Scenario Using Ray Tracing and ns-3
09:15 - 09:25 Maik Weber Insights into Software Defined Radio-Based Channel Emulation
09:25 - 09:40 Renato Zea Vintimilla Emulation of a V2X communication link using Over-the-Air (OTA) Testing
10:10 - 10:25 Matthias Hein Over-the-air vehicle-in-the-loop testing: Method and its application to automotive radar
10:25 - 10:35 Isabella Varga Data-driven radar target modelling
10:35 - 10:50 Sonakshi Gupta Environmental Modeling for Radar Verification and Validation
10:50 - 11:00 Muhammad Luqman Nazar Ground reference benchmarking for scenario-based virtual verification and validation
11:00 - 11:15 Lukas Ostendorf Automotive Data Collection for Development and Testing
11:15 - 11:25 Lukas Ostendorf Joint Scenarios for V2X and Radar
11:25 - 11:50 Thomas Dallmann 4CAD - What next?

BIOGRAPHIES: Thomas Dallmann received the Dipl.-Ing. degree in electrical engineering from RWTH Aachen University, Germany in 2010 and the Dr.-Ing. degree from RWTH Aachen University in 2017. From 2016 to 2022, he was with the Fraunhofer-Institute for High Frequency Physics and Radar Techniques FHR, Wachtberg, Germany and lead the Research Group Aachen in Aachen. He is currently Junior Professor at Technische Universität Ilmenau, Germany and responsible for the Radio Technologies for Automated and Connected Vehicles Research Group and Electronic Measurements and Signal Processing Group. His research is concerned with joint communication and radar sensing networks and virtual validation of automotive radars.
Thomas Kürner (Fellow IEEE) received his Dipl.-Ing. degree in Electrical Engineering in 1990, and his Dr.-Ing. degree in 1993, from University of Karlsruhe (Germany). From 1994 to 2003, he was with the radio network planning department at the headquarters of the cellular operator EPlus Mobilfunk GmbH & Co KG, Düsseldorf. Since 2003, he is Full University Professor for Mobile Radio Systems at Technische Universität Braunschweig. In 2012, he was a guest lecturer at Dublin City University within the Telecommunications Graduate Initiative in Ireland. Currently he is chairing the IEEE 802.15 Standing Committee THz and the ETSI Industrial Specification Group THz.
Vittorio Degli-Esposti is Full Professor with the Department of Electrical, Electronic and Information Engineering "G. Marconi" (DEI) of the University of Bologna. He teaches courses on Electromagnetic Fields, Propagation for Wireless Systems and Vehicular Radio Propagation. He is IEEE Senior Member and Editor of the IEEE Transactions on Vehicular Technology. He has been Vice Chair of EuCAP2010 and EuCAP2011, Chair of URSI EMTS2025 and Director of Research in 2015 and 2016 of Polaris Wireless Inc., California, USA. He received the "EurAAP Propagation Award 2023" and is author or co-author of 7 patents and more than 160 peer-reviewed technical papers.
Prof. Dr. Matthias A. Hein joined the TU Ilmenau in 2002 as head of the RF and Microwave Research Laboratory. He has founded the multi-purpose automotive antenna test range "VISTA - Virtual road simulation and test area" at the Thuringian Center of Innovation in Mobility. His research focuses on antennas and microwaves, wave propagation, and over-the-air testing. He has co/authored over 700 publications and talks, supervised 48 doctoral and 102 Master projects. His research has attracted a cumulative funding of nearly 25 MEUR. Since 2021, Matthias Hein is the Director of the Thuringian Center of Innovation in Mobility at TU Ilmenau.
Ainur Ziganshin received the B.E. degree from the Kazan National Research Technical University in 2020, the M.Sc. degree from the Technische Universität Ilmenau in 2023. He is currently pursuing his Ph.D. degree at the Technische Universität Ilmenau. His research interests include channel measurement data analysis, stochastic and deterministic channel modeling for ISAC, ray tracing for radiowave propagation, and object scattering.
Maik Weber was born in Vechta, Germany, in 2001. He received the B.Sc. and M.Sc. degrees in Computer and Communication Systems Engineering from Technische Universität Braunschweig, Braunschweig, Germany, in 2023 and 2025, respectively. In February 2025, he joined the Institute for Communications Technology at Technische Universität Braunschweig, where he is currently working toward the Ph.D. degree. His research interests include software defined radio-based wireless channel measurements and characterization with focus on sub-6 GHz applications.
Renato Zea Vintimilla received the MSc. degree in communications and multimedia engineering from the Friedrich-Alexander-Universität Erlangen-Nürnberg in Germany in 2016 respectively. Since 2018 he works as researcher for Fraunhofer IIS and Technische Universität Ilmenau in the development of testing techniques for wireless devices, particularly in the Over-the-Air testing method applied to GNSS devices. His research interests include signal processing, wireless communications and GNSS measurements.
Isabella Varga received the B.Sc. and M.Sc. degrees in electrical engineering and information technology from Technische Universität Ilmenau, Ilmenau, Germany, in 2021 and 2023, respectively. She is a research scientist pursuing her doctoral degree in the RF and Microwave Research Group at the Thuringian Center of Innovation in Mobility working in the field of radar technologies for automotive applications. Her current research focuses on radar signatures of extended targets based on reflectivity measurements, including modelling, calibration techniques and signal processing.
Sonakshi Gupta earned her Bachelor of Technology in Electronics and Communication Engineering from Guru Nanak Dev University, Amritsar, India, in 2018 and her Master of Science in Communication and Signal Processing from Technische Universität Ilmenau in 2022. She is currently a Research Scientist in the Radio Technologies for Automated and Connected Vehicles group at the Thüringer Innovationszentrum Mobilität (ThIMo). Her work focuses on statistical modelling, advanced driver-assistance sensor validation, and sensor virtualisation for simulation and testing environments.
Muhammad Luqman Nazar received his BSEE from University of Engineering and Technology (UET), Taxila in 2011 and MSEE from National University of Sciences and Technology (NUST), Islamabad in 2022. He is currently working as a Research Associate at Technische Universität Ilmenau, Germany. He is engaged in Virtual Verification and Validation (VVV) of Automotive Radars at Thuringian Centre of Innovation in Mobility (ThIMO). He is pushing boundaries for advanced scenario description and improving degree of realism in Over-the-air Vehicle-in-the-loop (OTA-VIL) test systems.
Lukas Ostendorf is a doctoral researcher at the Institute for Automotive Engineering at RWTH Aachen University, focusing on Vehicle Intelligence and Automated Driving. He previously earned a master's degree in Automation Engineering and a bachelor's degree in Mechanical Engineering at RWTH Aachen. His research centers on automated driving perception, with emphasis on multimodal sensing and 4D radar. In the 4-CAD project, he works on 4D-radar-based object detection, datasets, and evaluation metrics. His goal is to develop robust perception algorithms that leverage different kind of sensor information to enhance sensor fusion, environmental understanding, and the safety of automated vehicles.

Tuesday, April 21 10:10 - 11:50

SW3b Recent Advancements and Applications for Antenna Arrays and Systems (IEEE AP-S Technical Committee 2 "Array")

/ / Antennas

Room: The Hague

Dr. Diane Titz (Université Côte d'Azur)
Prof. Yong-Mei Pan (South China University of Technology)
Prof. Mauro Ettorre (Michigan State University)
Prof. Takashi Tomura (Institute of Science Tokyo)
Prof. Tian Hong Loh (UK National Physical Laboratory)
Dr. Martijn de Kok (Eindhoven University of Technology)
Prof. Zhi-Hao Jiang (Southeast University, China)
Prof. Oscar Quevedo-Teruel (KTH Royal Institute of Technology)

In the scope of the IEEE Antennas and Propagation Society (AP-S) Technical Committee 2: "Arrays" (TC-2) is responsible for monitoring and advancing the latest developments and trends in antenna array and system technologies. This scientific workshop aims at sharing and discussing the latest advancements and applications for antennas arrays and systems for enabling emerging radio technologies for 5G and beyond. The workshop will serve as a valuable platform for knowledge exchange and networking and is envisaged to gather experts and researchers in the proposed field from all around the world to present, discuss and showcase their latest innovative research in antenna arrays, and next-generation antenna systems.
In the scope of the IEEE Antennas and Propagation Society (AP-S) Technical Committee 2: "Arrays" (TC-2) is responsible for monitoring and advancing the latest developments and trends in antenna array and system technologies. This scientific workshop aims at sharing and discussing the latest advancements and applications for antennas arrays and systems for enabling emerging radio technologies for 5G and beyond. The workshop will serve as a valuable platform for knowledge exchange and networking and is envisaged to gather experts and researchers in the proposed field from all around the world to present, discuss and showcase their latest innovative research in antenna arrays, and next-generation antenna systems.

08:00 - 08:05 Dr. Diane Titz (Université Côte d'Azur) / Prof. Tian Hong Loh (National Physical Laboratory) Welcome and Workshop Scope

08:05 - 08:35 Prof. Yong-Mei Pan (South China University of Technology) Design of Wide-Angle Beam-Scanning Millimeter-Wave Dielectric Resonator Antenna Arrays
ABSTRACT: Dielectric Resonator Antennas (DRAs), composed primarily of dielectric material, offer high radiation efficiency in the mm-Wave band by eliminating conductor loss, making them ideal for mm-Wave systems. Complementing this, phased array technology enables rapid electronic beam steering, flexible shaping, and precise pointing through accurate amplitude and phase control, serving as a key enabler to overcome mm-Wave propagation bottlenecks. This report highlights our group's progress in wide-angle scanning DRA phased arrays. We propose a strategy that leverages dielectric resonant modes, ground plane image effects, and inter-element near-field coupling to broaden the element active pattern. This approach significantly expands the array's scanning range without introducing additional structural complexity.

08:35 - 08:55 Prof. Mauro Ettorre (Michigan State University) Non-dispersive Radiation: Concepts and Future Directions from Communications to High-Power Applications
ABSTRACT: The dispersive behavior of radiating systems significantly impacts the radiation of short pulses used in communication, sensing, and power transmission. This presentation will introduce fundamental concepts, outline limitations, and provide the metrics necessary for analyzing radiating systems. The aim is to clarify the scientific questions and obstacles related to the radiation of short pulses. Following this introduction, the presentation will discuss recent advancements addressing these challenges and offer innovative solutions for effectively radiating extremely short pulses with minimal dispersion.

08:55 - 09:15 Prof. Takashi Tomura (Institute of Science Tokyo) Origami Deployable Reflectarray Antennas for Small Satellites
ABSTRACT: 6G requires extended coverage over the air, sea, and space, in addition to ultra-high-speed communications and low latency. This talk presents origami deployable reflectarray antennas for small satellites. The antennas can be compactly stowed by origami fold patterns when onboard a rocket and deployed large in space. To further increase the functionality of the antennas, reconfigurable reflectarrays enable non-flatness compensation and beam steering.

09:15 - 09:35 Prof. Tian Hong Loh (UK National Physical Laboratory) A Metrological Millimetre-Wave Over-The-Air Test Platform Incorporating a Fully-Connected Hybrid Beamformer with a Large Antenna Array
ABSTRACT: Current efforts to develop cost-effective, energy-efficient wireless systems operating at millimeter-wave (mm-wave) frequencies with large-scale phased array antennas-driven by the high data-rate demands of future sixth-generation (6G) networks-have highlighted the need to explore the use of hybrid beamforming technologies. This talk presents a novel metrological mm-wave 5G new-radio MIMO testbed for radiated-two-stage (RTS) over-the-air (OTA) testing. The testbed features a highly reconfigurable fully connected hybrid beamformer with a large antenna array, a base station emulator, a channel emulator, and a user-programmable software-defined radio (SDR) platform. The evaluation of the RTS method is presented.

10:10 - 10:30 Dr. Martijn de Kok (Eindhoven University of Technology) Power Amplifier (PA)-Antenna Co-Design in Active Phased Array Antennas:
ABSTRACT: This presentation outlines a holistic co-design workflow for active phased arrays, integrating Power Amplifier (PA) load-pull modeling with antenna design using a custom simulation framework. The approach supports early stage design decisions and enables rapid optimization of the PA-antenna interface while accounting for finite-array effects and varying active reflection coefficients. A 16-element X-band array comprising Vivaldi antennas directly matched to gallium nitride (GaN)-based PAs is developed and realized to demonstrate the methodology. The presented co-design strategy offers a practical foundation for efficiently scalable and high-performance active array systems.

10:30 - 10:50 Prof. Zhi-Hao Jiang (Southeast University, China) Development of Reconfigurable Reflect-Arrays and Their Application for Beam-Steering Cassegrain Reflector Antennas
ABSTRACT: Reconfigurable arrays, realized by integrating RF switches into radiating or scattering elements, offer a new low-cost beamforming solution for communication and sensing applications. The first part of this report will focus on the design and experimental validation of Kaband reconfigurable reflect-arrays and transmit-arrays, including large-scale high-bit reconfigurable reflect-arrays, wideband dual-polarization reconfigurable reflect-arrays, and wideband dual-polarization reconfigurable transmit-arrays. In addition, the report will present the use of a reconfigurable reflect-array as the sub-reflector in an electrically large Cassegrain antenna to achieve two-dimensional electronic beam steering of its high-gain beam.

10:50 - 11:10 Prof. Oscar Quevedo-Teruel (KTH Royal Institute of Technology) Design Considerations for Array Radomes
ABSTRACT: Most of the practical implementations of arrays make use of a radome to protect the antennas from the environment. Consequently, radomes can have a negative influence in the performance of the array. Therefore, its analysis and design are crucial for the final implementation of most of the commercial arrays. In this talk, we will explain the practical considerations to take into account when an array is integrated with a radome. In addition, we will show how to fast simulate these radomes with ray-tracing techniques and physical optics. Finally, we will discuss on how to take advantage of the radome in our own benefit.

11:10 - 11:30 Dr. Diane Titz (Université Côte d'Azur) Antenna Systems for E-Band and Future Telecom Applications
ABSTRACT: 5GNR (Beyond 5G) and 6G wireless network access and backhaul as well as satellite telecommunications are targeting E-band (71 to 76 GHz and 81 to 86 GHz) and D-band (150 GHz) radio systems due to the wide available bandwidth the offer. This presentation will show several antenna and antenna-array designs within these bands manufactured using Digital Additive Manufacturing (DAM) techniques as well as High Density Interconnect (HDI) Planar Circuit Board (PCB). Part of this work has been done with the support of the European SHIFT (Sustainable, Technologies Enabling Future Telecom Applications) project.

11:30 - 11:50 Dr. Diane Titz / Prof. Tian Hong Loh / Prof. Yong-Mei Pan / Prof. Mauro Ettorre / Prof. Takashi Tomura / Prof. Zhi-Hao Jiang Panel Discussion

BIOGRAPHIES
Yong-Mei Pan (IEEE Fellow) is a full professor at the School of Electronics and Information, South China University of Technology, China. Her research focuses on dielectric resonator antennas, filtering antennas, MIMO antennas, and antenna-in-package, with over 150 SCI-indexed papers published and 12 US patents granted. Dr. Pan was awarded the IEEE Antennas and Propagation Society's Lot Shafai Mid-Career Distinguished Achievement Award in 2022, the Guangdong Province Science and Technology Award for Technological Invention (First Class) in 2020, and the Ministry of Education's Higher Education Scientific Research Outstanding Achievement Award for Natural Science (First Class) in 2016. Dr. Pan served as an Associate Editor for the IEEE Transactions on Antennas and Propagation (TAP) from August 2016 to October 2022, and she is currently a Track Editor of TAP.
Mauro Ettorre received a Laurea degree "summa cum laude" in Electrical Engineering and a Ph.D. degree in Electromagnetics from the University of Siena, Italy, in 2004 and 2008, respectively. Part of his Ph.D. work was developed at the TNO, the Netherlands. Since 2023, he has been a Professor at Michigan State University, East Lansing, USA. Previously, he was a Research Scientist at the CNRS, IETR laboratory in France. From 2014 until 2020, he co-led the multi-beam antenna activity for satellite applications in the joint laboratory between IETR and Thales Alenia Space, France. From 2016 until 2021, he led the mm and sub-mm waves team at IETR, and co-chaired from 2021 to 2023 the department ADH (Antennas and Microwave Devices Department) at IETR. Dr. Ettorre's research interests include the analysis and design of quasi-optical systems, periodic structures, wideband arrays, millimeter-wave antennas, non-diffractive radiation, and localized waves. He has authored over 97 journal papers and 250 conference communications and holds 14 patents (2 licensed) on millimeter-wave antenna technology. Dr. Ettorre is a Fellow of IEEE. From 2017 until 2023, he served as Associate Editor for the IEEE Transactions on Antennas and Propagation. Since 2023, he has served as Track Editor for the same journal. He currently serves as the Editor-in-Chief of the IEEE Antennas and Propagation Magazine. Dr. Ettorre is the 2024 IEEE MTT-S and AP-S Inter-Society Distinguished Lecturer. The research activities of Dr. Ettorre have been recognized with several prizes, including the 2009 French Ministry of Research award for the most innovative project in all natural sciences, the Young Investigator Award from the French National Research Agency in 2014, the Innovation Award at the 2018 ESA Antenna Workshop in the Netherlands, the Best Paper Award in Electromagnetics and Antenna Theory at EuCAP 2018, UK, the Best Antennas Paper Award at EuCAP 2021, Germany and Best Paper Award at the iWAT 2023, Denmark.
Takashi Tomura received his Ph.D. degree from Tokyo Institute of Technology, Japan. His doctoral research focused on the hybrid analysis of millimeter-wave broadband waveguide slot array antennas using the Method of Moments and the Finite Element Method. He previously worked at Mitsubishi Electric Corporation, where he was engaged in the research and development of reflector antennas for satellite payloads and ground station antennas for satellite communications. Since 2017, he has been with Tokyo Institute of Technology (now Institute of Science Tokyo), where he works on deployable origami-inspired antennas for small satellites and high-gain antennas and modules in the sub-terahertz frequency bands.
Tian Hong Loh (IEEE Fellow) is a Principal Scientist at the UK National Physical Laboratory (NPL) and the Science Area Leader for NPL's Electromagnetic Technologies Group. He leads a team of scientists undertaking ground-breaking measurement science research in support of the emerging electromagnetic technologies developments. He has edited one book, holds seven patents, authored, and co-authored over 240 refereed publications. He is currently President of the URSI UK Board, Chair of the EurAAP Measurement Working Group, Visiting Professor at the University of Surrey, UK, Representative of the IEEE APS at the IEEE FNTC, member of IEEE APS Standards Committee, IEEE TCAM and the IET, and senior member of IEEE and AMTA. His research interests include 5G/6G communications, MIMO antennas, smart antennas, small antennas, metamaterials, body-centric communications, wireless sensor networks, electromagnetic compatibility, and computational electromagnetics.
Martijn de Kok obtained his Bachelor, Master and PhD degrees Electrical Engineering (all cum laude) from Eindhoven University of Technology in The Netherlands. His PhD thesis, defended in 2025, was titled 'Active Phased Array Antenna Systems for Next-Generation Radars: Co-design, Integration, and Scalability.' In 2019 he was a visiting student at the Advanced RF & Optical Technologies group of the NASA Jet Propulsion Laboratory. In 2021 he became a guest researcher at the Radar Technology department of TNO Defense, Safety and Security in The Hague. In 2025 he joined TNO as a Scientist focusing on phased-arrays and high-power antenna systems for applications including large-scale radars and space. Dr. de Kok received the Best Antenna Theory and Design Paper Award at the 2025 EuCAP conference, and the 2025 Veder-prize for his contributions to Dutch radio science in that year.
Zhi Hao Jiang received the Ph.D. degree from The Pennsylvania State University, in 2013, and is currently a Professor with the State Key Laboratory of Millimeter Waves, Southeast University. He has published 3 books and more than 150 papers in peer-reviewed journals, and holds 12 granted U.S. patents and 30 granted Chinese patents. He was a committee member of the IEEE AP-S NTDC (2022 - 2024), serves as the Associate Editor of IEEE Transactions on Antennas and Propagation and as a committee member of IEEE AP-S TC-2 and IEEE MTT-S CEC, and has served as the TPC Co-Chair for multiple international conferences. He was a recipient of the Outstanding Youth Scholar of NSFC in 2021, the IEEE Microwave Prize in 2021, the Young Scientist Award at URSI-GASS 2020 and ACES-China 2019. His current research interests include millimeter-wave antennas and circuits, impedance surfaces, and analytical methods.
Oscar Quevedo-Teruel received his Telecommunication Engineering and Ph.D. Degrees from Carlos III University of Madrid, Spain in 2005 and 2010. In 2014, he joined the KTH Royal Institute of Technology (Stockholm, Sweden), where he is presently a Full Professor in the Department of Communication Systems in the School of Electrical Engineering and Computer Science. He is also the responsible for the Antenna Laboratory and Director of the Master Programme in Electromagnetics Fusion and Space Engineering. He was a distinguished lecturer of the IEEE Antennas and Propagation Society for the period of 2019-2022. He is an IEEE Fellow for his contributions to glide symmetry based metasurfaces and lens antennas. He has been a member of the EurAAP Board of Directors since January 2021. Since January 2022, he is presently the EurAAP vicechair. He was an Associate Editor of the IEEE Transactions on Antennas and Propagation since 2018-2022, and he acts as Track Editor in IEEE TAP since 2022. He is the founder and editor-in-chief of the EurAAP journal Reviews of Electromagnetics since 2020. He has made scientific contributions to periodic structures with higher symmetries, lens antennas, metasurfaces, physical optics and ray tracing. He is the co-author of more than 160 papers in international journals and more than 250 at international conferences.
Diane Titz (SMIEEE) received her Master degree from Paris-Saclay University in 2009 and her Ph.D degree from University of Côte d'Azur, France, in 2012. Since then, she is been as associate researcher with the Polytech'Lab at the University of Côte d'Azur, while teaching physics and chemistry to future engineering students. Her research interest include millimeter-wave to terahertz applications through the design of antennas, lens and their measurement. She has coauthored three book chapters and more than 80 publications. She was the recipient of the 2018 Lot Shafai mid-career distinguished achievement award. She also serves as an associate editor for the IEEE TAP and is a committee member of AP-S TC2.

Tuesday, April 21 10:10 - 11:50

SW8b Recent Advancements and Applications for Antenna Arrays and Systems (IEEE AP-S Technical Committee 2 "Array")

/ / Antennas

Room: Glasgow

A. Lavrenko (UTwente)
M. Polivka (Czech Technical University in Prague)
A. Austin (University of Bristol)
V. Palazzi (University of Perugia)
C. Li (Texas Tech University)
G. Marrocco (University of Rome Tor Vergata)

Nonlinear mechanisms are reshaping the landscape of passive wireless technologies from classical RFID to emerging harmonic and intermodulation backscatter-based sensors that operate without batteries or active components. These systems underpin a new generation of wireless sensing and IoT applications, enabling identification, localization, and environmental monitoring with ultra-low-power hardware. Antenna design is central to their performance: it governs energy transfer, harmonic generation, polarization behavior, impedance interaction, and system efficiency under varying, and sometimes extreme, constraints of size, bandwidth, and operating conditions. This workshop gathers researchers from antennas, microwave engineering, and applied sensing to discuss design, modeling, and integration challenges for antennas in nonlinear and passive wireless systems bridging communities in RFID, harmonic radar, chipless sensing, and sustainable IoT.

Workshop outline: The half-day workshop will comprise two 1h40 sessions combining invited technical presentations, a keynote talk, and a concluding round-table discussion. The first session will address the fundamentals of modeling and design of antennas for nonlinear passive wireless systems, featuring invited speakers from leading research groups. The second session will highlight integration, fabrication, and application examples across RFID, wireless sensing, and IoT domains. The workshop will conclude with an interactive round-table inviting end-users from applied fields to share their perspectives on current challenges, practical constraints, and emerging opportunities for antenna design for nonlinear technologies.

Session 1: Foundations and Antenna Design Perspectives
08:00 - 08:10 A. Lavrenko (UTwente) Welcome and Workshop Scope
08:10 - 08:35 M. Polivka (Czech Technical University in Prague) Wearable Patch-Type Harmonic Tags: Step-by-Step Design Considerations
08:35 - 09:00 A. Austin (University of Bristol) Conversion Efficiency Is Not a Number: 3D Pattern Measurements for Harmonic Tags
09:00 - 09:25 A. Lavrenko (UTwente) To Match or Not to Match: Antenna Design Requirements and Constraints in Compact Harmonic Transponders
09:25 - 09:40 All Discussion / Q&A

Session 2: Materials, Fabrication, and System-Level Perspective 10:10 - 10:35 V. Palazzi (University of Perugia) Design of Passive Wireless Sensors Using Harmonic Transponders: Architectures, Challenges and Technological Outlook
10:35 - 10:55 C. Li (Texas Tech University) Printable Nonlinear Tags and Handheld Devices for Clutter-Resilient Contactless Monitoring and Tracking
10:55 - 11:20 G. Marrocco (University of Rome Tor Vergata) The Laser-Induced Graphene Technology for Sustainable Radiofrequency Identification and Sensing
11:20 - 11:40 All Round-Table Discussion: What's Next for Antenna Design in Nonlinear Transponder Systems?
11:40 - 11:50 A. Lavrenko (UTwente) Wrap-Up and Outlook

Dr. Milan Polivka is an Associate Professor at the Czech Technical University in Prague, specializing in advanced antenna systems, nonlinear backscatter transponders, and RF measurement techniques. He is internationally recognized for his contributions to harmonic and intermodulation tag design, including dual-band antenna architectures, characterization of nonlinear scattering mechanisms, and precision link-budget modelling for passive transponder systems. Dr. Polivka leads several research activities on nonlinear tag metrology, compact sensing antennas, and EMC-related measurements, and has co-authored numerous journal and conference papers in these areas. His group is among the leading European teams advancing nonlinear tag antennas and their practical evaluation.
Prof. Valentina Palazzi is an Associate Professor at the University of Perugia, Italy, with research interests spanning RFID systems, chipless and harmonic transponders, and passive wireless sensors. She is widely recognized for her work on antenna-circuit co-design, dual-band and nonlinear tag architectures, and electromagnetic modelling of passive sensing platforms. Her contributions include innovative chipless sensing schemes, compact tag antennas for low-power applications, and analytical methods for characterising nonlinear backscatter mechanisms. Prof. Palazzi has published extensively in leading RF and antenna journals and plays an active role in the European RFID and wireless sensing research community.
Prof. Changzhi Li is a Professor of Electrical and Computer Engineering at Texas Tech University, internationally recognized for pioneering contributions to noncontact RF sensing, nonlinear radar, and harmonic signal processing. His research focuses on Doppler and harmonic radar architectures, nonlinear transceiver design, and high-sensitivity motion and vital-sign detection using low-power microwave systems. Prof. Li ha published extensively in IEEE Transactions, delivered numerous invited talks and tutorials, and his work has strongly influenced emerging applications in biomedical sensing, smart environments, and low-power IoT. He is a Fellow of the IEEE and a leading figure in advanced nonlinear RF sensing technologies.
ABSTRACTS: Wearable Patch-Type Harmonic Tags: Step-by-Step Design Considerations: This contribution presents a step-by-step methodology for designing wearable patch-type harmonic tags, with an emphasis on efficient harmonic generation, and a compact design. The choice of diode is determined based on the selected operating frequencies. An analytical model is used to identify the level of incident power at which these losses are minimal. A dual-band, differentially fed, dual-quarter-wave patch antenna topology is selected, which provides broadside radiation, and self-resonant operation without the need for external matching circuits. Impedance matching is further improved by the use of tuning slots, whose effect on resonance tuning is investigated. Finally, selected prototypes are experimentally characterized, demonstrating achievable performance in terms of conversion efficiency, and robustness in wearable scenarios.
Conversion Efficiency Is Not a Number: 3D Pattern Measurements for Harmonic Tags
The radiation efficiency of harmonic radar tags is typically measured and reported at a single incidence angle. However, the radiation efficiency is a three dimensional (re-)radiation pattern. In this presentation, the setup for three dimensional measurements of harmonic radar tags operating at 9/18 GHz will be presented, along with experimental results, interpretation, and future improvements. To Match or Not to Match: Antenna Design Requirements and Constraints in Compact Harmonic Transponders The design of compact harmonic transponders introduces unique challenges that go beyond conventional antenna matching paradigms. In these systems, the antenna must be co-designed with the nonlinear element, where impedance matching, radiation efficiency, and conversion efficiency are tightly interdependent. This talk revisits the role of matching in harmonic transponders, questioning when traditional approaches remain valid and when they become limiting. Emphasis is placed on practical design constraints arising from miniaturization, low-power operation, and integration. Through representative examples, the talk highlights key trade-offs and proposes guidelines for antenna-nonlinearity co-design in next-generation passive sensing systems.

Design of Passive Wireless Sensors Using Harmonic Transponders: Architectures, Challenges and Technological Outlook This talk will describe some of the most recent design strategies both at component and system level to develop energy-autonomous harmonic transponders with sensing capabilities, while maximizing the read range of the transponders. Practical examples with a case study related to automotive applications will be shown as well. This talk will also focus on the open challenges of this field and will highlight some promising technologies for future advancements in the field.
Printable Nonlinear Tags and Handheld Devices for Clutter-Resilient Contactless Monitoring and Tracking This talk presents printable, battery-free nonlinear tags and compact harmonic radar systems for clutter-resilient, contactless sensing and tracking. Operating at 4-8 GHz and 8-16 GHz, the systems exploit second-harmonic generation from diode-based printed tags to suppress linear reflections and enable reliable detection in complex environments. Scalable fabrication methods, including inkjet printing on flexible substrates, produce lightweight, conformal tags. Two compact high-linearity radar platforms ensure strong harmonic isolation and sensitivity. Demonstrations include accurate, noninvasive respiratory monitoring and object localization, establishing a scalable approach for healthcare, tracking, and nonlinear IoT sensing applications. The Laser-Induced Graphene Technology for Sustainable Radiofrequency Identification and Sensing This talk discusses nonlinear RFID transponders as a new frontier in antenna-enabled wireless systems, where the backscattered response is governed not only by tag geometry, but also by chip dynamics, mutual coupling, interrogation power, and material imperfections. Within this perspective, self-tuning chips enable environment-aware sensing, interacting transponders reveal equilibrium phenomena, and power-dependent responses generate distinctive electromagnetic signatures for physical unclonable functions. Additional nonlinear features may arise from imperfect graphene-based materials, further enriching the transponder behavior. The overall picture shows how nonlinear backscatter can extend RFID well beyond identification, opening new directions toward sensing, authentication, and physics-inspired IoT devices.

Round-Table Discussion: What's Next for Antenna Design in Nonlinear Transponder Systems? This round-table will explore emerging directions and open challenges in antenna design for nonlinear and passive transponder systems. Moving beyond conventional matching and efficiencydriven approaches, the discussion will address how antennas can be co-designed with nonlinear elements, materials, and system architectures to enable robust operation in realistic environments. Topics include compact and wearable implementations, advanced fabrication techniques, measurement methodologies, and the role of antennas in shaping system-level performance. By bringing together perspectives from design, materials, and applications, the session aims to identify key research priorities and opportunities for the next generation of RFID, sensing, and IoT systems.

Tuesday, April 21 10:10 - 11:50

IW4 Industrial Workshop - ARRAY - Purpose-Built Software For Phased Arrays, 5G/6G Base Stations, and AESA Radar Systems (TICRA)

/ / Measurements

Room: Stockholm

Mark Whale and Pasquale Giuseppe Nicolaci (TICRA)

ARRAY is the latest addition to TICRA Tools, the powerful suite of electromagnetic solvers developed by TICRA, dedicated to the design, analysis, and optimisation of phased array antennas. Recognising that the needs of the antenna designer in fields such as telecoms, defence, astronomy, and earth observation were not being fulfilled by general purpose EM solvers, TICRA has developed ARRAY with the end-user in focus. This workshop will showcase the capabilities of ARRAY, providing engaging examples taking the audience through a typical design chain to a completed array antenna, including aspects of optimisation. Our motivation is to highlight this new solver and exchange with tomorrow's antenna designers.

Workshop Outline: The workshop will follow a presentation format and will have the following agenda:

An introduction to TICRA and TICRA products
Description of ARRAY and capabilities
Array Generator and rapid array creation and layout
Demonstration of the new CAD Editor
Simulation models
Infinite array simulation
Full-wave methods for finite arrays
Optimisation capabilities
Application cases and real-world examples
Q&A

Mark Whale is part of the Applied Electromagnetics team where he works on R&D, analysis, and design of antennas for space and ground applications. Prior to joining TICRA, he worked at Ericsson AB, as well as on postdoctoral research projects at the University of Bern, Switzerland, and the Chalmers University of Technology, Gothenburg. Mark received his PhD in Physics from the National University of Ireland, Maynooth, in 2010.
Pasquale Giuseppe Nicolaci joined TICRA in 2021, and he is part of the AEM team, where he is involved in the development of R&D projects for space and ground segment antennas, customer technical support, and consultancy services in the antenna design domain. Before joining TICRA, Pasquale worked for AIRBUS Italy, where he gained experience in the design, manufacturing, and testing of active and passive antennas. Pasquale received his PhD in Information Engineering from Università Mediterranea of Reggio Calabria in April 2019.

Tuesday, April 21 10:10 - 11:50

IW2 Industrial Workshop - Antenna Integration and Compliance Strategies for Industrial LTE and 5G Routers (Westerno)

/ / Antennas

Room: Davos

Dr. Samaneh Sadeghi-Marasht, Westerno

Westermo industrial cellular routers integrate LTE and 5G radio modules operating across defined frequency bands, requiring antennas with precise electrical and mechanical characteristics. Key metrics include low return loss (S11), high gain, radiation efficiency, and multiband support. For 5G, MIMO configurations add complexity in design and placement. Our work shares Westermo's applied experience in antenna selection, integration, and compliance for industrial wireless systems. We present testing methodologies addressing EMC (emissions and immunity), radio certification across multiple bands, and challenges introduced by hardware changes impacting interference profiles. These insights aim to guide robust antenna-router integration strategies for reliable connectivity in mission-critical industrial environments.

Workshop Outline: This industrial workshop will be led by Dr. Samaneh Sadeghi-Marasht and will feature a keynote presentation on antenna requirements for industrial cellular routers. The program will include technical sessions covering three key areas: criteria for selecting antennas for LTE/5G routers, EMC testing for antenna performance validation, and design requirements for industrial applications. Each session will combine practical insights with applied methodologies, followed by interactive Q&A segments to encourage discussion. The workshop aims to provide participants with actionable strategies for robust antenna integration and compliance in mission-critical environments.

Dr. Samaneh Sadeghi-Marasht is an Approval Manager based in Dublin, Ireland. She earned her PhD from University College Dublin (UCD), where her research focused on RF systems and advanced antenna design for 5G applications. Dr. Sadeghi-Marasht has expertise in RF technologies, particularly in designing and optimizing high-performance antennas. She previously worked as an RF engineer and now works as an Approval Manager, ensuring that products comply with various wireless network standards.

Tuesday, April 21 10:10 - 11:50

IEEE **IEEE P3720 Working Group**

Room: Lisbon

Working Group meeting for IEEE P3720: Recommended Practice for Electromagnetic Measurements Using Reverberation Chambers. People interested to contribute to the WG are welcome to join the meeting.

Tuesday, April 21 12:00 - 12:40

IN01 Lars Jacob Foged - Plane Wave Generator Testing: Emerging Frontiers in Antenna and System Measurements

/ / Measurements
Chair: Carlo Rizzo
Lars Jacob Foged received his M.Sc. in Electrical Engineering from the California Institute of Technology in 1990. He is currently Vice President of Research and Development at Microwave Vision Group (MVG). He is a Fellow and Past President of the Antenna Measurement Techniques Association (AMTA) and received the AMTA Distinguished Achievement Award in 2017. Lars currently serves as Chair of the Antenna Standards Committee (ASC) of the IEEE Antennas and Propagation Society (AP-S). His involvement in the IEEE community also includes serving as Chair of the Industry Initiatives Committee (IIC) from 2016 to 2017 and contributing to the New Technology Directions Committee (NTDC). His efforts in bridging research and industry were recognized with the IEEE AP-S Industrial Innovation Award in 2023. He served as Vice-Chair of the European Conference on Antennas and Propagation (EuCAP) in 2011 and 2022, and as Chair of the EurAAP Working Group on Antenna Measurements from 2009 to 2012. Since 2006, he has been an active contributor to the European School of Antennas (ESoA), where he serves as lecturer, course organizer, and board member. Lars has authored two books and numerous peer-reviewed publications on antenna measurement techniques. His research has been recognized with Best Technical Paper Awards at AMTA (2013) and EuCAP (2021).
Room: Edinburgh

12:00 Plane Wave Generator Testing: Emerging Frontiers in Antenna and System Measurements

Lars Foged (Microwave Vision Italy, Italy)
The Plane Wave Generator (PWG) concept has been utilized in antenna and device testing for more than four decades. In recent years, it has gained renewed attention as a powerful alternative for the evaluation of antennas and integrated systems, particularly at lower frequencies where conventional Compact Antenna Test Range (CATR) and direct far-field measurement methods become impractical or cost-prohibitive. This paper provides an overview of PWG technology and revisits its historical evolution, highlighting representative implementations spanning frequency ranges from the VHF/UHF bands to millimeter-wave frequencies.

Tuesday, April 21 12:00 - 12:40

IN02 Richard W. Ziolkowski - Multipole Engineering: A Practical Approach to Compact, High Directivity Antennas

/ / Antennas
Chair: Samuel Arslanagic

Richard W. Ziolkowski received the B. Sc. (magna cum laude) degree (Hons.) in physics from Brown University, Providence, RI, USA, in 1974; the M.S. and Ph.D. degrees in physics from the University of Illinois at Urbana-Champaign, Urbana, IL, USA, in 1975 and 1980, respectively; and an Honorary Doctorate degree from the Technical University of Denmark (DTU), Kongens Lyngby, Denmark in 2012. He is currently a Professor Emeritus with the Department of Electrical and Computer Engineering at The University of Arizona, Tucson, AZ, USA. He was a Litton Industries John M. Leonis Distinguished Professor in the College of Engineering and was also a Professor in the College of Optical Sciences until his retirement in 2018.
He was also a Distinguished Professor in the Global Big Data Technologies Centre in the Faculty of Engineering and Information Technologies (FEIT) at the University of Technology Sydney, Ultimo NSW Australia from 2016 until 2023. He was the Computational Electronics and Electromagnetics Thrust Area Leader with the Engineering Research Division of the Lawrence Livermore National Laboratory before joining The University of Arizona in 1990. Prof. Ziolkowski was the recipient of the 2019 IEEE Electromagnetics Award (IEEE Technical Field Award). He is an IEEE Life Fellow, as well as a Fellow of OPTICA (previously the Optical Society of America, OSA) and the American Physical Society (APS). He was the 2014-2015 Fulbright Distinguished Chair in Advanced Science and Technology (sponsored by DSTO, the Australian Defence Science and Technology Organisation). He served as the President of the IEEE Antennas and Propagation Society (AP-S) in 2005 and has had many other AP-S leadership roles. He is also actively involved with the URSI (International Union of Radio Science) Commission B and the European Association on Antennas and Propagation (EurAAP).
Room: Berlin

12:00 Multipole Engineering: A Practical Approach to Compact, High Directivity Antennas

Richard W Ziolkowski (University of Arizona,USA)
A recent successful strategy to achieve superdirective performance has been to exploit mixtures of electric and magnetic multipoles. This multipole engineering paradigm has yielded unidirectional mixed-multipole antennas (MMAs) consisting of combinations of nearfield resonant parasitic (NFRP) elements that are excited by simple driven dipoles. Subsequently, highly efficient, superdirective uniform circular arrays of unidirectional MMAs and MMA-excited multilayered-spherical dielectric lens antennas have also been realized. The practical realizations of these basic and combined systems address concerns of efficiency, bandwidth, and fabrication/assembly tolerances. Superdirective endfire and broadside-radiating systems have been demonstrated. My presentation will share many of these superdirective exemplars highlighting their interesting radiated field properties and realizations.

Tuesday, April 21 12:40 - 13:30

WG2 EurAAP Working Group on Propagation (lunchtime meeting)

Room: Dusseldorf

Tuesday, April 21 12:40 - 13:30

WG1 EurAAP Working Group on Measurements (lunchtime meeting)

Room: Firenze

Tuesday, April 21 12:40 - 13:30

WG8 EurAAP Working Group on Measurements (lunchtime meeting)

Room: Madrid

Tuesday, April 21 13:30 - 14:40

P1-A01 Active and passive arrays

T08 Fundamental research and emerging technologies/processes / / Antennas
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)
Room: Poster Level 3

3.01 A Multi-Layer High-Gain 1x4 Antenna Array for Millimeter Wave Application

Asrin Piroutiniya (Universidad Carlos III de Madrid, Spain); Muhsin Ali (LeapWave Technologies, Spain); Ashish Kumar (Universidad Carlos III de Madrid, Spain); Alejandro Rivera-Lavado (LeapWave Technologies, Spain); Enderson Falcón-Gómez (University Carlos III of Madrid, Spain); Miguel Sanchez Rodas and Guillermo Carpintero (Universidad Carlos III de Madrid, Spain)

A high-gain, 1×4 antenna array for millimeter-wave applications is presented. The frequency bandwidth of the antenna is from 70 GHz to 85 GHz, which covers the E-band, with a maximum gain of 17 dB at 73 GHz. The proposed antenna is a two-layer structure utilizing Rogers 3203 as the substrate. A proximity-coupled feeding technique is employed to excite the radiating patches, while the input interface consists of a grounded coplanar waveguide (GCPW), which can be ribbon-bonded to a signal source chip. The finalized antenna PCB and aluminum housing were successfully fabricated. Single-element characterization was performed using a ground-signal-ground (GSG) probe measurement to validate the antenna performance. The measured return loss and E-plane radiation characteristics of the fabricated prototype confirm the performance of the antenna array and are in close agreement with the corresponding full-wave simulation results,
confirming the accuracy of the proposed design.

3.02 Phase-Only Synthesis of Pencil Beams by Incorporating Embedded Element Patterns

Katarina Vodvarka (University of Zagreb, Croatia); Mladen Vucic and Maja Jurisic Bellotti (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)

The performances of real-world antenna arrays are highly influenced by mutual coupling effects. Therefore, a design that takes into account these effects is highly desirable. In this context, we present optimization problems for phase-only synthesis of pencil beams, assuming the mutual coupling effects and the element radiation patterns are known in the form of embedded element patterns. For solving these problems, we utilize sequential quadratic programming. We illustrate the proposed approach through the design of arrays with dipole and patch elements. We consider forming pencil beams without and with null regions, having specified coefficients' magnitudes and arbitrary or even-symmetric phases.

3.03 Design of a Communication System for Environmental Data Collection Installed on a Vessel

Pedro H. A. Everling (Universidade Federal do Pampa, Brazil); Juner M Vieira (Universidade Federal Do Pampa (Unipampa), Brazil); Edson R. Schlosser and Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil)

This paper presents the development of antennas operating at 915 MHz for transmitting environmental monitoring data from a vessel to an user ground terminal (UT). A four-monopole array is analyzed to improve the communication link in comparison to the use of a single antenna. The array is fed by a 4 x 4 Butler matrix, hence allowing beam switching. Since the vessel has an electrical size of approximately 59λ0, the SBR+ solver available in ANSYS HFSS was applied to assess the installed performance. The results indicate that the single monopole maintains an omnidirectional pattern with gain of 2.68 dBi, whilst the four-monopole array allows achieving maximum gain between 8 and 10 dBi. The Butler matrix has been designed on a printed circuit board with dimensions 60 x 118 mm, with maximum measured phase and magnitude unbalances of 5° and 0.7 dB, respectively.

3.04 *A Compact Broadband and Wide-Angle Scanning Dielectric Rod Phased Array Antenna with High Aperture Efficiency*

Tong Xu (Harbin Institute of Technology, China); Yongming Cai (Fujian Provincial Institute of Architectural Design and Research Co., Ltd., China); Shu Lin (Haerbin Institude of Technology, China); LiBo Wang (Harbin Insititute of Technology, China); Xinyue Zhang (University College Dublin, Ireland); Xingqi Zhang (University of Alberta, Canada)

To achieve beam scanning characteristics under space-constrained conditions, this paper proposes a compact broadband and wide-angle beam-scanning phased array antenna with a high aperture coefficient. First, a dielectric rod antenna element is designed, achieving a peak gain of 9.5 dBi within the operating band. Through structural design, the radiation pattern of the antenna element exhibits identical beamwidths in both the E-plane and H-plane. The antenna achieves an aperture efficiency of 810%, enabling high-gain radiation characteristics within a compact aperture. Its operating principle is elucidated through analysis of the electric field distribution. At the center frequency, this phased array antenna delivers a peak gain of 15.8 dBi. It supports beam scanning within ±50° across the 5.2-7.2 GHz, with gain drop controlled within 3 dB. This phased antenna holds significant application potential for space-constrained platforms such as unmanned aerial vehicles (UAVs).

3.05 *A Low-RCS Phased Array Antenna with 4×4 Butler Matrix and Frequency Selective Rasorber*

Aishwarya Gupta (Indian Institute of Technology, Indore, India & Khandwa Road, Simrol, Indore, India); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain)); Saptarshi Ghosh (Indian Institute of Technology Indore, India)

This paper presents a low radar cross section (RCS) phased array antenna developed for secure 5G communication in the n79 band (4.7 GHz). A 4×4 Butler matrix is employed as a passive beamforming network, while a frequency selective rasorber (FSR) layer is introduced above the array configuration to suppress its out-of-band scattering response. The antenna array consists of 16 microstrip elements configured as a 1×4 linear super array of 2×2 subarrays, excited through a corporate powder divider to ensure uniform amplitude distribution. The Butler matrix generates four orthogonal beam states with consistent gain and accurate beam pointing across the operating band. The integration of the 3×10 FSR unit elements above the radiating surface significantly reduces monostatic RCS while maintaining high in-band transmission and stable radiation characteristics for different beam directions.

3.06 Digitally-Controlled Beam Steerable Patch Antenna for Vector Phased Array

Wen Dang, Long Qian, Noaman Nasser and Jin Zhang (Queen Mary University of London, United Kingdom (Great Britain)); Xiaodong Chen (Queen Mary, University of London, United Kingdom (Great Britain))

In this paper, a circular patch antenna with four independent ports is proposed to achieve wide-angle beam steering based on the Vector Phased Array (VPA) concept. Orthogonal capacitive gaps are introduced to adjust the operating frequency. Meanwhile, a comparable tuning effect can be realized by four groups of the shorting vias symmetrically connected to ground. By properly adjusting the input phase of each port through the digital beamformer, a steerable beam covering the upper halfspace can be achieved at 5.8 GHz. The proposed antenna achieves a maximum beam steering direction of approximately 24 ◦ far away from broadside, with a half-power beamwidth (HPBW) of 60.8 ◦ . The measured results show excellent agreement with simulations, confirming the feasibility of the proposed design. Therefore, the proposed antenna is a promising candidate for space-based solar power (SBSP) applications.

3.07 Determining Optimal Element Dimensions for a Beam Scannable Aperiodic Linear Array

Ramonika Sengupta (Eindhoven University of Technology, The Netherlands); Annie Cuyt (University of Antwerp, Belgium); David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands); Thomas Schäfer (Satcube, Sweden); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

A hybrid method combining exponential analysis and variable projection was recently introduced to reduce the number of elements in a uniform linear array while preserving its scan range. This work presents a simple extension to determine optimal element dimensions that maximize aperture filling and would thus improve the synthesized array's performance.

3.08 Analytical Synthesis of Flat-Top Radiation Patterns for Phased Arrays Based on Pencil Beam Flattening

Goran Molnar and Marko Matijaščić (Ericsson Nikola Tesla & Research and Development Centre, Croatia)

This paper presents an analytic method for the synthesis of steered flat-top beams using linear phased arrays with amplitude tapering and real antenna elements. The method flattens a given steered pencil beam by imposing maximum flatness at the beam peak. The proposed approach is demonstrated through the synthesis of flat-top beam patterns with specified beamwidth and minimum sidelobe level, in which the Gegenbauer beam is used. Compared to patterns obtained from other pencil-beam flattening methods, the proposed patterns exhibit lower sidelobe levels for the same beamwidth.

3.09 Distributed Phased-Arrays Exploiting Probabilistic Collaborative Beamforming with Excitation and Position Diversity

Sandra Costanzo and Giovanni Buonanno (University of Calabria, Italy)

Distributed phased arrays exploiting probabilistic collaborative beamforming joined with excitation and position diversity are analyzed in this work. As extension of a previous work, the adoption of diversity techniques allows for relatively significant performance improvements in terms of directivity and maximum sidelobe level.

3.10 Deep Learning Approach for Dynamic Synthesis of Fractal Reflective Surfaces in Electromagnetic Sensing Applications

Sandra Costanzo and Adil Masoud Qureshi (University of Calabria, Italy)

A deep learning approach for the synthesis of reflectarray-based reflective intelligent surfaces employing fractal-shaped elements is presented in this work. The proposed method is shown to be an order of magnitude faster than conventional synthesis procedures, such as that based on the intersection approach. Rapid synthesis allows timely reconfiguration of the far-field pattern, which is critical to ensure safe operation of implantable electronic devices (e.g., pacemakers) in human activity monitoring applications.

3.11 A 4x4 ISAC Antenna Array for Communication and Radar MIMO Operations

Merve Tascioglu Yalcinkaya (Barkhausen-Institut gGmbH, Germany); Thomas Dallmann (Technische Universität Ilmenau, Germany); Padmanava Sen (Research Group Leader, Barkhausen Institut gGmbH, Germany & Barkhausen Institut gGmbH, Germany); Gerhard P. Fettweis (Technische Universität Dresden, Germany)

In this paper, we present the design, analysis, and experimental verification of a 4x4 integrated sensing and communication (ISAC) multiple-input multiple-output (MIMO) antenna for boresight applications. The main contributions include the derivation of general requirements for ISAC MIMO antennas, realization of an exemplary scalable MIMO array, incorporation of a defected ground structure (DGS) to reduce self-interference and mutual coupling, and validation through fabrication and measurements. This work addresses the research gap of validated ISAC MIMO antennas meeting both application needs. A detailed comparison of antenna performance with and without DGS is also provided, alongside an evaluation of system-level suitability for future ISAC applications.

Tuesday, April 21 13:30 - 14:40

P1-AO2 Aerospace, space and non-terrestrial networks

TO3 Aerospace, space and non-terrestrial networks / / Antennas

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 3

3.12 Entropy-Driven Method for Irregular Polyomino-Tiled Scanning Array Design

Xinyao Chen (National University of Defense Technology, China); Nicola Anselmi (University of Trento, Italy); Zhenhai Xu and Wei Dong (National University of Defense Technology, China); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

Irregular polyomino subarrays have become a prominent research topic in antenna array synthesis thanks to the benefits of low cost and scanning performance. However, due to the enormous tiling solutions and the time-consuming process of selection, array design remains highly challenging. This paper employs entropy as the metric to maximize the aperiodicity of subarray distributions and adopts a customized relaxed integer optimization approach to solve the tiling problem. Compared with existing algorithms, the proposed method significantly enhances design efficiency and rapidly identifies solutions with superior overall scanning performance.

3.13 Wraparound Conformal Antenna Array Design and Modeling for Telemetry of Launching Vehicles

Willian Fontella (UNIPAMPA, Brazil); Abdou-Halique A. A. Bouari (Unipampa, Brazil); Alexis F. Tinoco-S. (Universidad de las Américas - UDLA & CICTE, Ecuador); Clara Souza Franco (UNIPAMPA, Brazil); Daniel B. dos Santos and Edson R. Schlosser (Universidade Federal do Pampa, Brazil); Juner M Vieira (Universidade Federal Do Pampa (Unipampa), Brazil); Lucas Santos Pereira and Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil)

This paper presents the design of a microstrip antenna array for telemetry of launching vehicles. An approximate approach is used to calculate de electric fields radiated by conformal microstrip antennas. The array must satisfy strict requirements, including omnidirectional pattern with low ripple and circular polarization, in order to increase communication robustness between the launcher and the controlling ground station. In order to obtain an omnidirectional radiation pattern, a study was conducted to determine the minimum number of elements that should be positioned along the circular cross section. For future validation, down-scaled mock-up and antenna have been designed, so as to enable testing the array design experimentally inside the laboratory whilst preserving the electrical dimensions (in wavelengths) as the full-size launcher.

3.14 Full Metal Cavity-Excited Annular Slot Antenna with a Quad-Section Shorted Configuration

Aurélie Dorlé and Alessandro H De Oliveira Cabral, Jr (ONERA, France)

A study is here proposed to complement the existing knowledge related to annular slot antennas. Overcoming the challenge of exploiting a cavity-fed system without any dielectrics, this paper presents an optimized solution featuring a simplified excitation with high radiation and aperture efficiency. A comparative analysis of different configurations is performed, from which the optimal solution emerges as a quadruple shorted slot. A 2x2 antenna subarray is designed at Ku-band and is demonstrated by a monolithic print through full metal additive manufacturing. The antenna exhibits a total efficiency of 84% with a realized gain of 14.1 dBi while showing a low profile and weight of 42 x 42 x 10.8mm3 and 32g without connectors. The full metal structure makes it suitable for small satellites applications.

3.15 Aperiodic Tiled Antenna Arrays with Simplified 3D-Printed Beamforming Networks

Nicola Anselmi (University of Trento, Italy); Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Lisa Berretti (IETR-INSA Rennes, France); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Esteban Menargues (SWISSto12, Switzerland); María García-Vigueras (IETR-INSA Rennes, France); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy)

This work addresses the need for compact, cost-effective phased array (PA) antenna systems for small geostationary satellites, which are emerging as affordable alternatives to traditional GEO platforms. It proposes a novel aperiodic tiled PA design that reduces the number of active control points while maintaining the required beamforming performance. The design leverages tiling optimization to create irregular, fully covering configurations with controlled side lobe levels (SLL) within a limited field of view. Finally, a prototype fabricated using 3D printing is presented to demonstrate the feasibility of the proposed approach.

3.16 A Modular GNSS 1×8 Receiver Array with RFSoC Digital Beamforming

Shiwen Tang, Haoze Luan and Peizhuo Yang (National University of Singapore, Singapore); Koen Mouthaan (NUS, Singapore)

A scalable modular GNSS receiving array is presented, in which antenna and receiver modules are independently designed and seamlessly integrated into a compact unit. A commercial GPS-band antenna module is characterized when mounted on ground planes with various sizes, showing stable impedance performance suitable for modular assembly. The receiver circuit module, providing approximately 28 dB gain, is directly mounted onto the back side. Measurement results confirm that the integrated unit maintains consistent gain, validating the modular concept. Using the proposed element, a 1×8 array is assembled which achieves a measured boresight gain of 35.4 dBi for horizontal polarization and 31.5 dBi for vertical polarization. The proposed approach offers an efficient and reconfigurable solution for compact RF front-end systems, with strong potential for scalable multi-element array applications.

3.17 Design of Low Profile 1-to-16 Hollow Parallel Plate Waveguide Power Divider

Qi Li (IETR, France); David González-Ovejero (Université de Rennes, France); Ronan Sauleau (Universite de Rennes, France)

This paper introduces a novel low profile 1-to-16 parallel plate waveguide (PPW) power divider network centered at 20GHz designed for applications with Continuous Transverse Stub (CTS) array antennas. The network integrates a conventional 1-to-2 power divider with two innovative 1-to-8 power dividers, optimized using Mode Matching techniques. The topology and performance of the 1-to-8 power divider are discussed and analyzed, with the overall 1-to-16 network evaluated via array factor calculations and E-plane radiation pattern. Operating over 18.7-21.5 GHz, the design achieves a 13.9% fractional bandwidth, maintaining a sidelobe level below -10dB and keeping the array factor peak within 1 dB of 12 dB. Compared with conventional networks constructed by stacking multiple 1-to-2 power dividers, this design exhibits a lower profile with a total thickness of 1.61λ. Future work aims to incorporate this power divider into a complete CTS array antenna, and to further enhance its operation bandwidth.

3.18 Design of SIW-Based Self-Quintuplexing Antenna for L, S, and C-Band Applications

Nrusingha Charan Pradhan (Central University of Karnataka, India); Slawomir Koziel (Gdansk University of Technology, Poland); Paramesha P (Central University of Karnataka, India)

This paper presents a geometrically simple substrate-integrated waveguide (SIW)-based self-quintuplexing antenna (SQA). The antenna structure consists of a modified X-shaped slot embedded in the SIW cavity. The antenna operates at five distinct frequencies: 3.28 GHz, 3.63 GHz, 3.89 GHz, 4.68 GHz and 5.62 GHz, while ensuring isolation better than 22.6 dB across the entire range. An equivalent circuit model is provided to validate the proposed model. The fabricated prototype, realized on a Rogers RT/5880 substrate, shows close alignment between simulated and measured outcomes. Furthermore, the measured antenna gains are 4.1 dB, 3.95 dB, 4.23 dB, 4.35 dB, and 5.7 dB at the respective resonant frequencies. The proposed device features a simple design, good isolation, and enhanced gain, making it suitable for a wide range of L, S, and C-band applications.

3.19 Multi-Band Circularly Polarised Metasurface Antenna Based on Characteristic Mode Analysis

Yifan Xue, Chenjiang Guo, Yanni Wang, Xia Ma and Jun Ding (Northwestern Polytechnical University, China)

This paper designed a novel four band circularly polarised metasurface antenna using the characteristic mode theory analysis method. The antenna adopts a sub-wavelength rectangular patch and an 'I' ring to form the radiation unit, and the feed structure consists of a slit coupling slot and a spiral microstrip line. Different from the traditional circularly polarised antenna, the antenna not only makes use of the fundamental and higher-order modes of the super-surface radiating unit, but also makes use of the slot modes of the coupling slit to form four sets of orthogonal modes. The distributions of the operating mode currents and phases are adjusted by modifying the dimensions of the radiating unit and the slit coupling slot. In addition, full-wave simulations of the antenna were performed and the results showed that circularly polarised radiation was achieved at 5.5 GHz, 8 GHz, 11.5 GHz and 12.4 GHz frequencies.

3.20 Compact High-Gain Endfire Antenna Arrays with Enhanced Element Isolation in the Ka-Band

Dennis Pfrommer (University Ulm, Germany); Christian Waldschmidt and Martin Hitzler (University of Ulm, Germany)

Endfire antennas are promising candidates for compact mmWave phased arrays, combining high directivity with simple PCB integration. However, achieving both high gain and isolation remains a challenge. This work presents a PCB-integrated Yagi-Uda antenna optimized for 30.5-31.5 GHz with resonator-based isolation enhancement structures. By inserting C- and I-shaped stubs between adjacent elements, isolation levels of 37.5 to 42 dB are achieved while maintaining a gain of 7 dBi. For comparison, a Vivaldi antenna is co-developed with identical element distance, offering wider impedance bandwidth and slightly higher gain of 7.3 dBi but with weaker isolation of 32.5 to 36 dB. The results emphasize the trade-off between size, bandwidth, gain, and isolation in endfire arrays. The proposed Yagi-Uda design demonstrates a compact, high-isolation solution for narrowband phased array applications such as long-range radar and space communication.

3.21 X-Band Radiating Panel of a Linear Array Antenna with High Gain and Wide Scanning Angle for Radar Applications

Romain Contreres (CNES, France)

A one-dimension X-band radiating panel in linear polarization is proposed in this paper. The single radiating element (RE) is composed of 4 stacked patch antennas aligned along the y-axis to produce an in-phase beam. The low profile radiating panel, constituted of 32 REs, is able to scan until +/-60 degrees in x-axis with the worst active return loss (WARL) below -6.3 dB in the band [9-10]GHz (10.52%) with a gain above 27dBi in the axis.

3.22 EBG Cloaking for Antenna Transparency in Compact Satellite-Based Systems

Gorka Casasus-Goyeneche (Universitat Politecnica de València & iTeam APL, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Javier Vera-Sánchez (Universitat Politecnica de Valencia, Spain); Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

Electromagnetic scattering from metallic VHF monopoles placed near higher-frequency apertures is a recurrent integration issue in compact LEO spacecraft. A thin, sleeve-type electromagnetic-bandgap (EBG) cloak, replicated only along the monopole axis, is introduced to preserve the VHF function while suppressing its visibility to the higher-frequency antenna. Compared with conventional two- or three-dimensional EBG skins, the one-dimensional replication simplifies geometry and fabrication. Full-wave results indicate that the array pattern with the cloaked monopole is practically indistinguishable from the monopole-free baseline, while the (sim)2~dB realized-gain loss induced by the bare monopole is recovered. The approach enables lightweight, fabrication-friendly electromagnetic coexistence in tightly packed satellite payloads.

3.23 Technology Developments for RF Payloads Based on Active Antennas and Digital Beamforming Supported by the European Space Agency

Salvatore D' Addio (European Space Agency, The Netherlands); Iain Davies (ESA ESTEC, The Netherlands); Václav Valenta and Jaione Galdeano (European Space Agency, The Netherlands); Carolina Tienda (ESA, ESTEC, Noordwijk, The Netherlands); Erio Gandini (ESA - European Space Agency, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Christoph Ernst (ESA, The Netherlands); Manuel Martin-Neira (ESA-ESTEC, The Netherlands); Adem Coskun and Ishuwa Sikaneta (European Space Agency, The Netherlands); Marc Zimmermanns (ESA ESTEC, The Netherlands); Natanael Ayllon (ESA/ESTEC, The Netherlands); Elena Saenz and Piero Angeletti (European Space Agency, The Netherlands)

This paper provides an overview of some of the recent technology developments and R&D activities supported by the European Space Agency for next generation satellite communication payloads and earth observation spaceborne instruments based on active antennas and on-board digital processing functions. In particular, for satellite communication payloads, recent technology developments on active antennas for LEO, MEO and GEO missions, including HPA MMICs, are presented. For earth observation instruments, recent active antenna technology developments for synthetic aperture radars and synthetic aperture radiometers are presented. An introduction to R&D activities in the area of digital signal processing and digital beamforming, is also provided.

3.24 Design of a 29GHz Waveguide Feed Network for Circular Polarization Diversity in Satellite Communications

Hanjo Ju (Korea Aerospace University, Korea (South)); Jung-hoon Han (Jeju National University, Korea (South))

This paper proposes a waveguide feed network to increase the channel capacity of a 29 GHz satellite communication system. The proposed structure combines a Quadrature Hybrid Coupler (QHC) and a Magic-T to generate two co-rotating circular polarizations with orthogonal phases from a single aperture, without requiring spatial separation. The performance, verified through simulation, includes a return loss below -20 dB and high port isolation of more than 20 dB in the target frequency band. Furthermore, the stable maintenance of a 90° sequential phase difference and uniform amplitude distribution at the output ports demonstrates that the proposed structure is highly effective for implementing circular polarization diversity.

3.25 Hexagonal-Pyramid Arrow-Slot Array for Space-Based ADS-B

Javier Vera-Sánchez (Universitat Politecnica de Valencia, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Gorka Casasus-Goyeneche (Universitat Politecnica de València & iTeam APL, Spain); Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

A compact, fully metallic 4 × 4 arrow-slot array is proposed as a modular building block for space-based Automatic Dependent Surveillance-Broadcast (ADS-B) reception in Low Earth Orbit (LEO). Each slot is center-fed by a microstrip line, and right-hand circular polarization is achieved through sequential rotation with 90 ◦ element orientation and phase progression. Six identical subarrays form a three-dimensional hexagonal-pyramid assembly providing continuous 360 ◦ azimuth coverage with beams tilted toward Earth. Full-wave simulations demonstrate excellent impedance matching, low inter-element coupling, and stable radiation characteristics across all faces. The proposed architecture combines the manufacturability and robustness of metal-only slot structures with the polarization control of phased arrays, offering an efficient and low-cost solution for next-generation space-based ADS-B payloads.

3.26 Combining Mechanical and Radio-Frequency Optimization with Additive Manufacturing to Design Hardened Space Antennas

Vincent Laquerbe and Romain Contreres (CNES, France)

This paper presents an innovative antenna design for S-band Telemetry, Tracking and Control links (TTC). The radiating part of the antenna is composed of a single wire helix using additive manufacturing. The wire has a complex 3D structure enabling wide-band (2.025 - 2.29 GHz) and wide beam width radiation (θ ± 60 ◦) with circular polarization. Its shape also brings specific mechanical properties to make it compatible with launch constraints. A matching circuit is embedded within the structure and connected to standard 50 Ω SMA connector. Since it is nearly made exclusively out of metal, this design is well-suited for harsh environments such as geostationary orbit and deep space mission. The antenna has undergone mechanical and thermal tests. Before and after results are presented and discussed.

3.27 Anti-Halo Antenna - a Counterweight Module for Circularly Polarized Scarabeus Antennas with Small Groundplanes for Automotive Applications

Maximilian Holzner (Universität der Bundeswehr München, Germany); Jasmin Moll (Universitaet der Bundeswehr Muenchen, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

In many mobile applications, antennas for mobile satellite reception have to be set on a small ground plane, which leads to impairments in their performance. Strong back lobes occur, which take away energy at the desired directions and produce ripples in the antenna pattern. In this contribution, we present a simple and effective structure that is printed underneath the antenna PCB for compensation of the spurious back lobe. The structure, which we call Anti-Halo, is combined with a circularly polarized scarabeus antenna for GNSS reception. As can be shown by example in simulation and measurement, the Anti-Halo structure eliminates disturbing left hand circularly polarized radiation in back lobe direction while it supports the wanted right hand circularly polarized radiation within a compact design.

3.28 5G Airborne gNodeB: Evaluation and Performances for Medium Altitudes

Carlos Gómez-Calero (Airbus Defence and Space, Spain)

Airborne gNodeBs (gNBs) mounted on large UAVs or manned aircraft are an emerging concept to provide rapid and flexible 5G coverage in rural, maritime, emergency, and/or defence scenarios. While high-altitude platforms (HAPS) and UAV base stations (BSs) have been studied, no prior work has systematically analyzed antenna array designs for airborne gNBs operating at medium altitudes (1--10 km). This paper presents a comparative analysis of antenna configurations, including uniform rectangular arrays (URA), circular arrays (UCA), triangular arrays (UTA), monopole references, and a possibility to include realistic measured pattern. Radiation properties, coverage footprints, and MIMO capacity at FR1 (700 MHz and 3.5 GHz) and FR2 (28 GHz) have been analyzed. Results highlight trade-offs between directivity, beamwidth, and footprint size, and quantify achievable capacity under line-of-sight (LoS) and two-ray propagation. This is the first systematic study of antenna arrays for airborne gNodeBs mounted on aircraft, offering insights for future airborne 5G/6G deployments.

3.29 Roof-Glass Integrated Microstrip Antenna for Vehicular SDARS Applications

Xiaotian Li (Volvo Car Corporation, Sweden); Hanieh Aliakbari (Volvocars, Sweden & Lund University, Sweden); Christian Lötbäck (Volvo Car Corporation, Sweden); Buon Kiong Lau (Lund University, Sweden)

In this paper, we propose the design of a roof-glass integrated microstrip antenna for vehicular SDARS tuners. The proposed microstrip antenna is sandwiched inside a multi-layer roof glass and uses a solar-heat reduction coating on the bottom side of the glass as ground plane. To offset the effect of the lossy glass, parasitic elements are added to enhance the antenna gain. Simulation results show that the microstrip antenna loaded with 3 × 3 parasitic elements achieves a boresight LHCP gain of 4.3 dBiC with a 3-dB beamwidth of 81.7° at the centre of the SDARS band. Moreover, full-car simulations reveal that the car body degrades the axial ratio performance of this antenna, but does not affect its LHCP gain performance. However, the antenna performance is stable over different antenna positions on the car roof.

Tuesday, April 21 13:30 - 14:40

P1-A03 **EM Modelling and Simulation Tools**

T07 Electromagnetic modelling and simulation tools / / Antennas

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 4

4.01 A Unified Framework for near-Field Power Synthesis in Half-Space Environments

Giada Maria Battaglia (Università Mediterranea di Reggio Calabria, Italy); Mario Del Prete (University of Campania Luigi Vanvitelli, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy); Sabrina Zumbo (Università Mediterranea di Reggio Calabria, Italy); Maria Antonia Maisto (Università degli studi della Campania Luigi Vanvitelli, Italy)

This contribution introduces a novel synthesis framework for accurately shaping near-field power distributions in half-space media. The formulation
incorporates the electromagnetic behavior of half-space configurations directly into the synthesis process by integrating a refined propagation model with a spectral-domain representation. Through the combined use of linear programming and spectral factorization, the method enforces user-defined power masks with high numerical stability and modest computational demand. Numerical validations demonstrate excellent agreement between the synthesized and target fields, confirming the method's capability to maintain accuracy even under strong dielectric discontinuities. The proposed framework establishes a robust foundation for advanced near-field control and can be extended to practical applications involving complex multilayer environments, such as medical imaging, subsurface sensing, and adaptive antenna design.

4.02 A Case for Slanted Polarization Based on 2-Ray Model

Radovan Zentner (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)

This paper provides an insight of propagation in vicinity of Earth in case of slanted polarization transmission. Using a simple two-ray model applied for different polarization excitations, vertical, horizontal and slanted, the benefits of slanted polarization are illustrated. Using this simple model an insight is provided into phenomena that occur for different polarization excitations. Thus, new tools for determining optimum polarization, especially for base station - user communication scenarios, such as mobile or nomad networks or broadcasting, are provided.

4.03 Mitigating Radio Frequency Interference in Radio Telescopes with Phased Array Feeds: A Simulation Study

Paola Di Ninni (OAA - INAF, Italy)

This contribution focuses on the modeling, simulation, imaging and mitigation of Radio Frequency Interference detectable by a radio telescope mounting a Phased Array Feed receiver. Nowadays, RFIs represent a big issue, in particular for radio astronomy since the very low sky signal levels to be measured. To face this problem, accurate simulations of realistic RFI scenarios are essential to make previsions on instrument response and provide simulated datasets useful to try mitigation algorithms. In this contribution, the authors will describe the above mentioned functionalities that are recently implemented in the simulator described in [10]. This simulator was initially developed for calculating noise performance for PAF-based radio telescopes with on-axis and off-axis optics; with these new functionalities, the simulator can manage wide scenarios of great interest. Numerical examples will be shown using PAF with wider-spaced GBT2 dipoles installed at the prime focus of the 20-m reflector at the Green Bank site.

4.04 Analysis of Differential Signals in a Concentric Dual-Polarized Tapered Slot Antenna

Stefan Andersson and Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

This paper presents a useful method for analyzing differential and common mode signals for dual-polarized antenna arrays in a unit cell environment. The conversion from single- ended S-parameters to mixed-mode S-parameters is reviewed, and the conversion method is extended to include coupling to single-ended ports. The method is verified through simulations with a concentric dual-polarized tapered slot antenna array. It will be shown that the coupling of differential and common mode signals contribute to the difference in performance between polarizations in an array with symmetrical elements.

4.05 Planar 3rd-Order Filtering Antenna Used for the Design of a Dual-Polarization Diplexing Antenna

Ignacio Maria Delgado-Lozano and Armando Fernández (Universidad de Sevilla, Spain); Vicente Losada (University of Sevilla, Spain); Rafael R. Boix (University of Seville, Spain)

This paper presents the design of a filtering antenna conceived as a third-order filter with transmission zeros. It consists of two magnetically coupled open-loop resonators connected to an aperture-coupled microstrip patch, which acts as the third resonator of the filter. A prototype operating at a center frequency of 5.5 GHz has been fabricated and measured, and good agreement has been found between simulations and measurements. The resulting antenna shows a sharp frequency selectivity in gain, which is a consequence of the transmission zeros of the filter. The filtering antenna has been used as the building block of a dual-polarization diplexing antenna. This antenna includes two diplexers, containing a pair of magnetically coupled resonators which feeds a microstrip patch. The diplexing antenna radiates in two bands centered at 3.5 GHz and 5.5 GHz for orthogonal linear polarizations, achieving a bandwidth around 7%, 7.5 dBi peak gain, and high out-of-band rejection.

4.06 X-Band Adaptive Applebaum Nullforming Array Processor on Xilinx Sx475T FPGA

Bopage Umesha Kumarasiri, Benn Roshnan Thevathasan and Sivakumar Sivasankar (FIU, USA); Constantinos L. Zekios (Florida International University, ECE & FIU, USA); Arjuna Madanayake (Florida International University, USA); Chamira U. S. Edussooriya (University of Moratuwa, Sri Lanka); Sundeep Rangan (New York University, USA); Aditya Dhananjay (Pi-Radio, USA)

The 6-24 GHz upper midband - FR3 range - is the next generation spectrum for mobile wireless applications. Traditionally allocated for defense and scientific use cases, the possible adoption of FR3 frequencies for commercial applications opens the possibility for severe interference between different commercial and scientific/defense systems. We demonstrate low-complexity adaptive array processing in the FR3 range using real-time implementation in the 10.7-10.8 GHz band, with 100 MHz of bandwidth using Xilinx Virtex-6 Sx475T FPGA technology. The demonstration supports a uniform linear array with 8 Vivaldi antennas (6-24 GHz) and can provide up to 6 nulls in the aperture pattern in addition to the desired RF beam. The FPGA back-end utilizes sampling at 200 MS/s and exploits digital signal processing to furnish up to 100 MHz of bandwidth at IF.

4.07 Full-Wave Electromagnetic Techniques to Analyze Advance Reflective and Periodic Surfaces

Borja Imaz-Lueje and Víctor Martín (Universidad Rey Juan Carlos, Spain); Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain)

In this contribution, we present an in-depth comparison of two analysis techniques for reflective periodic surfaces, such as reflectarrays. The former, calculates the radiation pattern through the previous knowledge of the incident field and behavior of the reflecting surface. The latter computes the farfield by the tangential currents of a tridimensional antenna model. A technical comparison of these two techniques has been conducted, through the evaluation of two reflectarray prototype. The predicted results achieved by each method exhibit a good trade-off between accuracy with measurements and computation time, though the second approach gives a higher flexibility to include other elements of the electromagnetic environment, such as the primary source, or supporting structures.

4.08 Lee-Mei Wave Function Decomposition of the Current on a Monofilar Axial-Mode Helix

Christopher G Hynes and Rodney Vaughan (Simon Fraser University, Canada)

The Lee-Mei current decomposition provides additional physical insight into the operation of wire antennas. The method is applied using the current on monofilar axial-mode helices to determine the Lee-Mei wave function modes, net forward and backward travelling currents, and generalized relative phase velocities. Such current decomposition provides a means to gain additional understanding of the operation of wire antennas.

4.09 Multi-Band Radome Optimization with Frequency-Dispersive Materials

Olga Basile and Marco Simone (University of Catania, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); Gino Sorbello (University of Catania, Italy)

This work presents an optimization methodology for the electromagnetic design of multilayer dielectric radomes intended for multi-band satellite communication systems operating in the 7.2-31 GHz range. The proposed approach exploits the Particle Swarm Optimization (PSO) algorithm combined with a frequency-dispersive transmission-line model of real materials, enabling accurate broadband optimization for Transverse Electric (TE) and Transverse-Magnetic (TM) polarizations and for oblique incidences up to 30 $^\circ$. The optimized 14-layer radome achieves a transmission coefficient above-0.32 dB across X, Ku, and Ka bands, validating the efficiency and robustness of the design method when compared with full-wave electromagnetic simulations. The results confirm the effectiveness of integrating dispersive modeling and stochastic optimization for broadband radome synthesis in high-performance SATCOM applications.

4.10 Beam Steering Based on Pancharatnam-Berry Metalenses

Aliza Fida (Università Degli Studi di Siena, Italy); Andrea Alu (Photonics Initiative, USA); Stefano Maci (University of Siena, Italy)

We present the design and modeling of a triple-layer metalens system for beam steering in the near-infrared (NIR) wavelength. Taking inspiration from the Risley prism concept, the system employs Pancharatnam-Berry (PB) phase modulation through nanopillar arrays to achieve precise and tunable wavefront control from a spherical incident wave. The first metalens collimates an incoming spherical wavefront into a planar one, while two mechanically rotatable metalenses introduce adjustable phase gradients, enabling independent steering in both azimuth and zenith directions. The proposed device, featuring an aperture of 16 μm (approximately 21.3 λ at the operating wavelength of 0.75 μm), demonstrates efficient and continuous beam steering. Full-wave simulations performed using a commercial FDTD solver confirm the system's effectiveness, underscoring its potential for compact, lightweight, and low-cost applications in LiDAR, optical communications, and infrared imaging.

4.11 Electromagnetic Wave Interaction and Beam Steering in Plasma Medium

Krushna Kanth Varikuntla (Queen's University Belfast, United Kingdom (Great Britain) & Queens's University Belfast, United Kingdom (Great Britain)); Mirko Barbuto (Roma Tre University, Italy); Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

This paper presents the effects of electromagnetic wave interaction with plasma medium and its application for wave manipulation as a use-case scenario. An efficient one-dimensional (1D) finite-difference time domain (FDTD) approach is used to model the wave propagation through the plasma medium at different plasma densities in transmission mode and reflection mode backed by a perfect electric boundary. Furthermore, the beam steering properties of the plasma for an incoming wave are studied and the results are reported. This study supports the development of plasma based reconfigurable surfaces, offering advantages in tunability, stealth and adaptive system designs.

4.12 Design of a Triband Wi-Fi Antenna Mounted on an RJ45 Connector

Lukas M van Vuuren (Taoglas, Ireland)

The design and fabrication of a patented tri-band Wi-Fi antenna, operating at the 2.4 GHz, 5 GHz and 6 GHz Wi-Fi bands, is presented. The antenna was designed through a combination of simulation and laboratory mock-ups, and the overall solution has been designed to be integrated on top of a range of compatible Registered Jack 45 (RJ45) Ethernet connectors. This is achieved through the use of a plastic carrier and conductive adhesive foam. The adhesive foam ensures the carrier remains in place, while also providing a ground connection for the antenna to the Printed Circuit Board (PCB). The antenna is fed with a coaxial cable. Passive antenna results and active measurements are presented.

4.13 Large Radius Omnidirectional Structural Cylindrical Antenna Using Parallel Feeding

Raphael Notter (Université de Rennes & French-German Research Institute of Saint-Louis, France); Loic Bernard (ISL & IETR, France); Sylvain Collardey (University of Rennes 1, France); Ala Sharaiha (Université de Rennes & IETR, France); Pouliguen Philippe and Paul Karmann (DGA, France)

This paper presents the design and realization of a large-radius omnidirectional structural cylindrical antenna fed through parallel aperture-coupled slots. Structural antennas use load-bearing components as radiating elements, enabling conformal and mechanically robust solutions with 360 omnidirectional coverage. A major challenge is the excitation of higher-order modes when the structure size becomes electrically large, which can degrade omnidirectional performance. In cylindrical geometries, radial modes are relatively insensitive to cylinder length but are strongly influenced by large radii, particularly for the fundamental omnidirectional mode. To address this, a systematic design approach based on Characteristic Mode Analysis (CMA) is proposed to evaluate and control higher-order modes. Parallel feeding is employed to achieve uniform current distribution, improving impedance matching and radiation stability. Simulations and measurements demonstrate stable omnidirectional radiation with low cross-polarization from 2.3 to 2.9 GHz, validating the feasibility of integrating efficient antennas into cylindrical structural components.

4.14 Optimization-Driven Design of a High-Efficiency Pixelated Rectenna for Low-Power Wireless Power Transfer

Rasool Keshavarz (University of Technology Sydney, Australia); Ali Raza (University of Engineering and Technology (UET) Lahore, Pakistan); Amanath Ullah (University of Technology Sydney, Australia); Akifumi. Nagatani (NTT Communications Corporation, Japan); Negin Shariati (University of Technology Sydney, Australia)

This paper presents a highly efficient rectenna (rectifying antenna) design optimized using a binary optimization algorithm. The proposed design incorporates a novel pixelated receiving antenna that directly matches the diode impedance of the rectifier, thereby eliminating the need for a separate matching network, which simplifies the overall structure and improves performance. The binary optimization algorithm is employed to fine-tune the configuration of the antenna, optimizing its reflection coefficient and impedance matching. The rectenna operates at a frequency of 2.5 GHz and achieves a RF-DC conversion efficiency of 38% under 0 dBm incident power, with an output voltage of 815 mV. This design offers significant improvements in compactness and efficiency compared to traditional rectennas with separate matching circuits. The proposed rectenna demonstrates versatility and effectiveness in low-power wireless power transfer (WPT) applications, making it a promising solution for energy harvesting and powering remote, low-power devices.

4.15 Wideband Circularly Polarized Self-Decoupling Stacked Patch Antenna Pair Based on Dual Axial Ratio Minima and Mode Counteraction

Shao-Hua Xing, Zhen-Guo Liu and Chao Zhang (Southeast University, China); Zhi-Yuan Yang and Lu Wang (China Telecom Corporation Ltd., China)

This paper presents a novel circularly polarized (CP) stacked microstrip patch antenna pair that features both a wide axial-ratio bandwidth (ARBW) and a wide decoupling bandwidth. Each antenna element of the pair radiates right-hand circular polarization (RHCP). By loading a stub onto each parasitic patch, an additional axial ratio (AR) minimum can be introduced in the low-frequency region (around 5.2 GHz), while the CP performance at higher frequencies (around 5.7 GHz) is simultaneously enhanced, thereby significantly broadening the 3-dB AR bandwidth. On the other hand, the perturbation of the overall coupling caused by the stub allows the feed probe of the load to remain within a weak-field region over a wide frequency range, thereby overcoming the inherent bandwidth limitation of conventional single-layer self-decoupled CP patch antennas. The proposed S-MPA pair achieves an effective operating bandwidth that fully covers the Wi-Fi 6 band (5.15-5.835 GHz).

4.16 Numerical Analysis of a 3D-Printed Metallic BFN Reconstructed by X-Ray Tomography

Vincent Laquerbe (CNES, France); Kateryna Kiryukhina (France); Julien Uzanu (ELEMCA, France)

This paper proposes a methodology to simulate and analyze complex 3D-printed RF components in order to evaluate the limitation of additive manufacturing techniques (mainly precision and surface roughness). The high-resolution CAD object is reconstructed using the draping technique which allows to calculate their real RF performances. The use case considered here is a Ka-band 1-to-4 beam-forming network, operating in the Tx frequency band 17.3 - 20.2 GHz for space telecommunication. The numerical results obtained from the reconstructed geometry are compared with the theoretical ones and measurements. It is shown that such high-fidelity 3D model allows one to retrieve the same results as the measurements and its imperfection due to the additive manufacturing process.

4.17 Integration of a Monopulse Antenna on Carrier Using CMA

Maxime Hodoul (University of Rennes, France); Raphael Notter (Université de Rennes & French-German Research Institute of Saint-Louis, France); Mohamed Himdi (Université de Rennes, France & IETR, France); Loic Bernard (ISL & IETR, France); Quentin Simon Simon (Universite de Rennes 1, France); Stéphane Méric (Institut National Des Sciences Appliquées (INSA Rennes), France & IETR, France); Ronan Adam (French-German Research Institute of Saint-Louis, France); Xavier Castel (IETR-Université de Rennes 1, France)

This work investigates monopulse processing tech-niques for angular estimation using phase monopulse antennas. The study focuses on the design and simulation validation of a linear array system optimized for accurate direction finding. Simulations analyze the impact of the number of array elements on resolution, ambiguity, and signal-to-noise ratio (SNR). An 8-element linear array antenna operating at 5.0 GHz and bandwidth BW =100 MHz is designed on a RO4003C of permittivity er=3.55 substrate to validate theoretical predictions. Radiation patterns show a maximum realized gain of 14 dBi, sidelobe level below -10 dB, and difference-channel null depth below -17.5 dB. The design successfully demonstrates the effectiveness of phase monopulse processing as a sensor for precise angular estimation in radar and tracking applications. Studies were conducted on the integration of this antenna onto a cylindrical carrier using CMA. This method enables to determine which dimension is most suitable for integration.

4.18 Truncated Calibration Table from Modal Analysis for Direction Finding in a Context of Electrically Small Antennas on a Larger Structure

Rabiou Zouliadine Ibrahim, Jr (Grenoble-Alpes-University, France & CEA-Leti, France); Serge Bories (CEA, France)

In the context of Direction Finding application, the a priori knowledge of the antenna elements far-field radiation, is tightly related with DOA accuracy performance. This paper presents a characteristic modes analysis of electrically small antennas integrated on about one wavelength dimensions structure. By limiting the number of selected modes used to reconstruct the radiation, the impact on DOA error is analysed.

4.19 Scan Impedance Mismatch Mitigation Using Multiport Elements

Leo Peltoniemi, Albert Salmi and Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

This paper presents a compact antenna design aimed at mitigating scan loss in infinite arrays. The unit cell simulations are used for designing a compact multi-feed element. By calculating the optimal feeds at each element port, both the total active reflection coefficient and gain are improved. Our findings demonstrate that incorporating multiple feeds to one element enhances beam-steering capabilities by enabling a broader scanning angle.

Tuesday, April 21 13:30 - 14:40

P1-A04 **Reflectors, reflectarrays and feed systems**

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 4

4.20 Design and Experimental Characterization of a Tunable Hexagonal Unit Cell for 5G Reconfigurable Intelligent Surfaces at 2.5 GHz

Tiago E. S. Oliveira (Universidade de Vigo, Portugal & Instituto de Telecomunicações, Portugal); João Ricardo Reis (IT & IPL, Portugal); Sergio Matos (Iscte-IUL / Instituto de Telecommunicações, Portugal); Samuel Rocha Madail and José Salgado (Altice Labs. SA, Portugal); Iñigo Cuiñas (University of Vigo, Spain); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

In this paper, an electronically tunable hexagonal-slotted unit cell with continuous phase control, designed for a reconfigurable intelligent surface (RIS) operating within the mid-band 5G NR frequency range (n41, 2.496-2.69GHz), is presented. The unit cell features a hexagonal geometry with overall dimensions of 46x46 mm2 and incorporates a BB833 varactor diode. This work details the design, simulation, and experimental validation of the proposed reconfigurable unit cell for potential use in RIS applications. The unit cell demonstrates relatively good amplitude and phase control, achieving a measured phase tuning range up to 310°, in strong agreement with simulation results. When implemented in a RIS, the proposed design attains aperture efficiencies of η=60.3% (σ=73.18 dB(mm2)) for reflection at 20° in azimuth and η=55.5% (σ=71.05 dB(mm2)) for reflection at 40 ◦ in elevation. These results confirm the high reconfigurability and excellent performance of the proposed unit cell, paving the way for practical RIS implementations.

4.21 Control Board Design Strategy Towards Scalable and Intelligent RISs

Muhammad Abdullah, Niklas Takanen and Quoc Duy Nguyen (University of Oulu, Finland); Thinh Nguyen (Doctoral Researcher, Finland); Tung Duy Phan, Nhan Nguyen, Markku Juntti and Ping Jack Soh (University of Oulu, Finland)

This paper presents a control-board strategy enabling the operation of scalable and intelligent reconfigurable intelligent surfaces (RISs). Instead of a wire-dense controller, nine compact tiles (3 × 3) are mounted behind the RIS, each driving a 4 × 4 unit-cell (UC) sub-array. These tiles are interconnected in a daisy-chained form, supported by an Arduino microcontroller. The overall RIS operates from 6.5 to 87 GHz, consists of 24 × 24 UCs, and is built from four 12 × 12 sub-boards. Nine controller tiles map to a contiguous 12×12 region for validation. A near-constant per-command write time of ~ 15.5 ms is measured, independent of the tile count (1-4). For autonomous operation, a lightweight contextual bandit machine learning model selects beams from local RF measurements, tracking a moving receiver without cascaded-CSI or exhaustive scans. This hardware-software stack features a practical, fault-tolerant, low-overhead RIS platform for 6G.

4.22 Dual-Frequency Dual-Beam Reflectarray Based on Frequency-Division Duplexing Reflection Phase-Shifting Element

Yi Sun and Shaowei Liao (South China University of Technology, China)

Former simultaneous dual-beam reflectarray (RA) designs employing frequency-division techniques suffer from limitations include inter-beam interference, reduced aperture efficiency, and restricted beam steering range. To address these problems, this paper presents a dual-frequency dual-beam Ku-band RA capable of simultaneous dual-frequency operation with independent control of the corresponding beams. The proposed RA is enabled by a frequency-division duplexing reflection phase-shifting element (FDRPE) that is formed by an integrated frequency-duplexing element (IFDE) with two independent reflective phase shifters. A 16 × 16-element prototype was fabricated and characterized, demonstrating 2-D independent beam steering over the low band (LB, 10.4-11.2 GHz) and high band (HB, 13.9-14.7 GHz) with minimal inter-beam interference (angular deviation ≤ 0.5°, gain variation ≤ 0.5 dB). Measurements show that the array attains maximum aperture efficiencies of 21.6% and 20.6% for the low and high bands, respectively, and supports a 2-D ±40° 3-dB gain variation beam steering range in both bands.

4.23 A Compact Quad-Polarization 1-Bit Unit Cell for Wideband Polarization-Insensitive Beam-Scanning Reflectarrays

Yi Sun and Shaowei Liao (South China University of Technology, China)

To overcome the polarization and bandwidth limitations of conventional designs, this paper proposes a compact quad-polarization 1-bit unit cell for beam-scanning reflectarrays (BSRAs). The design combines a current-reversal-based 1-bit phase-shifting technique for linear polarization with an equivalent-rotation-based phase-shifting technique for circular polarization within a single unit cell. Practical implementation is achieved via a capacitively coupled structure with a grounded patch and cross-polarization-suppressing slots, which together enable wideband operation and low cross-polarization. The unit cell supports HP/VP/LHCP/RHCP modes, covers 2.9-4.28 GHz (38.44%), and exhibits < 1 dB in-band reflection loss in the 1-bit states. Only two PIN diodes are required, driven by a single control signal, and the unit cell period is $0.36\lambda_0$ at the center frequency. The proposed unit cell offers a simple, low-loss, and area-efficient building block for polarization-insensitive beam-scanning reflectarrays.

4.24 Measurement of Large-Scale Transparent Metasurface Reflectors Based on the Concave Lens Principle

Osamu Kagaya, Sho Yoshida, Sangmun Lee and Toshiki Sayama (AGC Inc., Japan); Takumi Yoneda (NTT, Inc., Japan); Tomoki Murakami (NTT Corporation, Japan); Dan Mohri and Satoshi Suyama (NTT DOCOMO, INC, Japan)

The use of passive metasurface reflectors is gaining attention as a method for establishing a line-of-sight (LOS) environment in millimeter wave. Large-scale metasurface reflectors are challenging to evaluate in the far-field region due to their size and operating frequency. We prototype a large-scale metasurface reflector based on concave lens principle and evaluate it in the non-far-field region at millimeter wave. The trend of the measured reflection pattern in the non-far-field region agrees with the calculations. When evaluated in an actual outdoor environment, the reflection pattern is as designed, and received power is improved by 8 dB in comparison without reflector.

4.25 A Broadband All-Metal Folded Reflectarray for High Power Microwave Applications

Xin-zhi Bo (IT - Instituto de Telecomunicações, Portugal & It, Portugal); Zhen-Guo Liu (Southeast University, China); Ming Shen (Aalborg University, Denmark); Nuno Borges Carvalho (Universidade de Aveiro, Portugal & InstitutodeTelecomunicacoes, Portugal)

A Broadband all-metal folded reflectarray (AMFRA) is designed for high power microwave applications. The FRA is composed of a bottom two-bit polarization converter embedded with a feed and a top polarization grid. The electromagnetic waves from the feed are reflected once between the polarization converter and the polarization grid so that the FRA profile is reduced to half of the traditional reflectarray (RA). According to the simulation results, the designed FRA was able to obtain 3-dB gain bandwidth of 26.7% (9.1-11.9 GHz), and achieve maximum gain of 26.97 dBi at 10.2 GHz, with maximum aperture efficiency of 43.7%. The designed low-profile, low-cost, and metal-only FRA has great potential for application in high-gain, high-power satellite communication systems.

4.26 Reflectarray Antenna Based on Separated Parallelogram Unit Cell Fed by a Circularly Polarized Vivaldi Antenna

GangYoung Kim (Gyeongsang National University, Korea (South)); Wang-Sang Lee (Gyeongsang National University (GNU), Korea (South))

This paper proposes a compact reflectarray antenna based on separated parallelogram unit cells. Each cell comprises a PB(Pancharatnam-Berry) phase circular patch with a cross-shaped slot, converting incident RCP to reflected LCP while providing continuous 0°-360° phase control. The separated ground enables a deployable structure, and its cross slot shifts the transmission resonance out of band, stabilizing the reflection magnitude. At 14 GHz, a 20×20 array achieves a peak realized gain of about 23 dBi in the main beam, which is 13 dB higher than a standalone Vivaldi feed (9.5 dBi) under identical conditions. The axial ratio around the main beam remains below 3 dB, confirming good circular polarization. The proposed reflectarray offers a low-profile and practical solution with substantial gain enhancement.

4.27 Suspended-Slot Antennas Integrated with a Parabolic Reflector for UAV Jammer Applications

Pisit Janpangngern, Nattawat Thuanboon and Pattawin Changnam (Suranaree University of Technology, Thailand); Nuchanart Santalunai (Rajamangala University of Technology Isan, Nakhon Ratchasima, Thailand); Samran Santalunai (Suranaree University of Technology, Nakhon Ratchasima, Thailand); Chanchai Thongsopa (Suranaree University of Technology, Thailand)

This paper presents the design and assessment of three suspended-slot antennas operating at 1.575 GHz, 2.45 GHz, and 5.8 GHz, intended as high-power feeds for a 2.25-meter parabolic reflector in UAV jammer applications. The suspended structure offers wide bandwidth and supports up to 200 watts of input power. Antennas are positioned at the reflector's focal point to enhance gain across all bands. Simulated and measured results, including reflection coefficients, radiation patterns, and gain, show strong agreement. The proposed system offers a compact, high-gain, multi-band solution for directional jamming in drone countermeasure scenarios.

4.28 Performance Evaluation of a Compact Antenna Test Range Quiet Zone Considering Reflector Surface Errors

Jiaqi Liu, Mingming Wang and Dongsheng Li (Beihang University, China)

This paper proposes a method for predicting the quiet zone performance of a compact antenna test range (CATR) during the reflector surface assembly and measurement phase. The approach constructs an error-included reflector model through reverse modeling and geometric refinement of measured point cloud data, which is subsequently employed in electromagnetic simulations. The simulated quiet zone characteristics show good agreement with experimental measurements, thereby confirming the validity of the proposed method. Furthermore, a comparative analysis between the surface errors distribution and the quiet zone amplitude profile reveals a clear spatial correspondence between surface errors and amplitude ripples. This method enables early-stage prediction of quiet zone performance and realtime correction of out-of-tolerance regions during reflector assembly, offering practical guidance for improving the alignment accuracy of CATR reflectors.

4.29 A Simultaneous S/X/Ka Feed System for Prime Focus Parabolic Reflectors

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia)

The design of a simultaneous S/X/Ka feed system suitable for prime focus parabolic reflectors is described. Index Terms: horn antenna, triaxial horn antenna, reflector antenna, prime focus, parabolic reflector, S/X/Ka

4.30 2-Bit Mechanically RIS Unit Cell for 26 GHz Band

Marcos Baena-Molina, Angel Palomares-Caballero, Ginés Martínez-García, Ángel M. Sánchez-Zarco and Pablo Padilla (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain)

This paper presents the design of a mechanically reconfigurable 2-bit unit cell for reconfigurable intelligent surface (RIS). An optimized design has been developed, based on the controlled displacement of a metallized movable element driven by a stepper micromotor. This approach achieves a 90° ± 20° reflection phase shift between states with losses not exceeding -1.14 dB in the 26 GHz band of 5G. The simulated results for a RIS composed of 15x15 unit cells have been performed demonstrating the beam-steering capability of the proposed RIS design. Finally, a low-cost fabrication methodology has been described, using high-precision SLA 3-D printing and aerosol metallization.

4.31 Optically Transparent Metasurface for Radar Detectability Enhancement

Sergey Geyman (Tel Aviv University, Israel); Dmytro Vovchuk (Riga Technical University, Latvia); Denis Kolchanov (Tel Aviv University, Israel); Mykola Khobzei and Vladyslav Tkach (Yuriy Fedkovych Chernivtsi National University, Ukraine); Toms Salgals (RTU, Latvia); Vjaceslavs Bobrovs (Riga Technical University, Latvia); Hagit Gilon and Eyal Cohen (DR Utilight Ltd, Israel); Ofer Amrani and Pavel Ginzburg (Tel Aviv University, Israel)

Reliable object detection in automotive radar critically depends on a vehicle's radar cross section (RCS). However, modern car designs lack dedicated reflectors that maintain optical transparency. We present a 3D-printed optically transparent metasurface that enhances radar visibility in the 77-81 GHz band while preserving visual clarity. The structure consists of conductive wire arrays patterned to satisfy the first Bragg condition, ensuring in-phase backscattering under a 45° interrogation angle. The metasurface was fabricated on glass using silver-nanoparticle printing, achieving 90 % optical transparency and strong retroreflection. Both simulations and experimental measurements confirm narrow-beam high-RCS responses, with a 10 × 10 cm² prototype reaching 8 m² at 80 GHz. Extrapolation to a full windshield suggests RCS values approaching 1,000 m² - two orders of magnitude higher than typical vehicles. The proposed concept demonstrates a scalable route toward smart transparent automotive components.

4.32 Antenna Design for the Alpha-Loop 0.4 - 2 GHz Across-Track Scanner

Aurélien Neuhart (European Space Agency (ESA-ESTEC), The Netherlands); Manuel Martin-Neira (ESA-ESTEC, The Netherlands); Erio Gandini (ESA - European Space Agency, The Netherlands); Paul Moseley (European Space Agency, Switzerland)

The Alpha Loop is an alternative concept to the pushbroom radiometer baselined for the ESA CryoRad mission, aiming to explore the possibilities of an across-track scanner. The idea consists of rotating the whole spacecraft around the velocity vector, which forms a relatively shallow angle α with the plane of the aperture of the mesh reflector. The latter, modeled as a mass loop, presents an acceptable moment of inertia when rotated through an axis at the shallow angle α, hence the name Alpha Loop. This paper derives the key design parameters and governing formulas needed to evaluate the feasibility, performance constraints, and potential advantages of this novel mission architecture.

4.33 Surface-Wave Launcher Using a Finite Metasurface for Polarization-Selective Surface-Wave Control

Qifeng Shen and Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

We present a compact surface-wave launcher that integrates a printed patch-array metasurface to suppress unwanted higher-order surface-wave fields. The metasurface creates a \emph{mode-selective} impedance boundary condition that strongly reflects parasitic TE surface wave fields while maintaining high transmission of the desired TM mode. Analytical modeling and full-wave simulations show that a lambda/4 metasurface section increases the effective propagation constant and yields constructive TE1 reflection. A prototype metasurface-enhanced SWL was also designed and validated. Compared with a conventional uniplanar SWL, the proposed feeder achieves more than 8 dB TE suppression. Demonstrations in point-to-point surface-wave links and leaky-wave antennas reveal up to 3.2 dB higher surface-wave directivity, approximately 2 dB greater realized co-polarized gain, and approximately 5 dB lower cross-polarized radiation around the design frequency. These results establish the proposed SWL as an effective feed element for millimeter-wave and sub-THz surface-wave circuits and antennas or wherever planar TM SW launching is required.

4.34 Estimation of the near-Field Radiation Function of Leaky Feeder Cables in Free Space

Nima Jamaly (Swisscom, Switzerland)

We propose a reduced-order method to estimate the near-field radiation of leaky feeder cables (LFCs) in free space. Because LFCs extend for hundreds of metres, practical observation points lie in the near field, making far-field approximations unsuitable while full-wave analysis of the long, slotted LFCs remains computationally prohibitive. Our approach assumes the internal TEM mode is not phase-perturbed by the small slots, with amplitude governed by longitudinal loss. A single-slot pattern from full-wave simulation is assigned to each slot with position-dependent phase-centre shifts. Coupling among neighbouring slots is represented by equivalent electric polarisation currents. A multiport circuit model then yields embedded patterns whose superposition provides the field. Simulations of two representative LFCs show non-uniform near-field behaviour across polarisations. The proposed model enables link-budget analysis for systems with LFCs in free space and can be extended in conjunction with ray-tracing techniques, to tunnel environments.

Tuesday, April 21 13:30 - 14:40

P1-A05 **Wearable and implantable antennas for Biomedical and health**

T06 Biomedical and health / / Antennas

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 3

3.30 Conformal Circularly-Polarized Implantable Omnidirectional Capsule Antenna

Nashat Osama Elazab (University of Carlos III of Madrid, Spain); Abdenasser Lamkaddem (Universidad Carlos III de Madrid (UC3M), Spain); Kerlos Atia Abdalmalak and Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

This paper presents a multiband, conformal, omnidirectional circularly polarized (CP) implantable antenna with a wideband performance designed for ingestible medical devices. The antenna covers multiple biomedical frequency allocations, including the Medical Implant Communication Service (MICS, 401–406 MHz), the Industrial, Scientific, and Medical (ISM) bands at 433.1–434.8 MHz, 868.0–868.6 MHz, 902–928 MHz, 1470 MHz, and 2400.0–2483.5 MHz. These frequency bands collectively support telemetry, wireless monitoring, wireless power transfer (WPT), and power conservation in medical applications. The proposed antenna has compact dimensions of 15 × 7 × 0.25 mm^3 and demonstrates enhanced performance in key parameters. Simulation results within a phantom model show a peak gain of -15 dBi. At 915 MHz, it exhibits circular polarization with a 3 dB axial ratio bandwidth of 30%, while maintaining omnidirectional radiation characteristics.

3.31 A Self-Triplexing Circularly Polarized MIMO Antenna Enabling Transcranial Wireless Powering and Telemetry for IoMT Brain Implants

Syed Nazim Shah (Public University of Navarre (UPNA), Spain); Abdul Basir (Tampere University, Finland); Jamal Nasir (COMSATS University Islamabad, Abbottabad, Campus, Pakistan); Toni Björninen (Tampere University, Finland); Miguel Laso (Public University of Navarre, Spain)

In this paper, a compact six-port, triple-band, circularly polarized multiple-input and multi-output (MIMO) implantable antenna with self-triplexing capability is presented for intracranial applications. The antenna occupies a footprint of 12.4×14×0.2 mm3. It operates at 915, 1710, and 2450 MHz across the ISM and MedRadio bands. It achieves circular polarization with 3-dB axial-ratio bandwidths of 17.7%, 4.1%, and 7.4%. Mutual coupling is inhibited by meander-line patches with isolation levels of 25 dB or more, without the use of shorting vias, ground-plane slots, or decoupling circuits. Simulated realized gains of -39.6, -38.5, and -35.1 dBi at 0.915, 1.71, and 2.45 GHz, respectively, and low SAR values guarantee safety compliance. Link-budget analysis guarantees reliable communication with minimum coverage distance of 5.1 m for high data rates of 10, 78, and 120 Mbps. The antenna performance is analyzed using MIMO performance and diversity analysis in lossy, multipath tissue conditions.

3.32 915-MHz Implantable Miniaturized SRR-Based Printed Antenna for pH-Based Colon Cancer Hotspot Monitoring

Ahmed EF Zahran, Md Ahsan Halimi and Ibraheem Al-Naib (King Fahd University of Petroleum & Minerals, Saudi Arabia); Hussein Attia (King Fahd University of Petroleum and Minerals (KFUPM) & Interdisciplinary Research Center for Communication Systems and Sensing, Saudi Arabia)

This paper presents a miniaturized implantable antenna designed for monitoring colon pH (potential of hydrogen) levels, intending to facilitate early cancer detection. A semicircular monopole patch antenna, operating at the 915 MHz ISM band, is designed to fit within a standard '000' size medical capsule of 11 mm diameter and 26 mm height. By integrating three split-ring resonators (SRRs) lines, the design achieves an excellent impedance match with a simulated reflection coefficient of -34 dB and peak gain improvement of 6 dB. For enhanced data reliability, a two-element MIMO configuration was analyzed within a three-layer human tissue phantom. The MIMO system demonstrates excellent isolation (S21<-40 dB) and a low Envelope Correlation Coefficient (ECC<0.3). SAR analysis confirms the system complies with safety standards, and a gain of -22 dB is achieved. These results establish the proposed antenna as a strong candidate for advanced in-body wireless monitoring applications.

3.33 A Biologically Inspired Miniaturized Meandered Loop Antenna for Implantable Systems

Batoul El Hage, Youssef Tawk and Joseph Costantine (American University of Beirut, Lebanon)

This paper presents a compact meandered loop antenna specifically designed for implantable biomedical applications. The antenna achieves a high miniaturization factor, with dimensions of 2 × 1.72 × 0.05 cm^3, facilitating seamless integration within soft tissue environments. Inspired by the human kidney's cross-sectional geometry, the structure employs an eight-lobed meandered configuration that enhances current uniformity and maintains efficient radiation for an electrically small antenna. Operating at 2.1 GHz, the selected frequency ensures an optimal trade-off between antenna compactness, impedance matching, and tissue penetration. The prototype, fabricated on a Rogers 3003 substrate (εr = 3, thickness = 0.05 cm), and encapsulated in silicon RTV, demonstrates a differential impedance of 50 Ω and a well-defined resonance at the target frequency. The antenna is fabricated and tested, where the measurement results agree well with simulated data.

3.34 Efficient Muscle Analyzer System Design Using Compact Wearable Resonating Antenna for Health Monitoring

Tarakeswar Shaw (Birla Institute of Technology (BIT) Mesra, India); Bappaditya Mandal and Robin Augustine (Uppsala University, Sweden)

Microwave sensing offers a promising alternative to conventional medical imaging techniques such as X-rays, MRI, and CT for diagnostic applications. This paper presents a magnetic-resonating antenna-based system for local body composition assessment, primarily focusing on muscle quality evaluation. The system employs a simple planar circular spiral resonator with a notch, excited by a loop antenna, to form a wearable muscle analyzer. Designed on a three-layer tissue model (skin, fat, and muscle), the antenna operates within the ISM band (2.40-2.48 GHz). To evaluate muscle quality, the dielectric property of muscle tissue is varied in simulations, causing shifts in resonance frequency and phase. These variations enable prediction of muscle condition. A prototype of the wearable antenna is fabricated and tested on a three-layer phantom and a human arm, demonstrating strong agreement between simulated and measured results, validating the proposed system's performance.

3.35 Highly-Sensitive near-Field Electromagnetic Sensing Probe for Biomedical Applications

Abdulrahman Alqadami (King Fahd University of Petroleum and Minerals, Saudi Arabia); Muhammad Ikram (American University of Kuwait, Kuwait); Ibraheem Al-Naib (King Fahd University of Petroleum & Minerals, Saudi Arabia); Hussein Attia (King Fahd University of Petroleum and Minerals (KFUPM) & Interdisciplinary Research Center for Communication Systems and Sensing, Saudi Arabia)

This paper presents a compact near-field electromagnetic sensing probe based on a tapered rectangular waveguide for skin hydration assessment. The probe, with dimensions of 6.0 mm × 3.5 mm × 27.5 mm, operates within the frequency range of 7–11 GHz and employs a flexible high-permittivity dielectric material (PDMS-Al_2O_3-G) to reduce its size and enhance electromagnetic coupling with biological tissue. The tapered geometry provides efficient impedance matching and strong field localization, enabling sensitive detection of hydration-induced dielectric variations. Numerical simulations using a realistic 3D human hand model demonstrate stable reflection behavior under varying tissue conditions. By varying the skin dielectric properties by ±5–20%, obvious reflection shifts are observed, demonstrating high sensitivity to hydration-related dielectric changes. The results confirm the feasibility of the proposed design for real-time, non-invasive hydration monitoring and highlight its potential for further enhancement and implementation.

3.36 Demonstration of Snap-on Fasteners' Polarization- and Pattern-Reconfigurable Wearable Textile Antenna

Aris Tsolis (NCSR Demokritos, Greece); Sofia Bakogianni (National Centre for Scientific Research Demokritos, Greece); Theodore Zervos (NCSR "Demokritos", Institute of Informatics & Telecommunications, Greece); Chrysanthi Angelaki (NCSR Demokritos, Greece); J (Yiannis) Vardaxoglou (Loughborough University, United Kingdom (Great Britain)); Antonis A Alexandridis (NCSR Demokritos, Greece)

This paper presents the design, implementation and proof-concept of a novel reconfigurable wearable textile antenna. Four snap-on buttons are used, that classed the antenna as a mechanically reconfigurable radiating system. The fastening/unfastening of the buttons initiates the change into radiation patterns and polarization, unaffecting the operating frequency (2.4GHz). Thus, making the antenna a reconfigurable candidate for off and on-body communication links. The reconfiguration concept is validated via both free-space measurements and indoor demonstration measurements by using a liquid human torso phantom. The operation and potential of the reconfigurable wearable textile antenna is demonstrated by evaluating the signal strength at the antenna's port for both operating modes (on- and off-body communication). The evaluation is based on direct measurements at the antenna port (VNA measurements) but also on the RSSI of a common communication terminal operating in the WiFi (2.4GHz) frequency band.

3.37 Assessing Human Body Influences on the Localization Accuracy of a UWB Antenna Array in a Smartphone Form Factor

Tobias Lafer (NXP Semiconductors & Graz University of Technology, Austria); Klaus Witrisal (Graz University of Technology, Austria)

We propose a method to analyze the influence of the human body on the angle-of-arrival (AoA) estimation performance achievable with ultra-wideband (UWB) antenna arrays, using Cramer-Rao bounds (CRBs). A UWB antenna array has been developed in the form factor of a smartphone, based on an existing array design from the literature for 5G cellular applications. The array is subsequently placed on four common phone locations on a human body model, and the radiated fields for each location were determined using field simulations. Based on the radiated fields and the reciprocity property of the antenna array, the CRBs for the azimuth and elevation estimates of an incident plane wave under additive white Gaussian noise channel conditions can be determined. The CRBs for all four phone positions are finally compared to the CRBs for the free-space case, to assess the impact of the human body on the AoA estimation performance.

3.38 Circularly Polarized on-Glass Bidirectional Antenna for UHF RFID Applications

Thipamas Phakaew (Chiang Mai University, Thailand); Juin Acharjee (NSHM Knowledge CAMPUS DURGAPUR, India); Muhammad Uzair (King Mongkuts University of Technology North Bangkok, Thailand); Kittisak Phaebua (King Mongkut's University of Technology North Bangkok, Thailand); Dirk Heberling (RWTH Aachen University, Germany); Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok & The Sirindhorn International Thai-German Graduate School of Engineering, Thailand)

In this paper, a circularly polarized bidirectional antenna fabricated on a glass substrate is proposed for UHF RFID applications. The antenna design integrates a bent radiator element with a coplanar ground plane and four loading stubs to excite orthogonal surface currents, thereby generating circular polarization while broadening the impedance bandwidth. The measured results align closely with simulations, demonstrating an operating frequency range from 843 to 991 MHz, effectively covering the global 860-960 MHz UHF RFID band. The proposed on-glass antenna exhibits right-hand circular polarization with an axial ratio below 2.66 dB across the global UHF RFID band and a measured gain between 2.8 and 3.05 dBic. The antenna's compact size, bidirectional pattern, and circular polarization make it particularly well suited for UHF RFID-enabled glass doors and windows for access control systems.

Tuesday, April 21 13:30 - 14:40

P1-EO1 **Electromagnetic Surfaces and Absorbers**

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Electromagnetics
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 3

3.58 Circularly Periodic Multi-Band High Impedance Surface Integrated with a Wideband Spiral Antenna - Performance Results

Kshitij Lele and Chris Bartone (Ohio University, USA)

A circularly periodic multi-band High Impedance Surface was designed and integrated with a wideband spiral antenna while maintaining a low profile, and unidirectional radiation pattern with good gain. The multi-band HIS was designed to have 0° reflection phase at three design center frequencies: 1.375GHz, 2.4GHz, and 5.8GHz to provide multi-band performance. A design procedure for the HIS is presented. Rings of this HIS are divided into three sub-bands such that the wavelength represented by the design frequency of each sub-band corresponds to the circumference of the radiating spiral element at the center of each sub-band. A spiral antenna was placed at a short distance above the HIS. This full antenna structure was fabricated and tested in an anechoic chamber. Simulated and measured results at two frequencies within each sub-band are presented. The full antenna structure achieved good multi-band performance in terms of return loss, bandwidth, radiation patterns and total gain.

3.60 Design and Placement of RF Absorbers for 2.4 GHz Interference Mitigation in Laptop Environments

Chung-En Wu and Yu-Kai Huang (National Taipei University of Technology, Taiwan); Kuan-Hsueh Tseng (Micro-Star INTL CO., LTD, Taiwan); Cheng-Hsiung Chiang (Micro-Star INTL CO., LTD., Taiwan); Chao-Yu Chen (Micro-Star INTL CO., LTD, Taiwan); Chen-Kun Yang (Micro-Star INTL CO. LTD, Taiwan); Yen-Sheng Chen (National Taipei University of Technology, Taiwan)

Electromagnetic interference (EMI) from high-speed laptop circuits couples into the 2.4 GHz Wi-Fi band, degrading antenna matching and link quality. Conventional shielding and filtering are constrained by cost and layout. This work proposes compact RF absorbers tailored for laptop use to suppress coupling while preserving antenna performance. The study combines unit-cell design across substrates of different permittivities with placement evaluations from free space to integration with a grounded Wi-Fi antenna. Results show ceramic substrates yield unit-cell footprints below 4 mm but restrict usable bandwidth to <50 MHz, while 10 mm FR4 cells provide full 2.40–2.48 GHz coverage. A finite 50 × 10 mm² FR4 absorber reduced interference transfer by over an order of magnitude when positioned optimally, whereas a metallic sheet reflected energy and destabilized the source. With a grounded Wi-Fi 7 antenna, the absorber had insignificant effect, indicating absorber-antenna co-design is required for EMI suppression in laptops.

3.61 Scattering Suppression of Metal Square Rod with Mantle Cloak Structure Composed of Strip Conductor

Hiroshi Hashiguchi, Samu Fujisaki and Naobumi Michishita (National Defense Academy, Japan); Kiyoshi Sakimoto (& The Yokohama Rubber Corp., Japan); Teruki Miyazaki and Masato Tadokoro (The Yokohama Rubber Co., Ltd., Japan)

The mantle cloak has attracted attention due to its ability to suppress the reflection and scattering of incident waves from an object. This paper presents a mantle cloak composed of a strip conductor and a dielectric substrate for a square rod structure. The metal square rod is 0.2 wavelength in size at 3.5 GHz, and each strip conductor parameter is varied to obtain the mantle cloak characteristics. The operation mechanism of the scattering cancellation of this structure is clarified by the current distribution in the simulation. The validity of the proposed structure is demonstrated by the comparison of simulation and measurement results.

3.62 Enhanced Linear Phase Control of a K-Band Reconfigurable Intelligent Surface via Coupled Hollow I-Shaped Resonators

Kun Pang, Yufan Chen, Hangyu Lu and Baoxin Lei (Sun Yat-sen University, China); Shaoqiu Xiao (Sun Yat-Sen Univerisity, China)

This paper presents a K-band (20–26 GHz) reconfigurable intelligent surface (RIS) unit cell operating in the millimeter-wave range. The multilayer architecture comprises two resonant layers and one reflective layer, fabricated on RO3003 substrates with a total thickness of 1.9 mm and a unit size of 4 × 4 mm (≈0.30λ at 22 GHz). Four MA4AGP907 PIN diodes are symmetrically arranged along the x-z and y-z planes for reconfigurability. The reflective layer is gold-plated, and copper vias interconnect the resonant layers. Each resonant layer uses a 90°-rotated I-shaped patch to enable dual-mode coupling. This configuration ensures wideband stability and a phase-tuning range of about 360°. Within 22–23 GHz, the design achieves improved phase linearity and reflection loss below 1.6 dB in four primary coding states, while an additional state offers finer tuning with loss under 2.5 dB. The DC biasing network will be integrated with control algorithms in future work.

3.63 A Simple Equivalent Circuit Approach for Multi-Band Polarization Converters Design

Emilio Arnieri (University of Calabria, Italy); Francesco Greco (Antecnica Srls, Italy); Raffaele De Marco and Luigi Boccia (University of Calabria, Italy); G. Amendola (Universita della Calabria, Italy)

A systematic design method for multi-layer multi-band linear to circular polarization converters based on classical filter theory is presented. The proposed design method uses a couple of second-order band-stop filters on each layer to create a single-band polarizer. Multiple such layers are then cascaded together to create the desired N-band response. An equivalent circuit model for the multi-layer polarizer is investigated. Equivalent circuit parameters are determined from system-level performance indicators such as the desired center frequency of operation. Circuit parameters are then related to physical parameters using closed-form equations. A design example of a dual-band polarizer for K-Ka band applications is illustrated. Anyway, the method is general and can be applied to the design of more complex configurations for N-band applications.

3.64 A Width-Tunable Topological Valley-Locked Waveguide for mmWave Systems

Hai Lin, Zihao Yu and Rui Zhou (Central China Normal University, China)

Valley-locked topological waveguides integrate the robustness of topological transport with millimeter-wave systems, opening new pathways for the development of next-generation communication architectures. However, existing structures are constrained by modal fields confined to fixed domain walls, limiting their practical application potential. This work proposes a width-tunable topological valley-locked waveguide structure. By incorporating a tunable ridge channel within the domain wall region, the design achieves flexible adjustment of mode width while preserving robust transmission characteristics. The structure supports metal boundary conditions, reducing the waveguide's lateral dimension by 50% while maintaining excellent compatibility with conventional waveguides. The width-tunable characteristic introduced in this study provides a high-performance and highly compatible guided-wave solution for high-density millimeter-wave interconnect systems.

3.65 Pole-Zero Based Design Methodology for Frequency Selective Surfaces with Coupled Dipoles

Julio Sanchez-Paredes (UMA, Spain & Telma, Spain); Enrique Márquez-Segura (Universidad de Malaga, Spain)

Frequency Selective Surfaces (FSS) are widely used in antennas, radomes, shielding, and spatial filtering. Their design traditionally relies on equivalent circuits or full-wave optimisation, often providing limited physical insight. This study applies the pole-zero matching technique from filter theory to multilayer FSS with coupled dipoles, enabling precise placement of resonances and transmission zeros. Using a circuit-based model for initial design, followed by full-wave refinement, the approach offers both physical insight and accurate control of passband and stop bands.

3.66 Resistively-Enhanced EM Absorber for Next-Generation Stealth and Public Safety Application

Wahaj Abbas Awan and Domin Choi (Chungbuk National University, Korea (South)); Seonggyoon Park (Kongju National University, Korea (South)); Dongkyu Sim and Nam Kim (Chungbuk National University, Korea (South))

A compact, geometrically simple ultra-wideband (UWB) absorber is designed for electromagnetic (EM) applications like stealth or public safety. The unit cell design offers a compact size of 6.25 mm × 6.25 mm, consisting of a circular loop and cross-shaped stub. Four diodes are loaded into the circular loop while four resistors are loaded into the cross-shaped structure. Parametric analysis is carried out to optimize the value of resistor which results in UWB ranging 7.2-18.2 GHz. The absorber offers a peak absorption of 99.99% at 7.75 GHz and while the minimum absorption of 90% is observed at 12.5 GHz. A sample array is fabricated and tested to verify the results, where the strong comparison is observed. Along with that, the proposed absorber overperforms the literary work by offering a compact size, UWB, simple structure, and angular stability, thus making it a strong candidate for present and future electromagnetic applications.

Tuesday, April 21 13:30 - 14:40

P1-EO2 **Optimisation and FSS techniques**

TO4 RF sensing for automotive, security, IoT, and other applications / / Electromagnetics

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Level 3

3.39 Polarization Conversion Induced by Structural Asymmetry in Pixelated Metasurfaces

Haewon Jung (Korea Research Institute of Standards and Science, Korea (South)); Dal-Jae Yun (Chungnam National University, Korea (South)); In-June Hwang (Korea Research Institute of Standards and Science (KRISS), Korea (South)); Jin-Hyeok Kim, Seoleun Shin, Young-Pyo Hong and In-Ho Lee (Korea Research Institute of Standards and Science, Korea (South))

Metasurfaces composed of subwavelength unit cells offer versatile platforms for manipulating electromagnetic waves. Symmetric configurations preserve the polarization of incident waves, while structural asymmetry introduces additional scattering channels that lead to polarization conversion. This work experimentally demonstrates cross-polarized transmission in pixelated frequency selective surfaces (FSSs) with controlled asymmetry. Three designs were implemented using copper-on-PET structures, with asymmetry defined by shift, period, and defect parameters applied to the unit-cell pixels. Both symmetric and asymmetric variants were fabricated as 28 x 28 unit-cell arrays for free-space measurements in the Ka-band (26.5-40 GHz). Polarization-resolved measurements, calibrated with a gated-reflect-line procedure and refined with time-domain gating, enabled reliable extraction of co- and cross-polarized transmission coefficients. The results confirm that structural asymmetry controls the degree of polarization conversion, highlighting the potential of pixelated metasurfaces for polarization control and multifunctional electromagnetic applications.

3.40 Firat Outer Model Fractal Effect on Frequency Selective Surfaces

Leonardo Oliveira de Sousa (Universidade Federal Rural Do Semi-Árido - UFERSA, Brazil); Samanta de Holanda (Federal Rural University of Semi-Arid, Brazil); Gabriel G. Machado (Ulster University, United Kingdom (Great Britain)); Isaac B. T. da Silva (Federal Rural University of Semi-Arid, Brazil)

This work presents an original proposal of a Frequency Selective Surface based on the Circular Firat Fractal. The model proposes a consecutive reduction of reference radius and structure removal, presenting an outer radius reduction circle, which we named Firat Outer Model. The reference unit-cell is a circular patch, designed for 3.5 GHz. The proposed mathematical modeling was applied on the circular patch, and the unit-cells were redesigned to resonate at 3.5 GHz, aiming to evaluate the miniaturization behavior, where miniaturization factor of 90.23% was verified for the area occupied by a unit-cell. Transmission coefficients and angle mean deviation were evaluated, from 0° to 60°. The proposed model significantly reduced the reference dimensions, providing small unit-cells, which results in a higher concentration of elements in the array. Finally, the design achieves remarkable angular stability, with most angle mean deviations below 1%.

3.41 Design and Analysis of Equivalent Homogeneous Media Based on Polarizability Parameters of P .T.D-Symmetric Surfaces

Roee Geva (Tel Aviv University, Israel); Mario Silveirinha (University of Lisbon - Instituto Telecomunicacoes, Portugal); Raphael Kastner (Tel Aviv University, Israel)

The polarization inversion property of P.T.D - symmetric systems is linked to an equivalent representations of the system by general polarizability parameters. These nonunique representations allow for homogeneous models that can replace complex P.T.D structures while preserving their polarization characteristics. We utilize these models to mimic a simple wideband P.T.D structure in the low-frequency regime counting for realistic commercial materials.

3.42 Broadband Pixelated Log-Periodic Antenna Using Binary Particle Swarm Optimization

Rasool Keshavarz, Amanath Ullah, Javad Jafaryahya, Eistiak Ahamed and Negin Shariati (University of Technology Sydney, Australia)

This paper presents a novel approach to enhance the bandwidth of Log-Periodic Antennas (LPAs) through a pixelated configuration optimized using Binary Particle Swarm Optimization (BPSO). The proposed Pixelated Log-Periodic Antenna (PLPA) achieves substantial bandwidth improvement compared to conventional printed LPAs of similar size. Two optimized designs demonstrate notable performance gains: the first achieves a bandwidth of 970 MHz, corresponding to a 13% increase in fractional bandwidth, while the second reaches 1240 MHz, yielding a 22.2% enhancement. These results confirm that the pixelated design methodology effectively expands antenna bandwidth within a compact footprint, offering a practical and manufacturable solution for wideband wireless communication systems.

3.43 Rapid Surrogate-Aided Global Antenna Optimization with Dual-Resolution EM Analysis and Dimensionality-Reduced Fine-Tuning

Slawomir Koziel and Anna Pietrenko-Dabrowska (Gdansk University of Technology, Poland)

This work presents a novel cost-efficient framework for global antenna optimization. The search is performed within the space of operating parameters and supported by simplex-based regression models. A low-fidelity electromagnetic (EM) analysis is employed to carry out global exploration, which is subsequently refined through rapid fine-tuning using high-fidelity EM simulations. To accelerate the process, implicit dimensionality reduction is introduced by restricting finite-difference-based sensitivity updates to a limited set of critical directions that exert the strongest influence on antenna characteristics. Validation studies confirm that the proposed methodology consistently outperforms state-of-the-art benchmark techniques in terms of both reliability and computational efficiency.

Tuesday, April 21 13:30 - 14:40

P1-P01 **Propagation measurements and channel characterisation**

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Propagation

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Marta Cavagnaro (Sapienza University of Rome, Italy)

Room: Poster Area

3.44 Antenna Isolation Measurements for in-Band Full-Duplex in Broadcast Tower Deployments

Eneko Iradier, Marta Fernandez, Iñigo Bilbao, Jon Montalban Sanchez and Pablo Angueira (University of the Basque Country, Spain); Zhihong Hong (Communications Research Centre, Canada); Yiyan Wu (Western University, Canada)

In-band full-duplex (IBFD) systems offer the potential to double spectral efficiency by enabling simultaneous transmission and reception within the same frequency band. A key barrier to practical deployment, however, is the strong self-interference caused by transmitter-receiver coupling. Accurate characterization of antenna isolation under real-world conditions is therefore essential. This work reports field trials at two broadcast transmission sites to assess isolation performance under different tower configurations. Results indicate that isolation levels can exceed 100 dB in structurally complex environments, while simpler configurations typically yield 60-80 dB. Furthermore, the measurements show that isolation does not scale linearly with antenna spacing but remains stable over time, providing critical insights for the design of interference cancellation schemes. These findings establish practical guidelines for the deployment of IBFD technology in next-generation wireless networks.

3.45 Spatial Diversity and Multiplexing Modeling for Massive MIMO Channels in Industrial Environments

Yunqi Feng (Ghent University, Belgium & IMEC, Belgium); Pierre Laly (University of Lille, France); Eric P Simon (IEMN CNRS UMR8520, France); Valentin Picquet and Régis Zongo (University of Lille, France); Mamoun Guenach (Imec, Leuven & Alcatel Lucent, Belgium); Claude Desset (IMEC, Belgium); Nazar Muhammad Idrees (IMEC, Leuven, Belgium); Wout Joseph (Ghent University/IMEC, Belgium); Emmeric Tanghe (Ghent University, Belgium); Davy P Gaillot (University of Lille, France)

Spatial diversity gain and spatial multiplexing gain are two fundamental metrics to model the multiple-input-multiple-output (MIMO) channel performance. To evaluate the benefit of deploying massive MIMO in industrial environments for smart factory applications, it is important to assess the diversity gain and multiplexing gain based on realistic massive MIMO radio propagation channel measurements. Based on measured 64 by 4 massive MIMO channels, this papers models the spatial multiplexing gain and diversity gain by focusing on single user scenarios under different propagation scenarios. Cross-polarized channels are shown to have better multiplexing gains than co-polarized channels due to lower channel correlations, and the gains are close to the theoretical upper bound. However, diversity gains are more sensitive to the channel correlations, and are significantly lower than theoretical upper bound. The findings in this paper shows the importance of considering channel correlation for the application of massive MIMO in industrial environments.

3.46 EM Field Measurement Using Frequency-Modulated Infrared LEDs Array and Neuromorphic Camera

Jean Rioult (Université Gustave Eiffel, France); Sebastien Ambellouis (Gustave Eiffel University, France)

Mapping electromagnetic (EM) field distributions on planar surfaces conventionally relies on complex instrumentation, involving synchronized sensor arrays, digital ad-dressing, and high-speed data acquisition systems. In this article, we present a new scalable and low-cost multi-sensor architecture for high-speed EM field measurement and visualization. Each conversion module includes a detachable RF detection module, with a frequency conversion stage that encodes the detected EM amplitude as a frequency variation. This frequency-modulated digital signal is driving an infrared LED, enabling the optical transmission of the measurement data. A neuromorphic (event-based) camera operating at kilohertz frame rates captures the LED activity, providing a dense spatio-temporal representation of the EM field. This approach eliminates the need of electronic synchronization of the sensors and simplify the complexity of the hardware. The proposed setup enables real-time observation of EM phenomena such as antenna beam scanning or the movement of an energy spot during time reversal experiments.

3.46 Attenuation Assessment for Unshielded Facilities Based on Inside-to-Outside Propagation

Changhee Hyoung (Electronics and Telecommunications Research Institute, Korea (South)); Jong Hwa Kwon (ETRI, Korea (South))

This paper proposes and validates an inside-to-outside propagation method for assessing electromagnetic attenuation for unshielded facilities. Unshielded facilities, such as general buildings, are composed of heterogeneous materials and structural discontinuities. The proposed approach is based on the principle of electromagnetic reciprocity, positioning the transmitter inside the target space and the receiver externally. The validation was performed using a reconfigurable testbed emulating reinforced concrete and tempered glass windows. The reciprocal single-point method, utilizing a stirrer and directional antennas, was benchmarked against the multi-point spatial averaging method and the single-point method, as defined in the newly amended IEC 61000-4-23 standard. Results show strong consistency between the reciprocal inside-to-outside configuration and the standard outside-to-inside multi-point method. The mean electromagnetic attenuation obtained with the proposed method agrees with the multi-point baseline to within a practical tolerance. The proposed method enables reliable measurements with systems of limited dynamic range and easing on-site constraints.

3.48 Sub-6 GHz Channel Measurements in Cell-Free Networks with the MaMIMOSA Channel Sounder

Dimitrios G. Nixarlidis, Andy Regis Zongo, Valentin Picquet, Pierre Laly and Davy P Gaillot (University of Lille, France); Joumana Farah (INSA Rennes, France); Eric P Simon (IEMN CNRS UMR8520, France)

This paper presents an extensive channel measurement campaign for cell-free massive MIMO networks, conducted on the scientific campus of Villeneuve d'Ascq using the MaMIMOSA sub-6 GHz channel sounder. The transmitter comprises a 64-element patch antenna array, positioned at 36 distributed locations, while the receiver is a cart with eight omnidirectional antennas moved to 33 sites across multiple floors in two buildings and outdoor areas. Measurements were taken in both indoor and outdoor scenarios with dual polarization (vertical and horizontal) at the transmitter to investigate polarization diversity and depolarization phenomena. The resulting dataset enables emulation of a realistic cell-free network with 36 virtual access points and 264 user equipments. Preliminary analysis quantifies the influence of environment and polarization on key metrics such as signal-to-noise ratio (SNR), cross-polarization discrimination (XPD), and access point selection diversity, highlighting the role of distributed deployment and polarization for robust cell-free MIMO performance.

3.49 Characterizing Radio Propagation Conditions via Feature Extraction and Clustering of Static and Dynamic Channel Properties

Chiraphan Teekha (Ilmenau University of Technology, Germany); Michael Döbereiner (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany); Christian Schneider and Joerg Robert (Technische Universität Ilmenau, Germany)

As 6G wireless systems aim to operate across diverse environments and frequency bands, accurately characterizing radio propagation becomes increasingly important. Standardized models often overlook fine spatial variations caused by local geometry and mobility. This paper presents a reproducible framework for propagation characterization based on both static and dynamic channel features. Using RMS Delay Spread (DS), RMS Azimuth Spread of Arrival (ASA), and capacity, we extract features through spatial segmentation and slope-based analysis. An unsupervised clustering approach is applied to group similar propagation behaviors without relying on predefined assumptions. Beyond spatial variation, the evolution of propagation features is analyzed along segmented tracks, revealing transitions and trends that reflect changes in local environments during mobility. Validation through map-based analysis highlights strong spatial consistency and the ability to reflect environmental influence. Overall, the proposed framework offers an interpretable and automated method for understanding propagation behavior, supporting environment-sensitive characterization of the radio channel.

3.50 Evaluation of Antenna Performance in Controlled Environments: A Comparative Study

Adrian Bekasiewicz, Vorya Waladi and Rafal Lech (Gdansk University of Technology, Poland); Yingsong Li (Anhui University, China); Ilona Piekarz and Jakub Sorocki (AGH University of Krakow, Poland)

Far-field experiments performed in controlled setups are considered as a standard tool for validation of antenna simulation models. However, reliability of responses obtained in such laboratories is rarely subject to investigation. In this work, a study of measurements performed at three anechoic chambers is considered. The experiments involved evaluation of the radiation patterns, acquired for the same antenna, over a range of frequencies and their comparison against simulation results. The effects of post-processing on fidelity of the measurements are also investigated. The results demonstrate that the quality of responses is subject to conditions and test-protocols used within the test site at hand.

3.51 Measurements and Analysis of Maritime Ship-to-Ship Communications at 5.8 GHz

Paulo Victor G Sampaio (Brazilian Navy, Brazil); Rodrigo Amitrano Bilobran (Universidade Federal Fluminense & Marinha do Brasil, Brazil); Pedro Gonzalez Castellanos (Federal Fluminense University, Brazil); Roberto B. Di Renna (Universidade Federal Fluminense, Brazil); Anderson Soares (Marinha Do Brasil, Brazil); Luiz da Silva Mello (CETUC-PUC-Rio & Inmetro, Brazil)

Reliable high-data-rate maritime communications are often constrained by the complex and dynamic nature of the propagation channel. This paper presents an experimental characterization of the mobile ship-to-ship radio channel at 5.8 GHz, based on a measurement campaign conducted in offshore waters along the Brazilian coast. We analyze large-scale path loss to determine suitable propagation models for link budget prediction. The study specifically investigates the influence of local atmospheric effects, such as evaporation ducting. Furthermore, the characteristics of small-scale fading are statistically analyzed, providing a comprehensive channel model for designing and simulating robust maritime data links.

3.52 Optimization of SDR-Based Channel Emulators Through EVM and PDR Metrics

Maik Weber, Lennart Thielecke and Thomas Kürner (Technische Universität Braunschweig, Germany)

Channel emulators are an essential tool for validating wireless transceiver performance under reproducible and controlled propagation conditions. While traditional implementations rely on dedicated hardware, recent developments in software defined radio technology enable flexible, real-time emulation of complex channel models on reconfigurable platforms. However, the hardware nonidealities of software defined radios can introduce distortions that compromise the realism of the emulated channel. This paper presents a measurement-based optimization procedure to mitigate such hardware-induced impairments in software defined radio-based channel emulators. The proposed method jointly evaluates the error vector magnitude and packet delivery rate across a two-dimensional gain configuration space to identify optimal operating points ensuring both signal fidelity and reliable packet reception. Experimental results demonstrate that the optimized setup exhibits a distinct operating region where hardware distortions are minimized while maintaining full packet delivery, effectively reproducing additive white Gaussian noise channel conditions.

3.53 Tropospheric Scintillation Measurements on a Q-Band Satellite Link in Madrid

Domingo Pimienta-del-Valle and Jose M Riera (Universidad Politécnica de Madrid, Spain); Pedro Garcia-del-Pino (Universidad Politecnica de Madrid, Spain); Gustavo Siles (Universidad Privada Boliviana, Bolivia); Ana Benarroch (Universidad Politécnica de Madrid, Spain)

Tropospheric scintillation is one of the effects to be better studied in order to obtain a more complete characterization of the satellite-to-Earth propagation channel at millimeter waves. The availability of the Q-band beacon in the Alphasat satellite allows the development of such studies across Europe. In this paper, preliminary results about tropospheric scintillation in a Q-band link are presented. One year of measurements of the Alphasat 39.4-GHz beacon signal collected in Madrid, Spain have been used to analyze this effect. The results show a marked seasonal variability, with stronger scintillation events appearing in summer months. The statistical results are compared to the predictions of the relevant ITU-R model, which behaves considerably well for most of its range of application. Moreover, some conclusions are drawn when comparing these results with those obtained at the same site with different experiments in past years, at 19.7 GHz and 49.5 GHz.

3.54 Indoor Channel Characterization at E and D Bands in Conference Room Scenarios

Sana Salous, Jiahao Hu, Amar Al-Jzari and Yubei He (Durham University, United Kingdom (Great Britain))

Future sixth-generation (6G) wireless systems will require ultra-high data rates, driving the use of wider bandwidths in the E and D frequency bands. To investigate the propagation characteristics across the transition between these bands, wideband indoor channel measurements were conducted at 84.5 GHz and 145.5 GHz in two conference rooms with different layouts. The measurement setup employed a rotating transmitter (Tx) antenna to capture channel impulse responses (CIRs) at different angles, from which power delay profiles (PDPs) and path loss were estimated. The results show that the PDPs vary significantly with the Tx rotation angle and that higher frequencies experience larger propagation loss. Path loss was modeled using the close-in (CI) and floating-intercept (FI) models. These findings provide useful insights into indoor propagation behavior at high frequencies and can support future system design and modeling for 6G communications

3.55 Measurements and Ray-Tracing Comparison of Multi-Frequency Car Penetration Loss

Marina Lotti and Andrea Garzia (Fondazione Ugo Bordoni, Italy); Claudia Carciofi (Via Indipendenza 24, Italy); Simona Valbonesi (Fondazione Ugo Bordoni, Italy)

A proper and rigorous assessment of Penetration Loss inside cars is a crucial factor for propagation and coverage prediction of 5G and 6G networks, especially for automotive mobile communications scenarios. This paper presents a novel multi-frequency measurement campaign of car penetration loss in the frequency range 700-3800 MHz. This study complements previous experimental measurements by introducing new environments and scenarios, including a variety of geometrical configurations of vehicles and material compositions. Furthermore, the paper provides a detailed analysis of in-vehicle radio signal propagation using a combination of measurements and numerical simulations. The study examines how signal behaviour is influenced by a set of relevant variables, including frequency, vehicle orientation relative to the radio signal, the on-board device's position, and characteristics of the car glazing. Additionally, a preliminary analysis using 3D ray-tracing techniques is proposed to investigate the electromagnetic field behaviour inside the vehicle and the perturbations caused by a vehicle.

3.56 Indoor Measurements of 5G Sidelink for Broadband Public Safety Applications

Christoph Domnik (University of Duisburg-Essen & Hochschule Niederrhein University of Applied Sciences, Germany); Michael Meuleners and Christoph Degen (Hochschule Niederrhein University of Applied Sciences, Germany)

This paper presents indoor measurements of 5G sidelink coverage using on-board units originally designed for vehicle-to-everything communication. The objective is to evaluate the suitability and challenges of sidelink communication for broadband communication in the context of public safety organizations. The experiments focus on the packet loss rate during indoor data transmission under realistic deployment conditions. A direct sidelink connection between two on-board units is compared to a relay-assisted setup. The results show that the use of a relay is necessary to achieve good coverage in realistic scenarios, especially when communication over multiple stories is required.

3.57 Characterization of Tropical Rainfall Rates and Implications for Wireless and Satellite Communications

Khairayu Badron, Ahmad Fadzil Ismail and Atikah Balqis Basri (International Islamic University Malaysia, Malaysia); Yasser Asrul Ahmad (IIUM, Malaysia); Young Chul Lee (Mokpo National University (MMU), Korea (South)); Mohamed Safri Mahmud Mohayuddin (MEASAT, Malaysia)

Climate change, driven by global warming and greenhouse gas emissions, is profoundly transforming global weather patterns. These changes manifest through irregular rainfall, altered seasons, and increased frequency of extreme weather events. Besides impacting the environment, ecosystems, and human life, climate change significantly affects technological systems-particularly high-frequency satellite communication, which is critical for data transmission, wireless connectivity, and emerging applications such as autonomous maritime operations. This research will investigate the analysis of rainfall rate measurement in Malaysia and compare with the Ku and Ka band signal received from MEASAT 3D co-located with the optical laser sensor disdrometer

3.58 How Temporal Dispersion of Radio Channels Depends on Signal Bandwidth

Jarosław Wojtuń, Tomasz Grasza, Cezary Ziółkowski and Jan M Kelner (Military University of Technology, Poland); Aniruddha Chandra (National Institute of Technology Durgapur, India); Radek Zavorka (Brno University of Technology, Czech Republic); Josef Vychodil (Brno University of Technology & BUT Brno, Czech Republic); Jiri Blumenstein and Tomas Mikulasek (Brno University of Technology, Czech Republic); Ales Prokes (Brno University of Technology & Sensor, Information and Communication Systems Research Centre, Czech Republic)

The degree of temporal dispersion of a radio channel is the basis for assessing its transmission capabilities. This paper addresses the practical issue of measuring the temporal parameters of a signal transmitted in the millimeter-wave (38 GHz) range. These parameters provide the basis for assessing the degree of dispersion of the received signal. The measurement results show that both the mean and RMS values of the delay spread depend on the distance between the transmitter and receiver as well as the bandwidth of the transmitted signals. The function description of these relationships (model) is determined based on a statistical analysis of the obtained measurement data obtained in a selected indoor corridor under line-of-sight conditions.

Tuesday, April 21 14:40 - 15:20

IN04 Zoya Popovic - Millimeter-Wave GaN Front-End MMICs

/ / Antennas

Chair: Mauro Ettorre

Zoya Popovic is a Distinguished Professor and the Lockheed Martin Endowed Chair in Electrical Engineering at the University of Colorado, Boulder. She obtained her Dipl. Ing. degree at the University of Belgrade, Serbia, and her Ph.D. at Caltech. She holds an honorary doctorate from the Carlos III University in Madrid. She was a Visiting Professor with the Technical University of Munich, and Chair of Excellence at Carlos III University in Madrid. She has graduated over 75 doctoral students. Her research interests are in microwave and millimeter-wave high-performance III-V semiconductor circuits, medical applications of microwaves, wireless powering, industrial microwave applications and quantum RF sensing. She was the first woman to receive the URSI Issac Koga Gold Medal. She is a Fellow of the IEEE and the recipient of two IEEE MTT Microwave Prizes for best journal papers, the White House NSF Presidential Faculty Fellow award, the ASEE/HP Terman Medal, the Alexander von Humboldt Research Award and was named IEEE MTT Distinguished Educator. She currently serves as Editor in Chief of the Proceedings of the IEEE. She is a Fellow of the National Academy of Inventors and a Member of the National Academy of Engineering.

Room: Berlin

14:40 Millimeter-Wave GaN Front-End MMICs

Zoya Popovic (University of Colorado at Boulder, USA)
This talk presents an overview of GaN-based monolithic microwave integrated circuits (MMICs) designed and characterized at the University of Colorado and fabricated by various foundries. The MMICs perform all functions necessary for a phased-array analog front end and cover Ka through W bands. Specifically, a 26-30 GHz switchless half-duplex bidirectional amplifier chip is detailed, showing 2.9W of transmit power with 15 dB gain and 3.8 dB noise figure with 27 dB receive gain and 50 dB transmit-receive isolation. A switched 70-110GHz transmit-receive front end integrated on a single chip is also presented, with peak 0.8W of power and 15 dB saturated gain in transmit mode and 5.2 dB noise figure and 22 dB gain in receive mode, including the switch loss. Finally, a 75-100 GHz tunable quasi-circulator with 30 dB isolation, integrated with a power amplifier and low-noise amplifier, is demonstrated for full-duplex operation.

Tuesday, April 21 14:40 - 15:20

IN11 **Ke Guan - From GIS to CIR: HyperRT - An End-to-End Framework for Building High-Fidelity, Real-Time Wireless Digital Twins**

/ / Propagation
Chair: Thomas Kürner
Dr. Ke Guan is a Full Professor at the State Key Laboratory of Advanced Rail Autonomous Operation and the School of Electronic and Information Engineering, Beijing Jiaotong University. In 2024, he was elected a Life Fellow of the Royal Society for Arts, Manufactures and Commerce (Life FRSA). In 2016, he was awarded a Humboldt Research Fellowship. From February 2023 to July 2023, he was a Guest Professor at Technische Universitaet Wien, Austria. In 2025, He was selected as one of the "10 Leading Chinese Talents in Science and Technology in Europe" by the United Chinese Professional Associations in Europe. He is the major contributor of the clutter loss model in ITU-R P. 2108 and the THz channel model in IEEE 802.15.3d-2017. He has authored/coauthored two books and five book chapters, more than 200 journal and conference papers, and more than 20 patents. His current research interests include the digital twinning of electromagnetic propagation environments in various complex scenarios based on ray-tracing and machine learning. His project TwinSWAN won the 2024 IET Excellence and Innovation Awards. His papers received 14 Best Paper Awards, including the IEEE Vehicular Technology Society Neal Shepherd Memorial Best Propagation Paper Award in 2019 and 2022. He is Beijing Jiaotong University's contact person for 3GPP and ETSI and a member of the IEEE VTS Propagation Committee and the IEEE AP/S TC on Propagation and Scattering.

Room: Edinburgh

14:40 From GIS to CIR: HyperRT - an End-to-End Framework for Building High-Fidelity, Real-Time Wireless Channel Digital Twins

Ke Guan, Hao An, Ting Liu, Lei Yang and Bo Ai (Beijing Jiaotong University, China); Xinhui Wang (ZTE Corporation, China); Markus Rupp (TU Wien, Austria); Thomas Kürner (Technische Universität Braunschweig, Germany)

To realize smart ecosystems, wireless channel digital twins must generate highly accurate channel data in real time across diverse scenarios. A core bottleneck lies in producing high-fidelity channel impulse responses (CIRs) at network operation speed. This study introduces HyperRT, an end-to-end framework that integrates ray tracing (RT) and artificial intelligence (AI) to address this challenge. First, Geospatial-Electromagnetic Mapping Intelligence (GEMI) reconstructs 3D models autonomously. Second, a novel paradigm acquires electromagnetic (EM) properties of multi-type media in real-world environments. Finally, HyperRT overcomes the real-time high-fidelity channel characterization challenge through triple optimization in algorithm design, heterogeneous computing, and data analysis. This improves efficiency by 2-3 orders of magnitude over the high-performance ray-tracing platform CloudRT, automating the pipeline from Geographic Information System (GIS) data to final CIR. Demonstrated in 5G for Railway (5G-R) networks and Integrated sensing and Communication (ISAC) channel generation, HyperRT establishes a solid foundation for high-fidelity wireless channel digital twins.

Tuesday, April 21 15:50 - 17:30

A04 **Advanced Antenna Manufacturing Techniques**

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Krzysztof Nyka (Gdansk University of Technology, Poland), William Whittow (Loughborough University, United Kingdom (Great Britain))

Room: Dusseldorf

15:50 Graphene-Based Substrate Integrated Waveguide Leaky-Wave Antenna

Alireza Mallahzadeh and Mahyar Mehri (University of Surrey, United Kingdom (Great Britain)); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))
In this article, the concept, analysis, and design of a substrate integrated waveguide (SIW) leaky-wave antenna incorporating a graphene ribbon for millimeter-wave operation are presented. It is demonstrated that the SIW supports a leaky mode when the graphene ribbon forming its broad wall is biased with an appropriate DC voltage. Unlike conventional sinusoidally modulated graphene leaky-wave antennas (LWAs), the proposed structure features a uniform configuration and operates using a single bias voltage that controls its propagation constant. Using the transverse equivalent technique, the propagation constant and frequency-scanning behavior are characterized. Moreover, the proposed graphene-based SIW LWA provides fixed-beam radiation suitable for point-to-point communication. Based on this structure and the developed analytical model, an LWA with fixed-beam capability is designed and verified through simulation, exhibiting a 28.5% squint-free bandwidth that makes it well-suited for high-speed wireless applications.

16:10 Graphene-Based Transparent Fabry-Perot Antenna in D-Band

Muhammad Umar Riaz (Politecnico di Torino, Italy); Fabio Paonessa (Consiglio Nazionale Delle Ricerche (CNR-IEIIT), Italy); Giuseppe Valerio Bianco and Giovanni Bruno (CNR-NANOTEC, Italy); Antonella D'Orazio (Politecnico di Bari, Italy); Ladislau Matekovits (Politecnico di Torino, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

The limited bandwidth and availability of the electromagnetic spectrum below 100 GHz have led researchers to explore higher frequencies to provide high data transmission rates. This in turn requires innovative antenna technologies. This paper investigates the possibility of using multi-layer graphene to manufacture fully transparent antennas; i.e., antennas that can be integrated on a device screen. Experimental results in the D-band (110-170 GHz) show enhanced reflection behavior with respect to the glass support. This phenomenon is applied in constructing a transparent Fabry-Perot antenna. Simulated and measured results show good agreement, confirming the proposed design.

16:30 Additively Manufactured Fully-Metallic Multifunctional W-Band Antenna Architectures

Omar Orgeira and Jose Rico-Fernandez (Northern Waves AB, Sweden)

The continuous evolution of communication systems toward millimeter-wave and sub-terahertz frequencies demands highly integrated and precise antenna front-ends. Traditional subtractive manufacturing techniques face severe limitations at these frequencies due to assembly complexity and tight mechanical tolerances. Additive manufacturing (AM) has emerged as a key enabler to overcome these challenges, allowing the realization of compact, lightweight, and fully integrated metallic components. This work presents two fully-metallic antenna architectures operating in W-band. The first design consists of a Boifot orthomode transducer (OMT) connected to a scalar feed horn antenna (SFHA), produced in both, monolithic and two-part configurations, to evaluate the impact of integration on performance. The second design combines a SFHA with a septum polarizer providing dual circular polarization, each connected to an iris filter to enable dual-band operation. Experimental results of the first design show good agreement with simulations, confirming the suitability of AM for complex high-frequency antenna systems.

16:50 Additive Manufacturing of Dielectric High-Gain Horn Antenna for mm-Waves and THz Range

Ashish Kumar (Universidad Carlos III de Madrid, Spain); Muhsin Ali (LeapWave Technologies, Spain); Guillermo Carpintero (Universidad Carlos III de Madrid, Spain)

We present a single-element all-dielectric horn antenna for mmWave-THz applications that eliminates conductor loss while supporting hybrid integration. The antenna is excited by a dielectric-rod waveguide (DRW) feed, enabling seamless interfacing to on-chip or packaged sources as well as standard rectangular-waveguide front ends. An index-matched slot-waveguide termination (SWT) is introduced at the silicon-cyclic olefin copolymer (COC) interface to realize an anti-reflection interface. Numerical analysis validates reflections below -10 dB across 180-400 GHz and below -40 dB at 275 GHz. The SWT launch is expanded by a linear dielectric flare and collimated by an integrated lens, yielding a high-directivity aperture. The combined structure achieves a gain of 21 dBi at 180 GHz and increases up to 29 dBi at 400 GHz with clean E-plane patterns. The material stack and geometry are compatible with additive manufacturing and precision polymer molding, offering a scalable, high-efficiency antennas for next-generation mmWave/THz links and sensing.

17:10 3D-Printed Loxodromic Polarizer for Dual Circularly Polarized Omnidirectional Radiation in the Ka-Band

Javier Melendro-Jimenez (Universidad Politécnica de Madrid, Spain); Adrián Tamayo-Domínguez, Pablo Sanchez-Olivares and Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Jose Luis Masa-Campos (Universidad Politécnica de Madrid, Spain)

This paper presents the design of a spherically conformed anisotropic dielectric polarizer manufactured by 3D printing for Ka-band (26.5-40 GHz) applications. The polarizer consists of dielectric slabs arranged along loxodromic trajectories, providing the required anisotropy to convert the linear polarization of an incident omnidirectional spherical wave into circular polarization. When illuminated by an omnidirectional feed that exhibits linear polarization along the polar direction, the polarizer radiates a left-hand circularly polarized spherical wave. Conversely, when the feed is linearly polarized along the azimuthal direction, the polarizer radiates a right-hand circularly polarized spherical wave. The structure is experimentally evaluated in the 37-40 GHz range using a dual linearly polarized omnidirectional antenna as the feed. Both the antenna and the polarizer are manufactured using additive manufacturing techniques. Measured results show good agreement with full-wave simulations.

Tuesday, April 21 15:50 - 17:30

A07 Antenna Interactions and Couplings at Sub THz and THz Frequencies

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Dongjin Jung (Samsung Electronics, Korea (South) & Skyworks Solutions, USA), Edoardo Negri (Consiglio Nazionale delle Ricerche, Italy)

Room: Prague

15:50 Experimental Demonstration of Glass Wafer-Level Metasurfaces at Sub-THz Frequencies

Bilal Ouardi (CEA Leti, France); Antonio Clemente (CEA-Leti, France); Ronan Sauleau (Universite de Rennes, France); Olivier De Sagazan (University Rennes 1, France); Malo Robin (Université de Rennes, France)

This work presents a transmissive planar metasurface (MS) for wavefront manipulation at sub-terahertz (sub-THz) frequencies. The design employs 1-bit phase control through a three-layer metallic configuration based on polarization conversion. To evaluate fabrication trade-offs, the proposed unit-cell (UC) was implemented on a fused-silica (FS) substrate and compared with a PCB-based counterpart, which has been widely used for static MS. FS-based UC showed improved resolution of metallic patterns, reduced losses, broad bandwidths, and improved angular stability compared to PCB technology. The static sub-THz FS-based MS was fabricated using high-precision lithography and experimentally validated, demonstrating a high-gain beam over wide bandwidth and minimal

16:10 Experimental Verification of the Optical Coupling for a Lens Based Focal Plane Array of Distributed Absorbers Coupled KIDs at 6.98 THz

Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands); Giulia Conenna (SRON, The Netherlands); Daan Roos (SRON & University of Technology Delft, The Netherlands); Dimitry Lamers, Daniela Perez Capelo, Martijn Veen, David J. Thoen, Vishal Anvekar, Stephen J.C. Yates, Robert Huiting and Jochem Baselmans (SRON, The Netherlands)

Lens based focal plane array of distributed absorbers coupled to Kinetic Inductance Detectors (KIDs) are the chosen technology for the hyperspectral imager instrument of an space-based far infra-red observatory, PRIMA. In this paper, design, fabrication, and experimental verification of the optical coupling of such a detector at 6.98 THz is discussed. Specifically, the coupling of the detector array to incoherent distributed sources (i.e. normalized throughput) is quantified experimentally with good agreement against the simulated values from a previously established spectral based technique. The noise equivalent power of the KIDs is also measured with limiting value of 8 x 10^(-20) W/\sqrt(Hz) under negligible optical loading.

16:30 Experimental Evidence of Leaky Resonances in Terahertz Homogenized Metasurfaces Through the Analysis of Complex-Valued Reflection Coefficient

Stella Ventucci (Sapienza University of Rome, Italy); Edoardo Negri (Consiglio Nazionale delle Ricerche, Italy); Walter Fuscaldo (National Research Council (CNR), Italy); Dimitrios Zografopoulos (CNR-IMM, Italy); Francesco Maita (IMM-CNR, Italy); Luca Maiolo (CNR-IMM, Italy); Hugo Enrique Hernandez-Figueroa (Unicamp, Brazil); Emmanouil E. Kriezis (Aristotle University of Thessaloniki, Greece); Paolo Burghignoli and Alessandro Galli (Sapienza University of Rome, Italy)

Fabry-Perot cavity leaky-wave antennas (FPC-LWAs) represent an optimal antenna technology to operate at terahertz (THz) frequencies. The evaluation of the complex modal spectrum of FPC-LWAs is thus a key aspect for their effective use in the THz range. Specifically, the leaky modes can be experimentally identified using THz time-domain spectroscopy in reflection mode since the minima in the reflection-coefficient magnitude, corresponding to the device resonant frequencies, can be associated by reciprocity to the FPC-LWA radiative modes. In this work, we show-through full-wave simulations, analytical evaluations, and experimental results-that the reflection coefficient phase can also plays an essential role, showing that inflection points and zero-crossing points in correspondence of leaky resonances can be effectively detected through THz time domain spectroscopy in reflection mode.

16:50 Outdoor Antenna-Unit with Adaptive Beamwidth for THz Beam Alignment

Simon Haussmann, Maximilian Heckele and Mark Johannes Neff (University of Stuttgart, Germany); Ralf Henneberger (Radiometer Physics GmbH, Germany); Keizo Inagaki (National Institute of Information and Communications Technology, Japan & Waseda University, Japan); Ogaki Arata (Waseda University, Japan); Tetsuya Kawanishi (Waseda University, Japan & National Institute of Information and Communications Technology, Japan); Ingmar Kallfass (University of Stuttgart, Germany)

We present the characterization of a THz antenna system that is developed for high data-rate wireless point-to-point communication. The beamwidth of the antenna can be controlled in order to spread the THz beam to facilitate automated beam alignment of the highly directive beams. In antenna measurements in an anechoic chamber we verify the simulated characteristics of the antenna, which attest beam-adjustment from half-power-beam-width between 0.28° with an antenna gain of 58 dBi and 0.85° with a antenna gain of 48 dBi.

17:10 Effect of Array Length on Directivity of the THz Smith-Purcell Radiation Antenna Made of Graphene Nanotubes

Dariia O. Herasymova (Institute of Radio-Physics and Electronics NASU, Ukraine); Sergii V. Dukhopelnykov (University of Rennes & Institute of Radio-Physics and Electronics NAS Ukraine, Kharkiv, France)

This work investigates the far-field directivity from a modulated electron beam passing over a finite array of identical graphene nanotubes filled with low-permittivity dielectric. The excitation source is a free-space, in-density modulated electron beam with a fixed velocity. To accurately model the graphene's properties, we employ the Kubo formalism and resistive-sheet boundary conditions. Our core approach involves using the separation of variables in local coordinates combined with the Graf addition theorem for cylindrical functions, which effectively reduces the complex electromagnetic scattering problem to a well-conditioned matrix equation and ensures precise control over numerical accuracy. The potential applications are discussed.

Tuesday, April 21 15:50 - 17:30

A21 Lens Antennas

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Nuria LLombart (Delft University of Technology, The Netherlands), Daniel Sjöberg (Lund University, Sweden)

Room: Krakow

15:50 Design of a Geodesic Lens Antenna with Wide Scanning Coverage and Planar Focal Plane

Pilar Castillo-Tapia (Eindhoven University of Technology, The Netherlands); Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

Geodesic lens antennas are robust beamformers that can produce highly directive beams. However, these lenses require integration with the available system architecture. This integration is complicated by the curved focal arc in reported geodesic lens antennas. To address this challenge, a generalized ray tracing (RT) physical optics (PO) model has been developed to enable efficient design of geodesic lens antennas with any arbitrary shape. Here, we use this model to design a wide-scanning lens with a straight focal line, intended to be integrated with a linear feed array, producing a robust antenna system capable of wide-angle beam steering. The proposed antenna is compared with an antenna based on an optically transformed Luneburg lens, demonstrating the high radiation efficiency of the proposed method. The presented design shows the versatility of the in-house RT-PO model and the possibility of integrating highly efficient geodesic lenses with the rest of the antenna system.

16:10 Fourier Series-Based Optimization of Gradient Index Lens Permittivity Profiles Within Manufacturing Limits

Leonard Besse, Yanki Aslan, Sourav Patranabish and Kunal Masania (Delft University of Technology, The Netherlands)

This paper presents a novel method to parametrize gradient index (GRIN) structures based on a Fourier series distribution of the refractive index, scaled to the achievable range imposed by the material and manufacturing process. To demonstrate the proposed approach, a spherically symmetric lens is optimized and compared to a typical Luneburg Lens profile. A computationally efficient ray tracing algorithm is combined with Particle Swarm Optimization (PSO). An open source library is used to generate a dielectric crystal based on triply periodic minimal surface (TPMS) structures with spatially varying fill fraction. The lenses were printed using fused filament fabrication (FFF), fitted with a metallic cap, and radar cross section (RCS) measurements were taken in the 26-40 GHz range. The optimized lens offered marginal RCS improvements over a Luneburg lens with a truncated profile.

16:30 Adjoint Optimization of Dielectric Lens Antennas

Tyler G Burns and Sawyer D Campbell (The Pennsylvania State University, USA); Douglas H Werner and Pingjuan Werner (Pennsylvania State University, USA)

Adjoint-based gradient optimization enables the rapid synthesis of gradient-index (GRIN) and freeform dielectric lenses with high gain and compact form factors. However, achieving manufacturable binary structures while maintaining convergence efficiency remains challenging. This paper introduces a binary coercion strategy integrated within an adjoint optimization framework to drive material distributions toward discrete permittivity states without sacrificing gradient fidelity. Building on prior adjoint-based GRIN lens design methods the proposed approach embeds a converging Heaviside mapping kernel within the iterative update loop, enforcing a binary evolution of the permittivity field while preserving gradient sensitivity. Marking an important step toward practical adjoint-driven lens fabrication and multifunctional electromagnetic structures.

16:50 Design of Flat-Top Lens Using Conformal Transformation Optics for Antenna-in-Package Radar

Johan Zanichelli and Daniel Sjöberg (Lund University, Sweden)
This paper presents the design of a cylindrical, low-profile dielectric lens for antenna-in-package (AiP) radar applications using conformal transformation optics (CTO). The lens is designed to produce an angle-independent gain in the main lobe while suppressing high-angle radiation from a closely spaced Tx/Rx antenna pair, thereby reducing multipath effects in cluttered environments. The design is obtained through an optimization algorithm that estimates the field distribution on the lens using CTO with a geometrical optics approximation. The resulting relative permittivity, ranging from 1 to 2.7, makes the lens suitable for 3D printing. Full-wave simulations at 60 GHz confirm a stable main lobe within 30 degrees of boresight and suppression of high-angle radiation beyond 60 degrees. Sidelobe levels can be further reduced by adding boundary layers to the sides of the lens.

17:10 Ray-Tracing-Tailored Gutman Lenses for Enhanced near-Broadside Radiation of Array Antennas

Robert Molina-Burgués (Polytechnic University of Catalonia, Spain); Luis Jofre (Universitat Politecnica de Catalunya, Spain); Juan M. Rius (Universitat Politècnica de Catalunya, Spain); Jordi Romeu Robert (Politècnica de Catalunya, Spain)
A ray-tracing-tailored Gutman lens design is presented for efficient integration with planar array antennas of arbitrary size, enabling improved near-broadside radiation and smooth beam steering. The method introduces controlled defocusing by trimming the lens before its focal plane, allowing coherent field combination among array elements and enhancing Equivalent Isotropic Radiated Power. A fast inverse ray-tracing tool is developed to estimate key performance metrics, such as aperture magnification and EIRP gain, without requiring time-consuming full-wave optimizations. This tool enables rapid parametric analysis that reveals the influence of lens radius, cut position, and array geometry on near-broadside performance. An additional exponential GRIN modification extends the design's effectiveness and serves as a proof of concept for more complex GRIN distributions. Two design cases are simulated, and the results confirm the ray-tracing predictions, demonstrating up to +7 dB EIRP improvement and validating the approach as an effective solution for compact, high-gain array-lens systems.

Tuesday, April 21 15:50 - 17:30

CS11 Advances in Study and Design of 2-D Leaky-Wave Antennas

T07 Electromagnetic modelling and simulation tools / Convened Session / Electromagnetics
Chairs: Paolo Baccarelli (Roma Tre University, Italy), Davide Comite (Sapienza University of Rome, Italy)

Room: Firenze

15:50 Analysis of Anisotropic Dielectric Strip Grating for Leaky Wave Antennas

Nelson Castro (University Carlos III of Madrid, Spain); Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)
An analysis of the leaky modes supported by a dielectric strip grating intended for leaky-wave antenna applications is presented. The study begins with a discussion of the characteristics of the TM(^z) and TE(^z) modes supported by the periodic waveguide. The dispersion diagrams are then obtained using full-wave simulations, from which the generalized scattering matrix (GSM) is extracted and used to retrieve the complex wavenumber of each mode. Finally, the impact of employing an anisotropic composite material in the grating is investigated, demonstrating the additional degrees of freedom it provides for tailoring the dispersion and radiation characteristics of leaky-wave antennas.

16:10 Cylindrically Conformal Bi-Directional Leaky-Wave Antennas (LWAs) for Flexible Beam-Shaping

David F Hardy and Shulabh Gupta (Carleton University, Canada)
A one-dimensional (1-D) conformal Vivaldi leaky-wave antenna (LWA) printed on a flexible polyethylene terephthalate (PET) substrate suitable for a screen-printed process is presented. By wrapping the linear array into a circular form, the design achieves quasi-twodimensional (2-D) LWA operation, allowing for both conical and pencil beam generation through mechanical bending and frequency scanning. Numerical results in Ansys FEM-HFSS demonstrate that bending angles up to 330° maintain return loss above 10 dB across 8-12 GHz while producing bi-directional side-fire radiation. The effects of mechanical bending and frequency scanning on the radiation patterns are discussed using full-wave simulations.

16:30 2-D Leaky-Wave Antennas Based on Mirror-Symmetric 3-D Dielectric Woodpiles

Alessandro Romano (Roma Tre University, Italy); Vakhtang Jandieri (General and Theoretical Electrical Engineering (ATE), Faculty of Engineering, Germany); Guido Valerio (Sorbonne Université, France); Ludovica Tognolatti and Paolo Baccarelli (Roma Tre University, Italy)
A 3-D periodic woodpile lattice is employed to design a grounded 2-D leaky-wave antenna. The electromagnetic bandgap properties of the unit cell are tuned to achieve a minimum frequency of the upper band (air-band) at the point Z of the Irreducible Brillouin Zone, which corresponds to Bloch modes propagating in the vertical direction. After truncating the structure along the woodpile stratification, a mirror symmetry operation is imposed on the 2-D periodic lattice to obtain PEC and PMC symmetries. In particular, the propagation of the bound and leaky modes of the metal bisected woodpile is studied. Finally, the highly directive radiation of the infinite 2-D periodic lattice excited by an horizontal magnetic dipole is explained in terms of 2-D leaky waves. A 3-D numerical validation is accomplished by exciting the laterally truncated grounded woodpile antenna by using a slot on the metal plate.

16:50 Leaky-Wave Antenna Analysis Using Multi-Modal Network Theory with Open Periodic Boundaries

Oscar Senlis (Université de Rennes & CNRS, IETR, France); Anthony Grbic (University of Michigan, Ann Arbor, USA); Mauro Ettorre (Michigan State University, Electrical and Computer Engineering, USA); Vincent Laquerbe (CNES, France); David González-Ovejero (Université de Rennes, France)
This paper introduces a novel hybrid method that combines analytical techniques with a commercial solver to analyze periodic leaky-wave antennas. This approach is referred to as multi-modal network theory (MNT) with open periodic boundaries (OPBs). It is an iterative approach based on the full-wave simulation of a single unit cell and the analytical solution of an eigenvalue problem. The method accurately recovers the dispersion characteristics (phase and attenuation constants) of leaky-wave antennas using a reduced number of modes compared to previous methods. To validate the approach, the complex wavenumber of a slotted waveguide antenna is computed using OPB-MNT and compared against values extracted from a full-length antenna simulation. A periodic metal strip grating antenna is also analyzed and compared against previous state-of-the-art methods. For suitable leaky-wave unit cell topologies, the OPB-MNT provides a new general and reliable tool to derive the complex propagation constant of periodic antennas.

17:10 Exploiting Symmetries for Calculating the Dispersion Analysis of Open 2D Periodic Structures

Jesus Maria Jimenez-Suarez (KTH Royal Institute of Technology, Sweden); Sergio Garcia-Martinez (Universidad Politécnica de Madrid, Spain); Francisco Mesa (University of Seville, Spain); Pablo Sanchez-Olivares (Universidad Politecnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
An efficient quasi-numerical method for computing the dispersion diagram of open periodic structures with two-dimensional (2D) periodicity, specifically when the primitive cell exhibits internal symmetries, is introduced in this contribution. Unit cell analysis is reduced to a set of one-dimensional cases determined by the corresponding boundary conditions by exploiting these symmetries through the application of symmetry planes. This simplifies the geometry under study and enables the analysis of structures that are problematic when addressed in the full 2D framework. The proposed approach is based on the multimodal transfer matrix method, which we apply to a square unit cell within a parallel plate waveguide with a slot in the top plate, similar to those used in pillbox antennas.

Tuesday, April 21 15:50 - 17:30

CS14 Recent advances on theory and applications of characteristic modes in antenna modelling and design

T07 Electromagnetic modelling and simulation tools / Convened Session / Electromagnetics
Chairs: Liying Nie (Hefei University of Technology, China), Kurt Schab (Santa Clara University, USA)

Room: London

15:50 Parameterization of Characteristic Modes in Rotating Systems

Kurt Schab (Santa Clara University, USA); Kiersten C Kerby-Patel (University of Masssachusetts Boston, USA)
The scattering response of rotating targets is decomposed into characteristic modes. The parameterization of modal quantities (fields, currents, and eigenvalues) is studied in comparison to the more standard parameterization in frequency typically encountered in the analysis of static objects. Effects of discrete changes in symmetry are discussed in the context of modal tracking and micro-Doppler scattering response.

16:10 Automated Modal Classification for Cylindrical Structural Antenna Design

Raphael Notter (Université de Rennes & French-German Research Institute of Saint-Louis, France); Miloslav Capek (Czech Technical University in Prague, Czech Republic); Loic Bernard (ISL & IETR, France); Sylvain Collardey (University of Rennes 1, France); Ala Sharaiha (Université de Rennes & IETR, France); Pouliguen Philippe and Paul Karmann (DGA, France)
*T*his paper presents automated modal classification algorithms that simplify the analysis of metallic cylindrical structures and support the design and integration of structural antennas. Such antennas use the load-bearing structure itself as the radiating element, enabling very low-profile solutions with large effective surfaces, which is particularly attractive in aerospace and automotive platforms. Characteristic Mode Analysis (CMA) is commonly applied to identify the natural modes of the structure, select radiating modes, and define suitable feeding schemes. However, when the operating wavelength is much bigger than the physical dimensions of the structure, many higher-order modes arise, making the analysis complex and time-consuming. To overcome this challenge, an automated classification method that organizes and filters the modal set is proposed. The algorithm helps to automatically identify the modes relevant for antenna operation, thereby streamlining the design process of cylindrical structural antennas.

16:30 Revisiting Bandwidth of D-Band Patch and Stacked Patch Antennas Using Modal Analysis

Yuyan Cao and Buon Kiong Lau (Lund University, Sweden)
A rectangular conducting patch can be configured as a wideband or narrowband antenna, depending on its placement on the ground plane. The feeding method and the presence of a stacked patch also significantly influence the impedance bandwidth. In this context, the paper revisits the operating principles of patch antennas from the perspective of characteristic mode analysis (CMA), with a focus on implementing the antenna on low-cost substrate in the D-band. The results show that the fundamental mode's bandwidth increases dramatically with the height of the substrate. Practical feeding with a microstrip line severely degrades the modal bandwidth but also introduces a new broadside mode. Adding a stacked patch enhances both modes' bandwidths and enables joint excitation to achieve wideband dual-resonances, as demonstrated using a practical antenna design in full-wave simulation. Hence, CMA yields intuitive insight into the operation of patch and stacked patch antennas.

16:50 Design of a Spurious-Free Ring-Loaded Bowl-Shaped Antenna Using Characteristic Mode Analysis for Base Station Applications

Johan Lundgren (KTH Royal Institute of Technology, Sweden & CellMax Technologies, Sweden); Oskar Zetterstrom and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
Bowl-shaped antenna elements are common in the design of shared-aperture base station antennas. Arrays operating at different bands can be co-located on the same center line, thereby reducing the total antenna footprint. However, bowl-shaped antenna elements require a power divider for feeding the element. The power divider can excite spurious modes in the element, impairing the performance. In this work, characteristic mode analysis is used to study the intended and spurious modes separately. We demonstrate how the spurious modes can be moved out of the operating band while maintaining the matching by ring-loading the element. An antenna element loaded with a ring is proposed that operates in the band 617-894 MHz (36.7% fractional bandwidth). The element is fed using a robust metallic power divider and avoids excitation of spurious modes in the operating band. The proposed antenna element can be made cost-effective and provide high-power handling with high radiation efficiency.

17:10 Observation of Unit Cell Shape and Size of Periodic Structures on Their Characteristic Modes

Alexander Gausmann (Leibniz University Hannover, Germany); Dirk Manteuffel (Leibniz University Hannover)
In this paper the influence of the shape and size of the unit cell on its Characteristic Modes is investigated. If the patch is small compared to the wave length, the magnitude of the eigenvalue follows the conductor to non conductor ratio of the unit cell. With different shapes of unit cells two mechanisms can be shown. First, the differently shaped unit cells cause a higher or lower conductor to non conductor ratio inside the unit cell. Second, especially by small periodicities compared to the size of the patch, the different distance between the metallic parts in the lattice can cause higher capacitive coupling and therefore alter the eigenvalue towards a lower magnitude. This effect is comparatively small and applies mostly for bigger patch sizes.

Tuesday, April 21 15:50 - 17:30

CS16 Passive intermodulation in RF antennas and base stations

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Mattias Gustafsson (Huawei Technologies Sweden AB, Sweden), Alex Schuchinsky (University of Liverpool, United Kingdom (Great Britain) & Consultancy, United Kingdom (Great Britain))

Room: Copenhagen

15:50 Mechanisms of PIM Generations in Contact Junctions and Distributed Printed Circuits

Alex Schuchinsky (University of Liverpool, United Kingdom (Great Britain) & Consultancy, United Kingdom (Great Britain)); Mattias Gustafsson (Huawei Technologies Sweden AB, Sweden); Yi Huang (University of Liverpool, United Kingdom (Great Britain))
Passive intermodulation (PIM) in contact joints and PCB tracks, are studied as multiphysics phenomena. Inherent roughness of printed conductors and contacts is important for PIM generation. Tunnelling charges, heat flow and mechanical deformations are coupled and cause the signal distortion. The charge tunnelling is the fastest nonlinear process. The thermal effects in rough surfaces are slow, and the mechanical effects are even slower. The explicit relations for the PIM are obtained when asperity deformations of the contact joints vary from their minor compression to the full flattening. The presented analysis allows evaluation of the nonlinear contact resistance and the size of the actual contact surfaces in dependence on applied pressure at various stages of asperity deformations.

16:10 Harmonic Cancellation in a Multi Band Array Systems

Muhammad Ahmad Ansari and Souheil Ben Smida (Heriot-Watt University, United Kingdom (Great Britain)); Mohamed Helaoui (University of Calgary, Canada); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))
This paper presents a phase adjustment technique for suppressing harmonic distortion in broadband RF transmitter arrays, focusing on minimizing second harmonic distortion (HD2) caused by nonlinear power amplifiers. By applying optimized phase shifts across amplifier branches, the proposed method enables destructive interference of harmonic components while preserving the desired carrier signal. Simulation and experimental results demonstrate up to 15 dB HD2 reduction with only 2.5 dB output power loss, confirming scalability and stability of the main beam. The approach offers a simple, hardware-free, and efficient solution to enhance linearity and spectral efficiency in next-generation transmitter arrays.

16:30 Intermodulation-Based Passive Antenna Sensor for Real-Time Wireless Liquid Monitoring

Nanshu Wu (University of Illinois Chicago, USA); Duc Anh Pham and Pai-Yen Chen (University of Illinois at Chicago, USA)
This paper presents a purely passive antenna sensor for wireless liquid monitoring. The proposed structure comprises an antenna sensor integrated with a back-end circuit functioning as a self-modulated backscattering circuit. Owing to the combination of an RF-DC rectifier and a local oscillator (LO), the designed circuit can be powered up with the illumination of incident RF signal and produce intermodulation backscattering products back to the interrogator. With this sensing mechanism, different liquids can be distinguished by observing the locations of the intermodulation peaks in the Received Signal Strength Indicator (RSSI) spectrum. Compared with traditional methods, the proposed method can effectively mitigate the interference from cluttered environments while maintaining a compact and purely passive operating mechanism, thus significantly enhancing its applicability to a wide range of practical applications.

16:50 Recent Measurements of Passive Intermodulation (PIM) Challenges in Mobile Communication

Nezahat Gunenc, Martin Paulus, Franz Gasteiger, Martin Zwiefelhofer and Dennis Willigmann (Ericsson Antenna Technology Germany GmbH, Germany); Queenie Zhang (Ericsson AB, Sweden); Bo Göransson (Ericsson, Sweden & KTH, Royal Institute of Technology, Sweden); Marius Cismasu, Ingolf Meier and Kabir Kathuria (Ericsson AB, Sweden); Hao An and Chuanting Liu (Ericsson (China) Communications Co. Ltd, China); Hui David Zhang (Ericsson (China) Communications Co. Ltd., China)
This paper provides insights and practical engineering approaches to address the growing issue of Passive Inter-Modulation (PIM) in modern mobile networks. PIM challenges arise from higher modulation orders, full-duplex operation, increased RF transmit power, and multi-band configurations within constrained spaces. As a significant performance degrader, PIM mitigation is vital for maintaining capacity and quality in next-generation systems. The three conditions for PIM-non-linearity, sufficient RF power, and relevant carrier frequencies-are outlined as the PIM-triad. Real-world observations identify common PIM sources and difficulties in accurate measurement. Continuous wave (CW) and wideband (WB) LTE/NR signals are assessed under varying power, temperature, and frequency. A distinction is made between stable 'diode-like' and intermittent 'crackling' PIM, with their potential impact on uplink performance discussed.

17:10 Practical Characterization of Passive Intermodulation for General Excitations: From CW to Multicarrier/Modulated Signals

Davide Smacchia (ESA/VSC High Power RF Laboratory, Spain); Pablo Soto (Universidad Politécnica de Valencia, Spain); Mónica Martinez-Mendoza (Universitat Politècnica de València, Spain); Raúl Cervera Marín (Universitat Politècnica de València, Spain & Val Space Consortium, Spain); Javier Ossorio and Óscar Monerris (Val Space Consortium, Spain); Jose Vicente Morro Ros and Carlos Alcaide Guillen (Universitat Politècnica de València, Spain); Vicente Boria (Universidad Politécnica de Valencia, Spain); David Raboso (European Space Agency, The Netherlands)
Passive Intermodulation (PIM) is a well-known effect which can limit the performance of communication links. An accurate estimation of this high-power effect by means of prediction tools is extremely difficult, due to its subtle nature linked to small-scale imperfections in metal-to-metal contacts. As a result, its characterization must rely on experimental tests. In traditional PIM tests, two high-power CW signals are injected at the input of the device under test, and the power of a particular PIM term is captured at its corresponding frequency. Although the assembly of a high-performance PIM test bed is a difficult task, this still represents a simplistic case, since the hardware is typically exposed, during operation, to multiple high-power channels involving modulated signals. In this paper, we present some recent techniques that allow to extrapolate the results obtained from the classic two-tone CW test to more realistic scenarios with complex signals.

Tuesday, April 21 15:50 - 17:30

CS17 Advances in Multi-Antenna Channel Sounding and Modeling for 6G: From Far-Field to Near-Field

T07 Electromagnetic modelling and simulation tools / Convened Session / Propagation
Chairs: Zhiqiang Yuan (Southeast University, China), Fengchun Zhang (Aalborg University, Denmark)

Room: Gothenburg

15:50 RIS Nearfield Position and Velocity Estimation Using a Validated Propagation Model

Thomas Zemen (AIT Austrian Institute of Technology GmbH, Austria); Musa Furkan Keskin (Chalmers University of Technology, Sweden); Moustafa Rahal (University of Surrey, United Kingdom (Great Britain)); Thomas Wilding, Hamed Radpour and Markus Hofer (AIT Austrian Institute of Technology, Austria); Benoit Denis (CEA-Leti & Université Grenoble Alpes, France); Henk Wymeersch (Chalmers University of Technology, Sweden)

We investigate reconfigurable intelligent surfaces (RISs) for the task of position and velocity estimation in non-LOS (NLOS) indoor scenarios, using a snapshot based multi-step estimation algorithm. We evaluate a compound RIS structure prototype composed of four RIS tiles with (1)-bit phase control per RIS unit cell. Numerical simulation results taking the antenna patterns into account are presented for an (3,\text{m}\times 3,\text{m}) area of interest. We demonstrate that the initial grid search step using the far field assumption is not robust enough for small distances to the RIS center and propose a more robust algorithm. Furthermore, we show that the effect of the antenna pattern causes an increased position and velocity error. Our modified three-step algorithm achieves a position error of (7,)mm and a velocity error of (0.12,)m/s at a distance of (2,)m to the RIS center under a realistic numerical propagation model.

16:10 A Novel Half-Apertured Multiplicative Array for Antenna Pattern Synthesis and Its Performance Investigation in the near Field

Zhangzhang Jiang and Zhiqiang Yuan (Southeast University, China); Kai Zhao (China Electronic Product Reliability and Environmental Testing Institute, China); Wei Fan (SouthEast University, China)

Pattern synthesis plays a crucial role in antenna array design, enabling the realization of desired radiation patterns that are essential in modern communication. Extremely large-scale antenna arrays (ELAAs) have attracted considerable attention for next-generation wireless communications. However, their practical implementation is hindered by complex and costly architectures involving numerous antenna elements and associated radio frequency chains. The multiplicative array (MA), a well-established concept in pattern synthesis, can achieve a radiation pattern identical to that of a uniform rectangular array (URA) while using significantly fewer antenna elements. In this work, we first review the principle of the novel introduced half-aperture MA, which has been proposed in our previous work. Then, discuss its performance in the both far field and near field, which is lacking in the previous work. This innovation shows great potential for future research and implementation in large-scale array systems.

16:30 An Integrated Platform for Multi-Modal Environment Sensing and Channel Sounding

Xuejian Zhang, Ruisi He, Mi Yang, Zhengyu Zhang, Ziyi Qi and Zhicheng Qiu (Beijing Jiaotong University, China)

Integration of communication, sensing, and artificial intelligence is a key research direction for 6G, emphasizing the need for comprehensive environment awareness and intelligent channel modeling. High mobility causes non-stationarity and rapid channel variations, making traditional models inadequate for capturing fine-grained physical and electromagnetic characteristics. Multi-modal environmental sensing offers new opportunities for joint characterization of the environment and wireless channels, yet existing studies often rely on single-modality or simulated data, limiting accuracy in dynamic real-world scenarios. To address this challenge, this paper presents a multi-modal sensing-communication fusion platform integrating diverse sensors and channel sounders. The platform enables temporally and spatially synchronized acquisition of images, point clouds, position data, and multi-band, multi-antenna channel measurements. Its modular design allows rapid deployment in various environments. Key performance metrics, including dynamic range, phase stability, delay resolution, and data synchronization, are validated. The platform supports environment-channel joint modeling, channel prediction, and digital twin-based wireless research.

16:50 A Wideband SDR Correlative Channel Sounder: Design, Implementation, and Delay-Domain Validation in Industrial Environment

Muhammad Ismail, Robert Michael Edwards, Muhammad Hassan and James A. Flint (Loughborough University, United Kingdom (Great Britain))

Metallic industrial environments pose severe challenges for wireless systems due to complex multipath propagation. This paper presents a flexible wideband software-defined radio (SDR) channel sounder that enables the rapid, precise characterisation of industrial wireless channels. Built on USRP X310 hardware, the system operates across 70 MHz to 6 GHz having configurable bandwidth upto 100 MHz and polarisation and achieves 10 ns excess-delay precision. A custom designed GNU Radio Time-Labelled Capture Block enables timestamped IQ data capture for post-processing. Measurements in a metal workshop reveal that cross-polarisation alters multipath behaviour: RMS delay spreads increase from 46 ns (co-polarised) to 83 ns (cross-polarised), coherence bandwidth narrows to 0.24-4.3 MHz, and Rician K-factors drop by 10+ dB. These findings directly impact guard interval design, equalisation strategies, and frequency planning for industrial IoT and automation systems.

17:10 Measurement-Based Analysis of Outdoor Massive MIMO Channel Characteristics over FR3 Frequency Band

Enrui Liu and Pan Tang (Beijing University of Posts and Telecommunications, China); Haiyang Miao (Tsinghua University, China); Qi Zhen and Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Sen Wang (China Mobile Research Institute, China)

This study experimentally analyzes UMa channel characteristics at 8 GHz and 15 GHz using a massive MIMO platform. Results show that RMS delay spread remains stable under LOS but decreases from 8 to 15 GHz in NLOS, indicating reduced multipath dispersion at higher frequencies. All angular spread parameters (ASA, ASD, ESA, ESD) consistently decrease with frequency, demonstrating more directional propagation. Capacity analysis reveals that 15 GHz slightly outperforms 8 GHz in both LOS and NLOS scenarios due to more concentrated multipath energy and larger dominant singular values. Higher frequencies exhibit greater directionality, while lower frequencies offer broader multipath distribution and more stable performance. These findings provide valuable insights for multi-band MIMO modeling and 6G system design.

Tuesday, April 21 15:50 - 17:30

CS45 Scattering in 6G and Integrated Communications and Sensing

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Thomas Dallmann (Technische Universität Ilmenau, Germany), Diego Andrés Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany)

Room: The Hague

15:50 Scattering Measurements of an Empty and Filled Cardboard Box at Sub-THz for ISAC

Diego Andrés Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany); Jonas Gedschold, Manuel Kolb, Reiner S. Thomä and Thomas Dallmann (Technische Universität Ilmenau, Germany)

In recent years, the sub-THz frequency range has become increasingly important for industrial applications. The availability of unused spectrum and the need for high-gain radio interfaces make it possible to build high-resolution systems that are also well-suited for sensing tasks. In this work, we present a measurement setup and results from fully polarimetric scattering experiments carried out at 184.5 GHz to aid the development of integrated sensing and communication systems in the sub-THz range. The experiments compare both empty and filled cardboard boxes, clearly showing that objects hidden in such boxes can create significant multipath components. This allows the conclusion that usually overlooked side items, such as boxes on a shelf in an industrial scenario, can introduce complex clusters of multipath components.

16:10 Monostatic Dual-Polarized Sensing Channel Measurements for ISAC

Yifa Li and Kim Olesen (Aalborg University, Denmark); Jon Martens (Anritsu, USA); Jonathan Borrill (Anritsu Corporation, Sweden); Johan Wallblad (Anritsu, Sweden); Ivan Bonev (Denmark); Sigurd S. Petersen (Aalborg University, Denmark); Mengting Li (Aalborg University); Gert Frølund Pedersen and Fengchun Zhang (Aalborg University, Denmark)

In Integrated Sensing and Communication (ISAC) systems, dual-polarization is expected to provide richer information reflecting the physical characteristics of objects, which can enhance sensing capability. Conducting ISAC channel measurements with dual-polarized configurations is essential for understanding polarization-dependent scattering behaviors and developing polarization-aware channel models. This paper presents monostatic dual-polarized sensing channel measurements using a modulated-VNA-based ISAC channel sounder equipped with a dedicated monostatic dual-polarized antenna setup and a Directional Scan Sounding (DSS) scheme. The measurements were carried out in a laboratory environment at 7.2 GHz (FR3). Preliminary analysis of the measured power-range-angle profiles (PRAPs) reveals that the measurements can effectively indicate the locations and polarization-dependent scattering characteristics of objects in the environment. The observed polarization dependence is related to the object geometries, surface roughness, and material properties.

16:30 A Modeling Approach for Human Gesture Channels Based on Deep-Learning

Zhengyu Zhang (Beijing Jiaotong University, China); Neeraj Varshney (National Institute of Standards and Technology, USA); Jelena Senic (NIST, USA); Raied Caromi (National Institute of Standard and Technology, USA); Samuel Berweger (NIST, USA); Camillo Gentile (National Institute of Standards and Technology (NIST), USA); Enrico M Vitucci (University of Bologna, Italy); Ruisi He (Beijing Jiaotong University, China); Vittorio Degli-Esposti (University of Bologna, Italy)

Human gesture recognition has emerged as a promising application of Integrated Sensing and Communication (ISAC) in 6G networks, where gesture-induced body movements significantly reshape wireless propagation environments. However, existing statistical and deterministic channel models fail to capture fine-grained gesture dynamics and lack interpretability. In this paper, we propose a deep-learning-based framework for gesture-driven channel modeling. A Poisson neural network first predicts the number of multipath components (MPCs) associated with different body parts, followed by a Conditional Variational Autoencoder (C-VAE) that generates scattering points with spatial and temporal consistency. Based on real measurements at 28 GHz using a context-aware channel sounder with synchronized RF, camera, and Lidar data, the proposed framework reconstructs channel impulse responses (CIRs) with high fidelity. Experimental results demonstrate that the generated scattering points closely match measured distributions, while the reconstructed CIRs accurately reproduce power delay profiles.

16:50 Double-Polarized Backscattering Channel Characterization for Identification and Localization of Passive Sensors

Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France); Frederic Munoz (CEA LETI & University of Grenoble-Alpes, France); Grégory Gougeon (SIRADEL, France); Ali Hadj djilani (LAAS-CNRS, France & INP TOULOUSE, France); Francesco Foglia Manzillo (CEA-LETI, France); Moufida Bouslama (Faculty of Science of Tunis, Tunisia); Mbissane Dieng (CEA, LETI & Université Grenoble-Alpes, France); Yoann Corre (SIRADEL, France); Dominique Henry (LAAS-CNRS & CRCA-CNRS, Toulouse University, France); Hervé Aubert (Laboratory of Analysis and Architecture of Systems & Institut National Polytechnique de Toulouse, France)

This paper presents a backscattering channel characterization of an industrial environment, targeting the interrogation of purely passive antenna sensors and mapping of the environment. The passive sensors employ a dual-polarized antenna system to backscatter temperature-related information. On the reader side, a double-polarized transmitarray operating in the Ka band is used to extract the angular dependent polarimetric channel matrix. The proposed system is demonstrated through two complementary approaches: first, using real hardware and on-site measurements; second, via a digital twin embedding ray-tracing and high-fidelity representation of the backscattering behaviour and antennas. Both approaches confirm the feasibility of passive sensing in complex industrial scenarios.

17:10 Accelerated Full-Wave Computation of EM Wave Scattering Using Successive Symmetric over Relaxation and Eigenvalue Deflation

C***onor Brennan and Imtiaz Islam (Dublin City University, Ireland)***

The problem of computing 2D EM wave scattering from arbitrary dielectric bodies is addressed using an integral equation formulation discretised using the method of moments. Successive Symmetric Over-Relaxation (SSOR) is applied to the governing matrix equations along with eigenvalue deflation which is designed to separately account for the effect of those eigenvectors of the iteration matrix that have eigenvalues with magnitude greater than 1. An algorithm based on the Arnoldi iteration is used to identify these eigenvalue/eigenvector pairs. The method is validated against results using Mie series and alternative numerical formulations.

Tuesday, April 21 15:50 - 17:30

EO7a Electromagnetic theory: Components 1

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Kamil Karacuha (Istanbul Technical University, Turkey), Xenofon Mitsalas (University of Siena, Italy)

Room: Barcelona

15:50 Wideband Polarization-Insensitive Transmissive Polarization Rotator

Abdulrahman Mohammed Alnour Ahmed, Mohammad Alhassoun and Ahmed Abdelmottaleb Omar (King Fahd University of Petroleum and Minerals, Saudi Arabia)
This paper presents two compact polarization-insensitive transmissive polarization rotators (PITPRs) based on a planar loop-loaded strip configuration. The first design, PITPR I, employs orthogonal loop-loaded strips arranged with fourfold rotational symmetry to achieve stable polarization conversion and a -1 dB fractional bandwidth of 23.5% (5.6-7.15 GHz). To further enhance performance, PITPR II introduces an additional nested strip within each layer, creating an extra resonant path that broadens the bandwidth. The resulting design achieves a -1 dB fractional bandwidth of 34.2% (4.6-6.5 GHz) while maintaining a compact three-layer structure with a total thickness of 0.11λ0, where λ0 is the free-space wavelength at the center operating frequency. Compared with previously reported polarization-insensitive transmissive rotators, PITPR II offers the widest bandwidth with excellent polarization conversion efficiency and low-profile geometry, making it suitable for wideband radar and communication systems.

16:10 Broadband Conformal Meander-Line Polarizer: Equivalent Circuit Modeling and Cylindrical Aperture Integration

Alp Emir Gürsoy (Istanbul Technical University, Turkey & ASELSAN, Turkey); Mustafa Kuloğlu (ASELSAN, Turkey); Kamil Karacuha (Istanbul Technical University, Turkey)
In this paper, a multilayer meander-line-based design is presented for achieving wideband (8-16 GHz) linear-to-circular polarization conversion using an equivalent circuit model and unit-cell optimization. The circuit model results show good agreement with full-wave simulations. The designed polarizer exhibits a peak axial ratio of 1.76 dB across the operating band. The final polarizer is wrapped around the aperture of a horn antenna and is simulated to evaluate its integrated performance. For the overlapping band of the test antenna (9-16 GHz), a peak insertion loss of 0.92 dB is obtained while maintaining the desired polarization conversion.

16:30 Spherical Metallic Polarizers for Space Applications: A Method of Moments Approach

Agnese Mazzinghi (University of Florence, Italy); Angelo Freni (Università degli studi Firenze, Italy); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Jose Rico-Fernandez (Northern Waves AB, Sweden)
Additive manufacturing techniques have generated interest in using fully metallic conformal polarizers for space applications. While proof of concepts can be created with general-purpose design tools, more precise and specialized numerical techniques are necessary to accurately model these structures. We suggest using an ad-hoc Method of Moments that employs analytical Green's functions for magnetic sources exciting a radial transmission line in the presence of a metallic sphere.

16:50 Design and Analysis of a Multi-Stage LTCC Transition for GaN Flip-Chip Interconnect to SMA Edge Launch in C-Band SiP

Maryam Sadeghi, Dawood Shekari Beyragh and Mohamed Helaoui (University of Calgary, Canada); Ammar Kouki (École de Technologie Supérieure, Canada); Fadhel Ghannouchi (University of Calgary, Canada)
This paper presents a multi-stage, low-loss transition for routing GaN flip-chip signals to an SMA edge-launch connector, realized using Low Temperature Co-Fired Ceramic (LTCC) technology for System-in-Package (SiP) integration. Built on a five-layer LTCC substrate, the design manages a 389 um flip-chip pad pitch and utilizes varied tape thicknesses to optimize vertical routing and a constant 50 Ohm impedance. The three-section interconnect comprises a BGA-to-microstrip connection, a vertical microstrip transition, and a microstrip-to-SMA interface. Although optimized for the C-band (5 to 6 GHz), the design achieves exceptional broadband performance. Simulation confirms an insertion loss of less than 0.4 dB across the entire DC to 10 GHz bandwidth. Within the target 5 to 6 GHz range, insertion loss is better than 0.25 dB and return loss is better than 20 dB. This LTCC solution offers an efficient, high-density, minimal-loss route for high-speed GaN signals.

17:10 Predicting Mutual Coupling via a Unifying Local Propagation Condition (ULPC)

Andrea Pirisi, Riccardo Enrico Zich, Gabriel Felipe Martinez and Eleonora L. Zich (Politecnico di Milano, Italy)
Mutual coupling in compact electromagnetic platforms resists consistent local interpretation. This contribution introduces the Unifying Local Propagation Condition (ULPC), derived from a spacetime energy-density framework. ULPC is dimensionless, mesh-local, solver-agnostic, and computed in finite-element post-processing. It reduces to capacitive and inductive limits, recovers the zero-order Schelkunoff boundary, and provides maps that anticipate coupling onsets and guide adaptive refinement. Applied to cylindrical capacitors, inductors, and mutual inductors, ULPC reveals a common energetic identity across self and mutual regimes and links local field composition to measurable transfer. The result enables transition-aware design and reliable performance guarantees in dense arrays, reconfigurable surfaces, and compact platforms.

Tuesday, April 21 15:50 - 17:30

E18 RCS Reduction

TO8 Fundamental research and emerging technologies/processes / / Electromagnetics
Chairs: Sema Dumanli (Bogazici University, Turkey), Anders Malthe Westerkam (Aalborg University, Denmark)

Room: Madrid

15:50 A Two-Stage Optimization Strategy for Frequency- Space RCS Reductions

Haoman Wang (Zhejiang University, China); LiMing Xu (National Information Control Laboratory, China); Haogang Wang (Zhejiang University, China)
We propose a novel two-stage optimization strategy for frequency-space radar cross section (RCS) reductions using multi-layered metasurface (MM). In the two-stage approach, we sequentially obtain the phases and sizes of sub-units. In the 1st stage, a Huygens scattering model (HSM) is devised for the fast and efficient forward analysis with a deep neural network (DNN) trained as the corresponding surrogate model. In the 2nd stage, we build a multi-layered metasurface library (MML) to provide the physical implementation of frequency-phase (FP) curves. Subsequently, we find the intersection between the optimized phases and MML to obtain the physically realized solutions. A 240 mm × 480 mm sized rectangular MM is optimized in 6 GHz - 8 GHz. The optimized MM achieves average RCS reductions of over 10 dB with both azimuth and elevation in the frequency band. The maximum reduction for normal incidence reaches 26 dB.

16:10 Hybrid Reconfigurable Metasurface for Independent RCS Reduction and Beam Steering

Yuewen Gou and Si Peng (Northwestern Polytechnical University, China); Yikai Chen (University of Electronic Science and Technology of China, China); Ling Wang (Northwestern Polytechnical University, China)

Multifunctional metasurfaces capable of simultaneous radar stealth and communication remain challenging due to mutual interference between reflection and transmission modes. This paper presents a hybrid reconfigurable metasurface enabling independent control of reflection and transmission for radar stealth and beam steering. The metasurface integrates two functional layers: metal layer 1 with PIN diodes manipulates reflected waves via programmable coding states, while metal layer 3 with rotational patterns governs transmitted waves through geometric phase. In reflection mode, a checkerboard coding strategy achieves significant monostatic RCS reduction over 8-11GHz and 11-14 GHz by scattering energy into four quadrants. For transmission, phase compensation enables beam scanning to 45° at 10 GHz. Crucially, the two layers operate without mutual interference, allowing simultaneous RCS reduction and beam steering in full space. This design eliminates complex feed networks in phased arrays, offering a compact solution for multifunctional electromagnetic systems.

16:30 Flat and Shaped Chessboard Metasurface for X-Band RCS Reduction

Maria Guijarro-Maortua, Jesús Grajal and José Manuel Fernández González (Universidad Politécnica de Madrid, Spain)

A single layer chessboard metasurface capable of reducing the radar cross section in the X-Band is presented. To this end, the analysis and optimization of its unit cells and the complete structure have been carried out, with a reduced thickness of 1.524 mm. A monostatic radar cross section reduction below -12 dB has been achieved in the bandwidth 9.2 - 11.7 GHz (23.92%), which means a reduction in the monostatic detection range of 50%. Both polarizations have been validated, as well as an incidence angle of up to 60°. For the bistatic scenario, the bandwidth decreases as the angle of incidence increases. Furthermore, the shaping over a cylindrical target has been studied and it has been necessary to adjust the cell parameters to maintain the same response as with the flat design.

16:50 A Flexible Dielectric Scattering Surface Realized with Graphite Doped Silicone

Mehmet Emre Eralp (Middle East Technical University & Accelerate Simulation Technologies, Turkey); Isin Ozgen, Burak Ferhat Ozcan and Sema Dumanli (Bogazici University, Turkey); Ozlem Aydin Civi (Middle East Technical University, Turkey)

This paper presents a flexible and low-profile dielectric scattering surface designed for RCS reduction without using metallic patterns. The surface is fabricated from graphite-doped silicone, which allows for dielectric constant control between 3 and 15. The surface maintains a constant thickness of 2.5 mm, while the reflection phase of the dielectric cells is controlled by varying the dielectric constant. Two phase distributions are investigated: a checkerboard configuration for monostatic RCS reduction, and a modified cubic phase distribution for enhanced bistatic RCS reduction. Simulation results show that the proposed flexible checkerboard achieves a 10 dB monostatic reduction while the modified cubic phase distribution effectively suppresses bistatic reflections more than 14 dB at all angles. The proposed design offers a lightweight and conformal solution for electromagnetic stealth applications in X band.

17:10 High-Performance Metamaterial Based on Ultralight Lossy Dielectric Substrates

Udeshwari Jamwal, Kokila Khanal, Simon Ong, Sreekanth Ginnaram, Chin Keong Ang and Yang Yong (National University of Singapore, Singapore)

Developing ultralight and broadband electromagnetic (EM) absorbers is critical for systems that demand minimal weight and low-profile designs. Here, a planar sandwich metamaterial is developed using aramid nanofiber (ANF)-based aerogels as ultralight lossy substrates combined with patterned resistive sheet. ANF aerogels, fabricated via non-toxic aqueous route with carboxymethyl cellulose and CNTs, exhibit an ultralow density of 0.03 g/cm³-over 50 times lighter than conventional substrates-while retaining favorable dielectric properties. The sandwich design consists of two aerogel layers (2.4 and 3.0 mm) separated by a resistive film (~70 Ω/sq). Despite a compact relative thickness of only 0.097λ, the design achieves an ultrawide bandwidth of 19.62 GHz (5.38-25 GHz), corresponding to a 129% fractional bandwidth. This combination of ultralight density, intrinsic dielectric loss, and simple planar architecture represents a major advancement over conventional absorbers. ANF aerogels thus offer a transformative substrate platform for next-generation ultralight broadband EM absorbers.

Tuesday, April 21 15:50 - 17:30

E19 Reconfigurable and Frequency/Polarisation Selective Surfaces

T08 Fundamental research and emerging technologies / / Electromagnetics

Chairs: Rainer Kronberger (TH Cologne University of Applied Sciences, Germany), Symeon Nikolaou (Frederick Research Center & Frederick University, Cyprus)

Room: Rome

15:50 Electromagnetic Modeling and Scattering Computation of Large RIS with Physical Coupling Effects

Ayoub Mohammed Toubal and Youssef Nasser (Greenerwave, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France); Geoffroy Lerosey (Greenerwave, France)

This work introduces a fast and accurate simulation framework for Large Reconfigurable Intelligent Surfaces (LRIS), based on multiport network theory, impedance modeling Floquet mode analysis, and unit cell full-wave simulations. The proposed tool leverages the periodic nature of most RIS structures to efficiently model the electromagnetic response of unit cells and their mutual interactions.Key electromagnetic effects, including coupling and impedance mismatch, are explicitly accounted for, enabling a realistic performance evaluation of RIS scattering patterns. A major strength of the framework lies in its capability to simulate very large RIS arrays rapidly and with minimal computational resources, thereby overcoming the limitations of conventional full-wave solvers.The simulation results obtained with this new framework are compared with those obtained with the full simulation of the RIS, showing very good agreement. The tool is also applied to a practical RIS design in the FR2 band, and the simulation results are validated against real-world measurements.

16:10 A Scalable Reconfigurable Intelligent Surface with 3 Bit Phase Resolution and High Bandwidth for 3.6 GHz 5G/6G Applications

Markus Heinrichs (TH Cologne University of Applied Sciences, Germany); Aydin Sezgin (RUB, Germany); Rainer Kronberger (TH Cologne University of Applied Sciences, Germany)

Reconfigurable Intelligent Surfaces enable active control of wireless propagation channels, which is crucial for future 5G and 6G networks. This work presents a scalable RIS design operating at 3.6 GHz with both 1 bit and 3 bit phase resolution, supporting wideband applications. The unit cells employ low-cost printed circuit board technology with an innovative spring-contact feeding structure, enabling efficient assembly and reduced manufacturing complexity for large-area arrays. The design achieves broadband phase control, low power consumption, and high scalability, with experimental results demonstrating phase tunability across the n78 frequency band and competitive reflection performance compared to existing solutions. This RIS architecture provides a practical platform for experimental studies of smart radio environments, beam steering, and sensing applications in next-generation wireless networks.

16:30 Design, Realization and Measurements of a 3D-Printed Full Metal High-Pass Dichroic Mirror in Ka/Ka-Q/V Bands

Andrea Guarriello (Thales Alenia Space, France); Fabio Pelorossi (ESOC, ESA, Germany); Patrice Regnier (Thales Alenia Space, France); Romain Contreres (CNES, France); Hervé Legay (Thalès Alenia Space, France)
This paper presents the design, optimization, and experimental validation of an advanced wideband high-pass dichroic mirror for ground station beam-wave guide (BWG) architectures supporting quad-band satellite gateway operation. Conventional dichroic technology, based on thick metallic plates with half-wavelength or larger periodicity, faces intrinsic limitations in bandwidth, angular stability, and manufacturability as future gateways must handle Ka, Q, and V bands with stringent performance requirements. In this paper, an innovative quasi-TEM unit cell topology, compatible with 3D printing, is surveyed and presented to realize a 3D printing compliant metasurface with sub-wavelength periodicity. Multi-objective optimization and full-wave simulations confirm outstanding in-band transmission and Ka-band reflection, with low loss and high polarization purity under realistic illumination. Experimental breadboards were produced and tested using a quasi-optical measurement bench, showing good agreement for transmission and reflection coefficients and the suitability of the proposed novel unit cell for next-generation, high-capacity satellite ground infrastructures.

16:50 Design of a Radiation-Scattering Integrated Antenna Array Utilizing Polarization Conversion Metasurface

Yanni Wang, Chenjiang Guo, Yifan Xue, Zhirui Fu, Jun Ding and Xiaoyan Pang (Northwestern Polytechnical University, China)
A linearly polarized antenna array with a polarization conversion metasurface (PCM) as the core functional layer is proposed, integrating electromagnetic radiation and scattering regulation. The designed polarization conversion units are checkerboard-arranged and integrated on the top of a linearly polarized slot array, enabling simultaneous in-band and out-of-band radar cross section (RCS) suppression under linearly polarized plane wave illumination. Simulation results show its impedance bandwidth of 20.3% (5.3-6.5 GHz) and peak gain of 12.0 dBi. Compared with the reference array, it exhibits superior RCS reduction: 84.0% bandwidth and 25.0 dB maximum reduction under x-polarized incidence, and 83.0% bandwidth and 31.8 dB maximum reduction under y-polarized incidence.

17:10 Non-Reciprocal Polarization Reconfigurable Metasurface Using Liquid Metal

Adnan Nadeem (Frederick University, Cyprus); David Chatzichristodoulou (RF AND MICROWAVE SOLUTIONS LTD & Frederick Research Center, Nicosia, Cyprus); Nosherwan Shoaib (National University of Sciences and Technology (NUST), Pakistan); Photos Vryonides (Frederick Research Center, Cyprus & Frederick University, Cyprus); Dimitra Psychogiou (University College Cork and Tyndall National Institute, Ireland); Symeon Nikolaou (Frederick Research Center & Frederick University, Cyprus)
This paper presents a reconfigurable non-reciprocal metasurface (MSF) operating at 5.8 GHz, capable of circular-polarization (CP) conversion using liquid metal flowing inside straight additively manufactured channels. Each MSF unit cell employs a pair of back-to-back microstrip patch antennas with proximity feeding and two orthogonal slots that enable Left-Hand or Right-Hand Circular Polarization (LHCP/RHCP). Polarization switching is achieved by selectively filling the channels with LM and thus shorting and cancelling the effect of the corresponding slots. Two low-noise amplifiers (LNAs) integrated per cell provide unidirectional gain and establish strong non-reciprocity. The proposed 5×5 element MSF array demonstrates efficient RHCP-LHCP and LHCP-RHCP conversions, with simulated forward gain exceeding 40 dB and reverse isolation greater than 90 dB across the 5.8 GHz band. The design enables a compact, low-cost, and additive-manufacturing-friendly route for switchable polarization and non-reciprocal MSF applications. Fluidic reconfigurability with LM makes the use of 50 electronic switches unnecessary.

Tuesday, April 21 15:50 - 17:30

SW4 Advances in Active Phased Array Antennas: Modeling, Integration, and Characterization

/ / Antennas

Room: Glasgow

Sören Harms and Héctor Ortega González
Aymeric Cailleux (ESA)
Martijn De Kok (TNO)
David Gustafsson (Ericsson)
Jean-Philippe Fraysse (Thales Alenia Space France)
Teun van den Biggelaar (Antennex)
Sören Harms and Héctor Ortega González

The workshop will feature five 15-minute talks, each followed by a 5-minute Q&A. First, Aymeric Cailleux from ESA will discuss the modeling and interaction of power amplifiers with phased array antennas. Second, Martijn De Kok from TNO will address the co-design of power amplifiersand antennas for radar applications. Next, David Gustafsson will cover active components and related antenna challenges from the perspective of Ericsson, a telecommunications equipment provider. Then, Jean-Philippe Fraysse will outline recent active antenna R&D activities of ThalesAlenia Space France, a satellite manufacturer. Lastly, Teun van den Biggelaar from Antennex will present new measurement capabilities for active antennas using reverberation chambers.

15:50 - 15:55 Sören Harms and Héctor Ortega González Welcome and Introduction ANTERRA
15:55 - 16:14 Aymeric Cailleux (ESA) Modeling RF Frontend of Active Integrated Antenna Array for Direct-to-Device Communications
16:14 - 16:33 Martijn De Kok (TNO) Direct-matched Amplifiers and Radiating Elements in Active Phased Array Antennas
16:33 - 16:52 David Gustafsson (Ericsson) Analog RF Front-Ends for Phased Array Antennas: Advancements and Challenges
16:52 - 17:11 Jean-Philippe Fraysse (Thales Alenia Space France) Research Activities on Active Antennas at Thales Alenia Space - France
17:11 - 17:30 Teun van den Biggelaar (Antennex) Over-the-Air Characterization of Integrated Active Antenna Systems
17:30 Sören Harms and Héctor Ortega González Closing of the Session

BIOGRAPHIES
Aymeric Cailleux completed his Electronic & Telecommunication Engineering studies through an apprenticeship at INSA Rennes and Thales SIX GTS FRANCE Laval, specializing in aeronautics, in 2022. He undertook an internship at the European Space Agency (ESOC) on electro-photonic sampling and later an exchange at Chalmers University, working on power amplifier behavioral modeling. Currently, he is a System Engineer in SatCom at ESA-ESTEC and pursuing an MSCA Ph.D. within the HARMONY program, titled "Modeling RF Frontend of Active Integrated Antenna Array for Satellite Communications." His research focuses on active phased arrays, behavioral models, and satellite communications.

Martijn De Kok received the B.Sc. and M.Sc. degrees in Electrical Engineering (both cum laude) from Eindhoven University of Technology (TU/e), The Netherlands, in 2018 and 2020, respectively. He is currently pursuing a Ph.D. degree at TU/e. In 2019 he was a visiting student at the Advanced RF & Optical Technologies Group of the Jet Propulsion Laboratory, California Institute of Technology. In September 2021 he became a guest researcher at the Radar Technology Group of TNO Defense, Safety and Security in The Hague. Since 2025 he joined TNO as a scientist. His research interests include integrated millimeter-wave antenna systems and phased arrays for next-generation (satellite) communications and radar sensing.
David Gustafsson received his Ph.D. degree in Microtechnology and Nanoscience from Chalmers University of Technology, Gothenburg, Sweden in 2014. Since then, he has been with Ericsson Research, Gothenburg, where he is currently leading Ericsson's analog front-end and power amplifier research program.

Jean-Philippe Fraysse received the M.Sc. degree in Microwaves and a Ph.D. degree in Electronics from the University of Limoges in 1995 and 1999, respectively. He joined the research department of Alcatel Space, Toulouse, France, in 1999 where he was a MMIC designer. He is currently with the Research, Technology and Product Department, Thales Alenia Space, where he is an expert in integrated active antenna architectures. His research interests include advanced designs of key building blocks of active antennas, RF/antenna co-design with enabling technologies, and architecture trade-offs for advanced active antenna systems.

Teun van den Biggelaar received his MSc and PhD degree in Electrical Engineering (EE) with distinction from the Eindhoven University of Technology (TU/e), the Netherlands, in 2016 and 2020, respectively. During his PhD, he worked on a project supported by NXP Semiconductors and worked as guest researcher at NIST in Boulder, USA. Teun also worked for a period of two years at Ericsson in Gothenburg, Sweden, as Antenna Developer in the millimeter-wave team of the Antenna Systems and Technology division. From 2023 onwards, he is CTO and co-founder of ANTENNEX in Eindhoven, the Netherlands.

Tuesday, April 21 15:50 - 17:30

MO1 Material characterisation and non-destructive testing

T08 Fundamental research and emerging technologies/processes / / Measurements
Chairs: Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)), Michael J Havrilla (Air Force Institute of Technology, USA)

Room: Paris

15:50 Method for Unique Permittivity Extraction Using Transmission-Only Free-Space Measurements at THz Frequencies

Ugur Cem Hasar (Gaziantep University, Turkey); Bing Xue (Aalto University, Finland)
An extraction method is proposed to determine the unique complex permittivity of planar samples using transmission-only free-space measurements at THz frequencies. Different from previous transmission-only free-space methods, which require a preliminary knowledge of complex permittivity, or a second sample, or a mechanical movement, our method determines the correct complex permittivity even for thick samples by simply incorporating time-domain analysis (producing an initial estimate) into frequency-domain measurements. This also facilitates its application for complex permittivity at every frequency in the band. Measurements over 220:330 GHz of three relatively thicker samples were utilized to validate our method and compare its performance.

16:10 Up to the Surface and Beyond: Analysis of Bulk Solids Leveraging Multispectral Radar Echoes and Deep Learning

Robin J. Schmitz (Ruhr University Bochum, Germany); Christian Schulz, Jan Barowski and Ilona Rolfes (Ruhr-Universität Bochum, Germany)
Bulk solids are ubiquitous in industrial processes, and even subtle variations in the particle properties can have significant effects. Conventional methods for analysis of bulk solids often require direct material contact or are vulnerable to the environments. The objective of this contribution is to extend the advantageous probing capabilities of radar systems to analysis of bulk solids -- with respect to shape, size, and material. By combination with conventional methods, process monitoring and control can be enhanced. For this purpose, radar echoes are classified by DL methods, with a particular emphasis on spectral signatures. Measurements were conducted using an ultra-wideband 68 to 92 GHz FMCW radar system, followed by decomposition into multispectral subbands. Several solids common in industrial settings, such as plastic pellets, were selected as representative examples. The major finding is that these bulk solids reveal characteristic spectral signatures, enabling rapid and robust classification with up to 99% accuracy.

16:30 A Compact Setup for Material Characterization Using the Beam-Guide Fixture and D-Band Transceiver IC

Valeri Mikhnev (CENTERA Labs, Institute of High Pressure Physics, Polish Academy of Sciences, Poland); Dmytro B. But (CENTERA Laboratory, Institute of High Pressure Physics PAS, Poland); Wojciech Knap (CENTERA - Center for Terahertz Technology Research and Applications, Poland)

Accurate characterization of dielectric materials at sub-terahertz frequencies is usually carried out with the use of measurement setups based on expensive laboratory equipment such as network analyzers or terahertz systems of time-domain or frequency-domain spectroscopy. The assembly and adjustment of such setups require a lot of efforts and care. The recent progress in high-frequency electronics makes it feasible to build measurement devices based on single-chip transceiver integrated circuits having functionality of the network analyzers. In this work, a compact material characterization kit including a low-cost D-band transceiver IC integrated with a custom beam-guide fixture for the material samples is presented. The signal processing algorithm to retrieve the dielectric constant and loss tangent of the tested material is outlined. The device is easy to use and tolerant to the position of the sample in the fixture. The performance of the device is demonstrated for a wide range of dielectric materials.

16:50 Reflector Loss Measurements of a Low-Cost Copper Mesh Sample Using a Radiometer

Alexandra J Brönnimann (University of Bern, Switzerland); Lorenzo Ciorba (University of Bern & Institute of Applied Physics, Switzerland); Tobias Plüss and Axel Murk (University of Bern, Switzerland)

The electromagnetic losses of a low-cost copper mesh sample are measured using a radiometer. Through a reflection measurement with a pyramidal absorber terminating the transmitted optical path, the mesh total loss is extracted from the acquired sky brightness and the physical ambient temperatures. Due to the polarizing wire grid of the radiometer, the mesh is simultaneously measured at 22-31 GHz and 51-52 GHz for TM and TE polarizations, respectively. Measurements for the 31 GHz channel are in agreement within 0.19% with simulations performed with the full-wave solver of Ansys HFSS using Floquet ports. Larger discrepancies are observed for the lower (22-30 GHz) and higher (51-52 GHz) frequency channels where main sources of error are the radiometer spillover and sky brightness temperature uncertainty, respectively.

17:10 Uncertainty Analysis of a Surface Scattering-Aware Material Extraction Algorithm for THz-TDS Systems

Alperen Sari, Yeganeh Farahi, Costas Constantinou and Miguel Navarro-Cía (University of Birmingham, United Kingdom (Great Britain))

This study examines the influence of surface roughness-induced scattering losses on the dielectric parameter extraction process in terahertz time-domain spectroscopy. Our material extraction methodology, based on a ray optic transfer function, is stress tested on synthetic, natural wood, and engineered wood samples. The results indicate that the proposed ray-optics-based scattering model remains valid for surfaces with low to moderate roughness, where the ratio of RMS roughness to wavelength is below approximately 0.1. The study further presents an uncertainty analysis addressing the effects of average sample thickness and surface roughness on the extracted dielectric parameters. Supported by detailed simulations, the results reveal that up to 10 %uncertainty in both surface roughness and average sample thickness influences the loss tangent (up to 21.94% for the selected case simulation), whereas variations in the average thickness exert a stronger impact on the real part of the complex permittivity (up to 8.71%).

Tuesday, April 21 15:50 - 17:30

IW3 Industrial Workshop - GNSS Evolution Masterclass: Bridging Theory and Field Performance (Taoglas)

/ / Antennas

Room: Stockholm

Lukas van Vuuren, Taoglas

This workshop offers a comprehensive exploration of GNSS technology, charting the evolution from single-band to advanced multi-band systems. Participants will gain insights into diverse GNSS applications such as real-time navigation, asset tracking, precision agriculture, surveying, and autonomous vehicles. The session covers essential antenna characteristics, GNSS performance metrics, and correction technologies like RTK, PPP-RTK, and Galileo HAS. Practical evaluation methods are discussed, with real-world measurement demonstrations comparing environments, antenna types, and the impact of correction services on accuracy and reliability. This workshop is suitable for those in academia and industry who wish to further their knowledge of GNSS technologies and GNSS antenna characteristics.

Workshop Outline:
Introduction
GNSS Evolution - journey from single-band to multi-band
GNSS Applications - overview of typical GNSS applications
GNSS Antenna Characteristics - key antenna parameters for GNSS
GNSS Performance Metrics - GNSS metrics used for evaluation of system performance
GNSS Correction Services - overview of correction services
Taoglas GNSS Evaluation - Taoglas GNSS evaluation techniques
Real-World Measurements Demonstration - real-world test setups and results
Q&A

Lukas van Vuuren is a Senior Antenna Design Engineer at Taoglas, and specialises in GNSS antenna development and performance validation. His work includes rigorous lab testing, seamless integration into customer devices, and comprehensive field testing across diverse antenna setups and configurations. He is responsible for incorporating the latest GNSS receiver technologies into test environments as soon as they become available, ensuring solutions remain at the forefront of innovation. With hands-on experience bridging theory and real-world application, he is passionate about sharing practical insights and best practices to help engineers master the evolving challenges of GNSS performance.

Tuesday, April 21 15:50 - 17:30

EA EurAAP awards and EuCAP 2026 Grants ceremony

Room: Main Auditorium/Dublin

Wednesday, April 22

Wednesday, April 22 8:00 - 9:40

A11a Antennas for Satellite Communication 1

T03 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Steven Shichang Gao (Chinese University of Hong Kong, China), Stefania Monni (TNO Defence Security and Safety, The Netherlands)

Room: Barcelona

8:00 Scan Limitations of Open-Ended Three-Ridged Waveguide Apertures for Satellite Communications

Sören Harms (Thales Alenia Space, France & Eindhoven University of Technology, TNO Defense, Safety and Security, The Netherlands); Jean-Philippe Fraysse (Thales Alenia Space, France); Alessandro Garufo (TNO Defense Safety and Security, The Netherlands); Ulf Johannsen (Eindhoven University of Technology, The Netherlands); Stefania Monni (TNO Defence Security and Safety, The Netherlands)
Open-ended ridged waveguide phased array antennas (PAAs) have recently attracted significant attention due to their low losses and high power handling capabilities for low Earth orbit satellite communication applications. In this paper, the scan limitations of open-ended hexagonal three-ridged waveguide PAA apertures are analyzed in terms of active reflection coefficient, coupling coefficient, axial ratio, and realized gain. Strong degradations at the maximum scan angle are observed when a large element periodicity near the grating lobe threshold is used. The underlying sources of these degradations are studied in detail for several element periodicities.

8:20 A Scalable Dual-Polarized K/Ka-Band SATCOM Phased Array with Enhanced XPD

Arne Hemerijckx (Ghent University, Belgium & IDLAB, IMEC, Belgium); Kamil Yavuz Kapusuz (Ghent University-Imec, Belgium); Amanjeet Singh (Ghent University, Belgium); Sam Lemey (Ghent University-imec, Belgium); Jo Verhaevert (Ghent University - imec, Belgium); Hendrik Rogier (Ghent University, Belgium)
A single-element cross-polarization discrimination (XPD) enhancement technique for scalable, dual-polarized K/Ka-band phased arrays is presented. The array employs sequentially rotated stacked-patch elements, where the XPD is enhanced through the rotation of the staggered feeds. Both receive (Rx) and transmit (Tx) topologies are implemented within a common multilayer stack-up, utilizing stacked standard printed circuit board (PCB) manufacturing techniques. Experimental validation demonstrates operational bandwidths of [17.7-21.1] GHz and [24.9-33.7] GHz for the Rx and Tx bands, respectively. Measurements confirm single-element XPD improvements of 5.7 dB at Rx and 6.8 dB at Tx frequencies, corresponding to an estimated error vector magnitude (EVM) reduction of about 50 % and 40 %, respectively. The measured 2x2 arrays achieve grating-lobe-free beam steering up to 30 degrees, confirming the suitability of the proposed approach for wideband, dual-polarized satellite communication (SATCOM) front ends.

8:40 Silver Coated Polymer Antenna for K/Ka-Band Satcom Applications

Romain Greard and Léonin Lassauce (Planexus, France); Mauro Ettorre (Michigan State University, Electrical and Computer Engineering, USA); Khalid Sayegrih and Lionel Algarra (Planexus, France); Ronan Sauleau (Universite de Rennes, France)
This paper introduces a high-gain antenna in a metalized polymer. The antenna consists of a long-slot array fed by a corporate feed network and a pillbox beamformer with a total diameter of 150 mm and 70 mm height. The antenna is realized using CNC-milled Acrylonitrile Butadiene Styrene (ABS), later coated with a thin conductive silver layer to ensure efficient operation at millimeter-wave frequencies. Full-wave simulations and experimental validation confirm good impedance matching over both the RX (17.3-21.2 GHz) and TX (27.5-31 GHz) bands of K/Ka-band Satcom links. The overall structure weighs 1.1 kg and achieves a 60% weight reduction compared to aluminium-based implementations, demonstrating the feasibility of polymer-based fabrication as a cost-effective and mechanically efficient alternative for K/Ka-band Satcom antennas.

9:00 A Proximity-Coupled-Fed Phased Array Antenna Achieving ±80° Scanning for Super-Lightweight Ku-Band SATCOM Receivers

Jianping Zeng, Tzu-Yuan Huang and Hua Wang (ETH Zurich, Switzerland)
A Ku-band phased array antenna employing an air-substrate proximity-coupled-fed configuration is proposed for lightweight SATCOM applications. The design adopts a proximity-coupled feeding that replaces the conventional direct-contact feeding, while the parasitic patch and metasurface layers are air-loaded to further reduce PCB weight and broaden both bandwidth and scanning range. This configuration substantially reduces the PCB lamination count from three to one and decreases the total thickness from 3.7 mm to 1.7 mm, yielding a super-lightweight configuration with only 29% of the mass of conventional designs. The resulting phased array maintains active VSWR ≤ 2 and stable gain performance over ±80° scanning across all azimuth planes within 10.7-12.8 GHz. Measurements of an 8 × 8 prototype confirm close agreement with simulations, demonstrating a lightweight, low-complexity and fabrication-friendly solution for integrated Ku-band phased array receiver systems.

9:20 A Low-Profile Circularly Polarized Dielectric Patch Antenna for K-Band SATCOM Millimeter Wave Applications

Ali-Abdullah Albarakati (Umm Al-Qura University, Saudi Arabia); Salam Khamas (University of Sheffield, United Kingdom (Great Britain))
This paper presents a compact, low-profile circularly polarized (CP) dielectric patch antenna (DPA) for millimeter-wave (mmWave) applications. The proposed structure employs an unequal cross-slot aperture to perturb the high-permittivity dielectric patch, simultaneously realizing wide impedance and axial ratio (AR) bandwidths while maintaining a simple fabrication process. Simulated and measured results demonstrate a 10-dB impedance bandwidth of 10.65% and a 3-dB AR bandwidth of 3.4%, with a measured gain of 6.5dBic as well as 50 degree of AR beamwidth. This work represents the first experimental demonstration of a compact mmWave CP DPA. It overcomes the common limitation of linear polarization (LP) in high-permittivity dielectric antennas, establishing a viable path for integrated CP solutions in the mmWave spectrum for satellite communications (SATCOM).

Wednesday, April 22 8:00 - 9:40

A12a Array Antenna Deployments and Interactions 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Astrid Algaba-Brazález (Technical University of Cartagena, Spain), Vasilii Semkin (New York University Abu Dhabi, United Arab Emirates)

Room: Gothenburg

8:00 A Compact Phase-Gradient Metasurface Dome for Enhanced Scanning Range in Phased Arrays

Miguel Poveda-García (Technical University of Cartagena, Spain); Davide Comite (Sapienza University of Rome, Italy); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain)
This paper explores a compact phase-gradient metasurface-based dome (metadome) designed to enhance the scanning range of phased arrays operating at Ka band. The proposed metadome is implemented using a single substrate layer and can be simply fabricated with standard printed-circuit technology. It increases the array gain by up to 3.8 dB in the 50°- 75° range, with only about 1.1 dB of degradation at broadside. To the best of the Authors' knowledge, this is the most compact metadome reported to date that extends the scanning range of a phased array while maintaining a reasonable broadside gain.

8:20 Study of a Technological Solution Enabling the Design of a Dual-Polarized Unit Cell for an X-Band Active Phased Array for Earth Observation

Elaa Djebbi (XLIM UMR CNRS 7252, University of Limoges, France); Silvia Hernandez Rodriguez (XLIM - University of Limoges, France); Marc Thevenot (XLIM-UMR CNRS 7252, University of Limoges, France); Julien Lintignat (XLIM UMR 7252 Université de Limoges/CNRS, France); Benoît Lesur (Safran Data Systems, France); Cyrille Menudier (XLIM Université de Limoges, France)
This paper discusses the technological challenges involved in designing a 16x16 active phased array panel operating in the X-band (7.9-8.5 GHz) for Earth Observation applications. These challenges are mainly related to the size and complexity of the multi-layer printed circuit board (PCB) stack-up of the radiating element and the integration of the Radio Frequency Integrated Circuits (RFICs) with the radiating panel, while ensuring the expected performance. Indeed, a prototype of the PCB stack-up is presented, demonstrating the technological evaluation and validation for large, multi-layer PCBs, with simulation and measurement results showing good agreement. The design and analysis of a dual-polarized radiating element are then detailed. The proposed unit cell achieves an active reflection coefficient below -12.9 dB for scan angles between 0 and 40 degrees in elevation, and an effective isolation of 18.8 dB between the two feeding ports, confirming its suitability for Earth Observation applications.

8:40 A Phased Array Antenna System in High-Speed Wireless Back-Haul Link for 6G Mobile Networks

Bonghyuk Park (Electronics Telecommunications Research Institute, Korea (South))
This paper presents an upper-mid band 22GHz-23.6GHz beamforming integrated circuit and planar dipole antenna for phased array radio technology in high-speed wireless backhaul link. A 4-channel beamforming IC and four radiating elements are used to construct a single 4-channel beamforming module, which is then vertically integrated to create a 16-channel phased array radio module. The wireless experimental results demonstrate that the performance of the fabricated phased array radio module is consistent with the design predictions obtained through simulation.

9:00 Phased Array Antenna Technologies for Communication Systems in Future Aerial Platforms

Gonzalo Expósito-Domínguez (Airbus DS & Military Transport, Spain); Francisco Jiménez-González (Airbus, Spain); Carlos Gómez-Calero, Juan Jose Sanz-Fernandez, Andres Borges-Alejo, Fernando Estevez-Llaveria, Jennifer Lopez-Morillas, Francisco Javier Pacheco-Loeches, Victor M. Lobato-Fernandez, Alvaro Morso-Granero, Jose A. Rodriguez-Butragueño, Rodrigo Manrique-llamazares and Ana Lopez-Yela (Airbus Defence and Space, Spain); Antonio Montesano (AIRBUS DS, Spain)
The future of aircrafts is based on advanced technologies which includes communication systems. The project aims to enhance communications performances and mission capabilities for Defence applications (UAVs, transport or combat aircraft, and/or helicopters). In order to improve the airborne communication system, Airbus Defence and Space leads the design and implementation of novel active antenna arrays for different applications: SATCOM (Ka-band) and a Low Probability of Detection and Low Probability of Interception (LPD/LPI) airborne data link (Ku-band). This paper presents the new technologies for the both SATCOM and Data-Link antennas for airborne applications, covering from design to implementations and measurements.

9:20 Compact, Low-Profile, Dual-Broadband, Dual-Polarization mmWave Antenna Array for 5G Handheld Devices

Sheng-Yeh Yang and Yun-Ting Tsai (National Taiwan University, Taiwan); Sung Mao Liao, Chien Ming Hsu and Chuanchien Huang (Taiwan); Kuo-Chu Liao (AsusTek Computer, Inc., Taiwan); Shih-Yuan Chen (National Taiwan University, Taiwan)
This work presents a compact, low-profile, dual-broadband, dual-linearly-polarized 1×4 antenna array for 5G handheld devices. Implemented on a multilayer RO3006/RO4460G2 stack and excited by blind via-feeds, the array covers 24.25-29.5 GHz (Low Band, LB) and 37-43.5 GHz (High Band, HB). It achieves inter-port isolation > 15 dB and peak gains ≥ 9 dBi (LB) and ≥ 10 dBi (HB) within a compact 3.5 mm × 22 mm × 0.75 mm volume. A systematic design-from LB and HB sub-elements to a co-located dual-band element and finally the 1×4 array-shows that an edge-fed LB and a corner-fed HB sub-element, combined with optimized metal-layer allocation, minimize coupling while maintaining bandwidth and polarization purity. Simulated and measured results of a prototype verify manufacturability and performance. The proposed array is ready for beamforming IC integration in commercial 5G terminals.

Wednesday, April 22 8:00 - 9:40

A15a **Control and Evaluation of RIS and LIS Systems 1**

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain), Sergio Matos (Iscte-IUL / Instituto de Telecomunicações, Portugal)

Room: Krakow

8:00 From Unit-Cell Design to AI-Ready Control: A Deterministic Framework for a 1-Bit RIS at 29 GHz

Daniel Segovia-Vargas and Pol Comella-Hernández (Universidad Carlos III de Madrid, Spain); Carlos Bousoño-Calzón (University Carlos III of Madrid, Spain)
This paper presents a complete simulation-based workflow for the design and control of a 1-bit Reconfigurable Intelligent Surface (RIS) operating at 29 GHz. The proposed approach links the electromagnetic (EM) design of a bowtie- shaped unit cell, simulated in Ansys HFSS, with an analytical configuration framework based on the generalized Snell's law. The resulting model synthesizes quantized phase distributions {0, π} for beam steering and reflection control. The RIS layouts are automatically generated via Python scripting and validated through analytical propagation models. Results demonstrate correct beam steering and low reflection loss using a purely deterministic control scheme, paving the way for future data- driven RIS configurations. The generated analytical configura- tions naturally form structured datasets, making the framework AI-ready for future machine learning-based control strategies.

8:20 A Comparative Analysis of Single and Dual RIS Deployment for Signal Enhancement in L-Shaped Corridors

Ana Burladean and Angelo Freni (University of Florence, Italy); Paola Pirinoli (Politecnico di Torino, Italy); Agnese Mazzinghi (University of Florence, Italy)
Achieving uniform wireless coverage in complex indoor environments remains a significant challenge due to structural obstructions and non-line-of-sight areas. This paper investigates signal enhancement in the shadow zone of an L-shaped corridor using entirely passive Reflective Intelligent Surfaces (RIS). We compare the performance of a single-RIS setup against a novel dual-RIS configuration strategically deployed near the corner. To model realistic multipath propagation, we developed a custom ray-tracing algorithm that takes advantage of the regular geometry of the indoor environment to improve processing speed. Our methodology involves a detailed analysis of the RIS response as a function of the number of multipath components included in the simulation. The coverage analysis shows that the dual-RIS setup significantly outperforms the single-RIS alternatives, providing a substantial improvement in both the received power level and its spatial uniformity in the shadowed region, thereby eliminating the critical coverage gaps typical of single-reflector designs.

8:40 Secrecy Key Generation Performance in RIS-Assisted Indoor Scenario Under on-the-Shoulder Attack

Alessandro Santorsola (Polytechnic University of Bari, Italy & BV TECH Spa, Italy); Giovanni Magno (Politecnico di Bari, Italy); Vincenzo Petruzzelli (Polytechnic of Bari, Italy); Sabino Roberto Caporusso (BV TECH spa, Italy); Giovanna Calo (Politecnico di Bari, Italy)
Reconfigurable Intelligent Surfaces (RISs) are crucial for future 6G networks, enabling massive MIMO gains, adaptive beamforming, and enhanced spectral efficiency. However, the inherent openness of the wireless medium requires robust defense against passive threats. Secrecy Key Generation (SKG) offers a complementary defense by leveraging channel reciprocity and randomness to establish shared keys. This work analyzes SKG performance in an RIS-assisted indoor scenario with Alice and Bob under an on-the-shoulder attack by a passive eavesdropper. We model the RIS using the diagonal phase shift matrix, representing the isolated reflection response of its unit-cells. Our analysis quantifies the trade-offs across RIS dimension, communication throughput, key entropy, and key mismatch. The results demonstrate a fundamental trade-off between optimizing the RIS phases for maximum throughput and the resulting degradation of key entropy and the security margin. Conversely, unoptimized phases, though resulting in lower throughput, maintain high entropy and robustness against attacks.

9:00 Multi-Faceted Reflecting Surfaces Adapted to Spherical Profiles in mm-Wave Scenarios

Borja Imaz-Lueje (Universidad Rey Juan Carlos, Spain); David Fuentes (University of Alcalá, Spain); David Casillas-Perez (Rey Juan Carlos University, Spain); Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain)
This paper presents a multi-faceted surface operating as a passive reflecting surface in a mm-wave scenario, typical for 5G/B5G or 6G communications. The reflecting surface has been optimized to adapt the orientation of the panels to an architectural element with an spherical profile (dome). The multi-faceted scheme consists of irregular triangular panels to ensure assembly and proper approximation of the doubly-curved spherical profile. Some preliminary electrical studies has been conducted to evaluate the reflecting electromagnetic skin. This structure demonstrates its feasibility to deviate the field to a certain direction of space, while it maintains a high camouflage with the environment.

9:20 Smart Electromagnetic Surfaces to Improve V2X Communications in Millimeter-Wave 5G

Jorge Vallejo, Borja Imaz-Lueje and Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Celia Fontá Romero (Universidad Politécnica de Madrid); Ana Arboleya (Universidad Rey Juan Carlos, Spain)
This contribution proposes the design of smart electromagnetic surfaces to improve vehicular communications (V2X) in millimeter-wave 5G. First, a dual-band passive electromagnetic skin (EMS) providing two different reflected beams is presented. The EMS can be used to improve coverage of blind zones in urban scenarios at 28 GHz, while enabling vehicle-to-infrastructure (V2I) communications at 60 GHz. The concept has been validated by the fabrication and test of a dual-band EMS prototype, with satisfactory results. The second design consists of a multifaceted electromagnetic skin (MEMS) which can be attached to tunnel vaults or to the road safety barriers, enabling signal redirection to improve vehicle-to-vehicle (V2V) communications at 60 GHz.

Wednesday, April 22 8:00 - 9:40

A29a Reconfigurable Antennas 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain), Richard W Ziolkowski (University of Arizona, USA)

Room: Madrid

8:00 A Dual-Linear Polarization Dual-Beam Reflectarray with Reconfigurable Beam Power Ratio

Yukang Chen (Southwest Jiaotong University, China); feng Quanyuan (Southwest JiaoTong University, China); Yan Wen and Han Hao (Southwest Jiaotong University, China)
This work designs a dual-linear polarization, dual-beam reflectarray (RA) fed by a rotatable horn antenna. The RA element allows an incident linearly polarized (LP) wave to be decomposed into two orthogonal LP components in reflection. The phases of these components are independently controlled by the structure of the element, while their power ratio is determined by the polarization direction of the incident wave. Based on this principle, a RA comprising 22×22 elements is designed and simulated. The simulation results demonstrate that the RA can generate two orthogonal LP beams, and the power ratio between them can be continuously reconfigured from 1:0 to 0:1 by rotating the feed horn. These features make the proposed RA a competitive candidate for multi-mode communication systems, offering a passive and low-cost approach to beam power control.

8:20 Polarization Diversity Antenna with a Reconfigurable Y-Shaped Feed Based on Inverted Microstrip Gap Waveguide Technology

Junaid Ahmed Uqaili (Public University of Navarra, Spain); Dayan Pérez-Quintana (KTH Royal Institute of Technology, Sweden); David Osuna Ruiz and Alicia E. Torres-García (Public University of Navarra, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain)
The possibility of making reconfigurable antenna based on the inverted microstrip gap waveguide (IMGW) technology is investigated in this work. This antenna exhibits a simple structure, which consists of the Y-shaped feedline integrated in IMGW. The two PIN diodes are incorporated in the gap introduced in the perpendicular arms of the feedline to control the electrical length. The proposed antenna can be operated in two modes, the left-hand circular polarization (LHCP) and the right-hand circular polarization (RHCP) modes by electrically controlling the bias states of PIN diodes. This study opens the avenue of reconfigurability to improve existing reconfigurable antennas based on the gap waveguide (GW) technology.

8:40 Reconfigurable Antenna for Multi-Target Localization

Ruihua Ma (Xidian University China); Li Xiaoping (Xidian University, China); Erik R Algarp (EPFL, Switzerland); He Huang (Xidian University, China); Anja K. Skrivervik (EPFL, Switzerland)
This paper presents a frequency- and pattern-reconfigurable antenna designed for high-resolution multi-target detection. The proposed antenna is composed of 16 sector-shaped patches whose operating states are controlled by PIN diodes. To overcome the issue of correlated echoes originating from the same transmitting antenna, frequency reconfigurability is employed to achieve frequency-domain decorrelation. After decorrelation, the antenna can generate multiple distinct radiation patterns. Each pattern is treated as a virtual array element, replacing a conventional multi-element array for target localization using the MUSIC algorithm. By combining frequency-domain decorrelation with pattern-based virtual array synthesis, the proposed approach provides a compact sensing platform that achieves accurate multi-target localization while significantly reducing system size and complexity.

9:00 Analysis and Design of a Reconfigurable Fabry-Perot PIN Loaded Cavity Antenna

Ludovica Tognolatti, Mirko Barbuto, Alessio Monti, Cristina Ponti, Giuseppe Schettini, Alessandro Toscano, Filiberto Bilotti and Paolo Baccarelli (Roma Tre University, Italy)
This contribution presents a preliminary investigation into the design of a reconfigurable leaky-wave Fabry-Perot cavity antenna (FPCA). The proposed structure consists of a resonant cavity formed by a Partially Reflective Surface (PRS) on the top and a reconfigurable High-Impedance Surface (HIS) acting as the ground plane. The reconfigurability is enabled by loading the HIS with PIN diodes, allowing dynamic control of the electromagnetic response of the cavity. Both the PRS and the HIS are implemented as periodic arrays of metallic patches printed on thin dielectric substrates. A comprehensive analysis of the fundamental leaky modes for both Transverse Electric (TE) and Transverse Magnetic (TM) polarizations is carried out. The dispersion characteristics are derived by numerically solving the dispersion equation obtained via the Transverse Resonance Technique (TEN). The results offer valuable insights into the radiation mechanisms and reconfigurable capabilities of the structure, supporting the development of an efficient and flexible antenna

9:20 Reconfigurable Metasurface Antenna for Varactor-Based TE Channels

Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy); Arya Kanathil (University of Siena, Italy); Dona Joseph (Wave-Up Srl, Italy); Cristian Della Giovampaola (Wave Up Srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Enrica Martini and Stefano Maci (University of Siena, Italy)
A reconfigurable metasurface (MTS) antenna for varactor-based transverse electric (TE) channels is presented. The realization of a reconfigurable TE channel, capable of operating over the frequency band centered at f = 6.675 GHz under the influence of varactor diodes, is discussed. Biasing modifications to preserve the TE field distribution while maintaining smooth dispersive behavior are illustrated, and a simple feeding mechanism based on a tapered slot is introduced for the 6.225-7.125 GHz band. Full-wave simulations demonstrate a broad range of achievable propagation constant values through varactor diodes (VDs) and versatile control of the leaky-wave (LW) aperture field. The performance of the structure shows potential impact because it enables the accommodation of TE channels in MTS antennas to achieve dual-polarized hyperbolic structures.

Wednesday, April 22 8:00 - 9:40

CS30a New progress in AI-driven antenna design 1

T08 Fundamental research and emerging technologies/ Convened Session / Measurements
Chairs: Nelson Fonseca (Anywaves, France), Bo Liu (University of Glasgow, United Kingdom (Great Britain))

Room: Paris

8:00 A Novel Digitally Coded Ultra-Wideband Antenna Optimized by SADEA-VI

Qiang Hua (University of Huddersfield, United Kingdom (Great Britain)); Xinxin Liu (University of Glasgow, United Kingdom (Great Britain)); Mobayode O. Akinsolu (Wrexham University, United Kingdom (Great Britain)); Xinrui Wang (Liverpool John Moores University, United Kingdom (Great Britain)); Pavlos Lazaridis (University of Huddersfield, United Kingdom (Great Britain))
This paper presents the design of an ultra-wideband (UWB) antenna optimized using the surrogate-assisted differential evolution algorithm VI (SADEA-VI). The proposed antenna employs a digitally coded pixel structure as a parasitic structure integrated into a square-ring slot configuration, enabling wideband impedance matching and stable radiation performance. Simulation and measurement results demonstrate that the antenna covers the 3.1-10.6 GHz UWB band with $|S11| \leq -10$ dB, achieves a realized gain above 1 dBi. These results highlight the effectiveness of digital coding combined with surrogate-assisted optimization for broadband antenna design.

8:20 Design of Dual-Band Millimeter-Wave Choke Ring Antennas Using Artificial Intelligence

Nelson Fonseca and Charalampos Stoumpos (Anywaves, France); Maddy Clements (Clements, United Kingdom (Great Britain)); Alberto Montemiglio and Jonathan Davis (ADSP, United Kingdom (Great Britain)); Tomas Navarro (ESA, The Netherlands); Nicolas Capet (ANYWAVES FRANCE, France)

Artificial intelligence (AI) is emerging as a powerful tool to assist engineers in designing novel antenna systems. In the frame of an ESA funded activity, ADSP and Anywaves teamed up to explore the potential of generative AI in supporting the development of new antenna solutions. A dual-band choke ring antenna was selected as use case. The goal was to evaluate the capabilities of generative AI techniques to improve upon previous results obtained using conventional techniques. The targeted TT&C application requires a wide beam, which was set as the main requirement. Some improvement in performance was demonstrated despite the limited data set available. A choke ring antenna prototype with the best profile was manufactured and tested. Good agreement was observed between simulations and measurements. Further improvements are anticipated using a more iterative process, combined with a more diverse training data set. The results reported confirm the potential of AI-augmented design methods.

8:40 Large Language Model-Driven Efficient Feature Extraction for Triple-Band Antenna Design

Yu Yao (University of Plymouth, United Kingdom (Great Britain)); Fraser Davies (University of Edinburgh, United Kingdom (Great Britain))
Large Language Models (LLMs) have demonstrated exceptional capability in extracting electromagnetic features and offer new opportunities for antenna design that traditionally depends on expert intuition. In this paper, the features of classical microstrip antennas are extracted using an LLM to generate triple-band antennas. Starting from an elliptical antenna A1 and a slotted dual-band antenna A2 as references, a hybrid triple-band antenna B1 is created. It is further optimised through impedance matching learning using reference A3 to produce antenna B2. The resulting B2 integrates slotted squares and circular rings and resonates at 5.13-5.26 GHz, 5.67-5.80 GHz, and 7.74-7.98 GHz. It supports 5G vehicular connectivity, unmanned system relays, and X-band satellite links. Measurements confirm that the simulated performance is achieved.

9:00 Machine Learning-Based Active S-Parameter Modeling for Linear Antenna Arrays

Peiqin Liu, Yumeng Wu and Zhi Ning Chen, Z. N. Chen (National University of Singapore, Singapore)
This paper presents a machine learning-based approach for efficiently modeling active S-parameters of linear antenna arrays. A dataset comprising 256 excitation phase combinations and their corresponding active S-parameters of a four-element linear microstrip patch antenna array is generated through full-wave electromagnetic simulation to train an artificial neural network (ANN) model. The trained ANN model accurately predicts the active S-parameters of the four-element array across diverse excitation scenarios, demonstrating strong agreement with simulation results. The proposed method achieves high prediction accuracy with low computational cost, offering an effective way for the rapid analysis and optimization of antenna arrays.

9:20 Neural Beamforming of Large and Highly Coupled Antenna Arrays

Niels Skovgaard Jensen, Lasse Hjuler Christiansen and Min Zhou (TICRA, Denmark)
By neglecting the effects of mutual coupling in antenna arrays, idealised beamforming algorithms often lead to inaccurate and unreliable results. Conversely, proper inclusion of coupling effects typically renders state-of-the-art optimisation-based synthesis methods computationally prohibitive, limiting their practical use. To address these challenges, this paper introduces a neural correction framework for real-time beamforming in large, highly coupled antenna arrays. The method combines three key components: (i) a conjugate matching baseline providing a physics-informed initialisation of the excitations, (ii) a neural network correction, predicting residual excitations to satisfy complex beamforming objectives, and (iii) a Fast Direct Solver enabling efficient computation of embedded element patterns for large arrays. Together, these components enable coupling-aware, real-time beamforming for both simple steering and advanced radiation goals. The approach is validated on a strongly coupled, large-scale dual-fed multilayer patch array with hundreds of ports, demonstrating accurate and scalable performance.

Wednesday, April 22 8:00 - 9:40

CS44a Pre-Clinical and Clinical Microwave Devices - from Diagnosis to Treatment 1

T06 Biomedical and health / Convened Session / Propagation
Chairs: Raquel C. Conceição (Universidade de Lisboa, Portugal), Jorge A. Tobon Vasquez (Politecnico di Torino, Italy)

Room: Prague

8:00 Terahertz Frequency Band Selection for Biometric User Identification

Vanessa J Wood (Queen's University, Belfast, United Kingdom (Great Britain)); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain))
Continued increase in global mobile data traffic is pushing demand for fast wireless communications. As the usable spectrum extends higher in frequency, the unique properties of the terahertz (THz) spectrum, defined as 100 GHz to 3 THz, become available for exploitation. Furthermore, as mobile device functionality grows, so does the risk of unauthorized access. This, coupled with the rising risk of mobile phone theft, drives a need for more frequent user authentication. The THz spectrum enables high-bandwidth communications and, due to the mm-scale wavelength, high-resolution sensing. This paper investigates potential THz frequency bands that can be used for both a future generation of communications and continuous mobile device authentication through measurement of a biometric user signature.

8:20 Preliminary Design and Evaluation of a Hexagonal Patch Antenna for Microwave Hyperthermia at 434 MHz

Giorgia Deiana, Matteo Bruno Lodi, Marco Murgia, Gabriele Atzeni and Alessandro Fanti (University of Cagliari, Italy)
This work presents the design, fabrication, and characterization of a compact hexagonal patch antenna for radiative microwave hyperthermia at 434 MHz. Derived from an ultra-wideband topology, the antenna was optimized in CST Studio Suite to achieve efficient tissue coupling and wideband matching, with a 100 MHz bandwidth centered at 434 MHz. Fabricated on FR4, it was characterized in free-space, phantom, and in-vivo conditions using a vector network analyzer. Dielectric measurements of adipose and muscle phantoms confirmed agreement with reference data. Experimental results validated simulations, showing robust matching and stable performance under biological loading. Hyperthermia tests with the ALBA ON 4000D system achieved safe heating at 43°C and a specific absorption rate of 57 W/kg, meeting therapeutic standards. The proposed antenna demonstrates compactness, efficiency, and broadband operation, making it a promising applicator for superficial microwave hyperthermia.

8:40 Microwave Imaging with Dual-Feature Deep Learning Framework for Clinical Hepatic Steatosis Classification

Sazid Hasan, Ahmed Beriche, Sasan Ahdi Rezaeieh and Amin Abbosh (The University of Queensland, Australia)
Early detection of hepatic steatosis remains challenging with conventional imaging methods. An enhanced signal-processing approach is introduced to improve diagnostic accuracy and clinical reliability within the HepNet deep learning framework. The method applies multitaper spectrograms and continuous wavelet transforms to extract detailed time-frequency features from backscattered signals at the microwave band, reducing spectral leakage and improving tissue response characterization. A maximum mean discrepancy transfer learning technique addresses differences between simulated and clinical data by minimizing feature distribution mismatch across domains. The HepNet architecture, trained on 3D electromagnetic simulations and adapted to patient data, achieves an F1-score of 0.914, outperforming the previously achieved 0.885 score using only CWT-based features, with validation against ^{1}H-MRS ground truth. These findings demonstrate that combining advanced time-frequency analysis with domain-aligned transfer learning significantly improves the reliability and clinical applicability of electromagnetic methods for hepatic steatosis assessment.

9:00 Preliminary Analysis of Breast Microwave Images of Cancer Patients

Daniela M Godinho (Universidade de Lisboa, Portugal); Luís Ramos and Arymar Andrade Junior (ULS do Estuário do Tejo, Portugal); Raquel C. Conceição (Universidade de Lisboa, Portugal)
Microwave Imaging (MWI) has been studied for breast cancer detection in the last few decades. In this paper, we present a preliminary analysis of a patient study with our new breast MWI prototype, comprised by a single circular antenna configuration with ten antennas. The results are promising for breast cancer detection.

9:20 Microwave/MR Imaging for Breast Cancer Diagnosis: First Patient Experience

Paul M Meaney, Zamzam Kordiboroujeni and Roberta Diflorio-Alexander (Dartmouth College, USA); Xiaoyu Yang (Quality Electrodynamics, USA); Keith D. Paulsen (Dartmouth College, USA)
We are developing a microwave imaging system for use in combination with an MR imaging system for breast cancer diagnosis. We have overcome substantial obstacles such as material compatibility, signal interferences between systems, and substantial space limitations caused by the small MR bore. We utilize our monopole-based concept immersed in a lossy coupling bath to suppress unwanted multi-path signals. In this situation, the high attenuating liquid suppresses unwanted signal reflections off the tank walls, allowing us to dramatically reduce the tank size and make it sufficiently small to be portable for transporting into the MR exam room. Even with these innovations, it is only possible to perform these exams on larger bore clinical systems. Translation to an actual clinical exam has also been slowed by MR availability and the IRB protocol approval process. Notwithstanding, we have now performed our first combined microwave/MR clinical exam and present preliminary results.

Wednesday, April 22 8:00 - 9:40

CS5a Propagation for Smart Mobility Scenarios 1

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Ke Guan (Beijing Jiaotong University, China), Ibrahim Rashdan (German Aerospace Center (DLR), Germany)

Room: London

8:00 Deterministic Modeling of Dynamic ISAC Channels in RF Digital Twin Environments

Cesar Montaner, Saúl Fenollosa and Andres Ortega (Universitat Politecnica de Valencia, Spain); Hugo Beltrán (Universitat Politècnica de València, Spain); Narcis Cardona (The Polytechnic University of Valencia, Spain)
This paper introduces a methodology to calibrate Radio-Frequency Digital Twins (RF-DTs) for Integrated Sensing and Communication (ISAC) in dynamic wireless environments. The approach leverages high-resolution ray tracing in combination with wideband channel sounding to ensure consistency between simulated and measured propagation. The methodology is validated in urban scenarios featuring both mono-static and bi-static configurations, as well as moving user platforms and vehicles. Results show that the calibrated RF-DT reproduces key propagation effects, including multipath evolution, dynamic scatterers, and Doppler-induced signatures, with close agreement to measurements. These findings confirm that accurate geometry, material modeling, antenna patterns, and diffuse scattering are essential for realistic high-frequency ISAC simulation. By bridging the gap between simulation and measurement, the proposed calibration framework provides a scalable tool for developing and evaluating ISAC algorithms in complex, time-varying environments envisioned for 6G.

8:20 Lidar-Millimeter Wave Radar Collaborative Target Perception and Cross-Region Tracking for Corner Blind Zones

Ji Zihao (ChangAn University, China); Yue Lyu, Chen Liang and Wei Wang (Chang'an University, China)
Early perception of sudden traffic targets in urban road blind spots is a key challenge for autonomous driving. This paper innovatively fuses the multipath effect of millimeter-wave radar (MMWR) with LiDAR point clouds and proposes an improved extended Kalman filter (EKF) tracking framework to achieve cross-regional cooperative tracking of non-line-of-sight (NLoS) blind spot targets. Through multi-source sensing data spatiotemporal synchronization, improved E-DBSCAN clustering, and a data association strategy based on Bayesian velocity likelihood, the system effectively solves the problems of target loss and false tracking under occlusion conditions. Field experiments verify that compared with a single sensor, the fusion scheme proposed in this paper improves the average positioning accuracy in NLoS scenarios by more than 21.5% and extends the effective tracking duration by 55.6%, providing an effective technical approach for achieving safe and reliable blind spot warning.

8:40 Multi-Link Micro-Doppler Signature Measurements for ISAC Human Activity Recognition

Yupeng Wang, Keita Nishi and Minseok Kim (Niigata University, Japan)
Integrated sensing and communication (ISAC) with distributed antenna networks (DANs) offers high-precision sensing by exploiting micro-Doppler signatures from subtle target motions, yet real-world testbeds for detailed Doppler analysis remain limited. We introduce a time-synchronized, multi-link channel-measurement system that combines multiple channel sounders to capture ISAC channels in a DAN. Each node employs a wideband software-defined radio (SDR) and an 8-element antenna array, enabling time-domain sampling and Doppler measurement under monostatic, bistatic, multistatic, and mixed radar configurations. This paper overviews the developed hardware architecture and presents test measurements validating performance, along with initial deep-neural-network-based human activity recognition (HAR) results.

9:00 Validation of the Prediction of Throughput in High-Speed Trains

Mostafa Jassim, Ahmad Hamada and Thomas Kürner (Technische Universität Braunschweig, Germany)
Rapid deployment of 5G technologies in railway environments requires accurate modeling and validation to ensure reliable gigabit-level connectivity for passengers. In this work, we present a system-level simulation framework supported by extensive measurement campaigns conducted on the Karow-Malchow test track in Germany at train speeds of 50 km/h and 140 km/h. A dedicated propagation model was developed and validated against measurements, including a Vehicle Penetration Loss (VPL) model derived from real data to capture the attenuation introduced by train structures.

9:20 Measurement-Based Path Loss Completion Incorporating Shadowing Correlation for mmWave Railway Communications

Kai Mao (Université Gustave Eiffel, France); Hanpeng Li (Nanjing University of Aeronautics and Astronautics, China); Marion Berbineau (COSYS, Université Gustave Eiffel, IFSTTAR, Univ Lille & Railenium, France); Jean-Christophe Sibel (Mitsubishi Electric R&D Centre Europe & Wireless Communication Systems, France); Nicholas Attwood and Francois Gallée (IMT Atlantique, France); Qiuming Zhu (Nanjing University of Aeronautics and Astronautics, China & XYZ Company, China); Patrice Pajusco (IMT Atlantique, France)
Channel map construction is promising and feasible for railway communication scenarios thanks to fixed tracks, where the path loss (PL) is one important component. Based on the sparse millimeter-wave (mmWave) channel measurement data, this paper proposes a PL completion method incorporating shadowing correlation. In this method, a covariance function is introduced into the traditional PL model instead of the uncorrelated Gaussian random variables. Then, the distribution of the PL to be completed is derived from a joint prior distribution, with the hyperparameters estimated from sparse channel measurement data. The proposed PL completion method is validated by mmWave channel measurement data at 60 GHz in a railway scenario. The accuracy of the proposed method under different levels of data sparsity is also analyzed for this measurement case.

Wednesday, April 22 8:00 - 9:40

CS8a Advanced Quasi-Periodic Electromagnetic Structures for Metasurface, Transmitarray, and Reflectarray Applications 1

T08 Fundamental research and emerging technologies/processes / Convened Session / Electromagnetics
Chairs: Antonio Clemente (CEA-Leti, France), Enrica Martini (University of Siena, Italy)

Room: Rome

8:00 Quasi-Periodic and Aperiodic Space-Time Modulation Schemes for Metasurfaces

Davide Ramaccia (RomaTre University, Italy); Yonggeng Zhu (Nanjing University of Science and Technology, China); Mengmeng Li (Nanjing University of Science and Technology & Communication Engineering, China); Alessandro Toscano and Filiberto Bilotti (Roma Tre University, Italy)
This contribution presents and discusses the electromagnetic functionalities achievable through the application of diverse Space-Time (ST) modulation schemes to reconfigurable metasurfaces. We analyze the simplest configuration-binary coding-which relies on only two discrete states in amplitude and/or phase to control the surface properties. Three distinct classes of ST modulation schemes are examined via theoretical analysis and experimental validation. The results demonstrate that a single metasurface can deliver a broad range of diverse and specialized functionalities merely by dynamically altering the applied ST scheme. Specifically, we showcase the utility of unconventional ST patterns, including quasi-periodic profiles with engineered time delays, entirely random aperiodic distributions, and aperiodic profiles.

8:20 Design of Meta-Cells for Polarization Conversion and Beam-Forming in Transmission and Reflection

Francesco Foglia Manzillo (CEA-LETI, France); Rayan Ouazar (Sorbonne Université, France); Alessio Berto (Université de Rennes, France & Institut d'Electronique et des Technologies du numéRique (IETR), France); Guido Valerio (Sorbonne Université, France)
In this paper unit cells for metasurface-based transmit-reflect arrays are designed. The cells provide an even splitting of an incident field into a reflected and a transmitted wave. Two designs are described: the first one converts the linearly polarized incident field into linearly polarized reflected and transmitted waves, whose propagation directions can be chosen independently. The second shows that the theory formulated in the case of isotropic Huygens' metasurfaces can be used to convert a linearly polarized incident field into circularly polarized reflected and transmitted waves. Physics-based guidelines are given, which lead to design separately the three impedance sheets composing each cell thus noticeably simplifying parametric analyses.

8:40 A Fully Analytic Approach for the Design and Voronoi Realization of Arbitrarily-Shaped Quasi-Periodic Leaky Wave Antennas

Afshin Abbaszadeh and Jordan Budhu (Virginia Tech, USA); Kelvin J Nicholson (Defence Science and Technology, Australia)
A conformal leaky wave antenna (CLWA) that sits conformal to the surface of a drone is designed based on an extension of the holography technique to arbitrarily-shaped surfaces. The interference pattern between a conformal TM surface wave field modeled as as trajectories of conformal surface rays carrying a section of a radial conformally expanding wavefront and a scanned circularly polarized radiated wave is constructed. The Voronoi discretization technique and a point shifting approach is adopted to realize the holographic surface impedance. Numerical simulations are used to obtain the far-field radiation patterns and show excellent agreement with stipulated fields in design. The CLWA is fabricated using an in-house custom conformal antenna manufacturing process and measured in StarLab near field range. The measured results agree well with the simulated patterns. This study paves the way for the design and realization of electrically large arbitrarily shaped CLWAs.

9:00 3D-Printed High-Permittivity Dielectrics for Ka-Band Beam-Steering Transmit-Array Antennas

Yang Cai (Aalborg University, Denmark); Duarte A. Barbosa (ISCTE-IUL, Portugal); Sergio Matos (Iscte-IUL / Instituto de Telecomunicações, Portugal); Peng Mei (Huazhong University of Science and Technology, China); Joao M Felicio (Instituto Superior Técnico, Portugal & Instituto Telecomunicacoes, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Shuai Zhang (Aalborg University, Denmark)

High-permittivity dielectric (HPD) materials (εr > 10) play a key role in advanced antenna designs. Recent developments in low-cost 3D-printable HPD enable the realization of non-conventional geometries, broadening their potential applications. This work demonstrates the use of such materials in transmit-array (TA) design. TAs are typically realized using stacked PCBs or conventional 3D-printed dielectrics (εr < 3); while dielectrics provide higher bandwidth than PCB counterpart, their aperture efficiency is limited by the higher lens thickness. By employing 3D-printed HPD, we can achieve broadband performance with a lens thickness comparable to PCB-based designs, while retaining the versatility of additive manufacturing. We focus on the design of TAs for mechanical beam-steering antennas in the Ka-band. Simple homogenization techniques used for lower-permittivity materials are insufficient for HPD. We then presented the design of an HPD TA with a diameter of 14 λ_0 and a height of 0.4 λ_0, fabricated using low-cost fused deposition modeling (FDM). When illuminated by a standard horn (F/D=0.5), it achieves 27.4 dBi gain, elevation scanning up to 45° via horizontal in-plane feed displacement with a 2 dB scan loss, and a 1-dB gain bandwidth of 16.3%.

9:20 A Reflect-Array for Dynamic Triple-Channel Polarimetric Holography Based on Anisotropic Impedance Surface

Weimin Zeng, Zhi Hao Jiang and Wei Hong (Southeast University, China)
In this work, a reflect-array for dynamic triple-channel polarimetric holography is presented. By leveraging the full degrees of freedom of the anisotropic impedance surface (AIS), the proposed reflect-array supports three independent polarization modulation channels, each generating distinct holographic patterns in the far-field region. Specifically, the required aperture field distributions for the three holographic patterns are calculated using an alternative projection method, while the admittance distributions of the AISbased reflect-array is synthesized exploiting a covariance matrix adaptation evolutionary strategy. The performances of the triple-channel polarimetric holography is verified by full-wave simulations. Furthermore, the reconfigurable unit cell of the reflect-array is experimentally validated, further confirming the feasibility of the proposed dynamic polarimetric holography system.

Wednesday, April 22 8:00 - 9:40

EO6 Electromagnetic theory: Components 2

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Electromagnetics
Chairs: Ville Viikari (Aalto University & School of Electrical Engineering, Finland), Francesca Vipiana (Politecnico di Torino, Italy)

Room: Copenhagen

8:00 Accounting for Structural Scattering and Mutual Coupling in Characterization of Multiport Time-Modulated Scatterers

Aleksandr D. Kuznetsov, Albert Salmi and Jari Holopainen (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)
In this paper, we discuss the role of structural scattering and mutual coupling in characterization of multiport time-modulated scattering structures. Describing the scatterer using generalized scattering matrix formulation, we demonstrate a theoretical link between these two effects accounting and establish that they must be treated jointly for physically consistent modeling. To illustrate the impact of their inclusion, we perform a comparative analysis of computed and measured scattering responses for a multiport prototype. The results reveal considerable discrepancies between the models with and without these effects, highlighting that omission of structural scattering and mutual coupling leads to an underestimation of levels of harmonics and distortion of the scattered power patterns.

8:20 Time-Modulated Graphene Resonator Array for Selective Sideband Amplification

Ioannis Koutzoglou (Aristotle University of Thessaloniki, Greece); Theodosios Karamanos (Sorbonne Université, France & Université Paris-Saclay, CentraleSupélec, France); Stamatis A. Amanatiadis and Nikolaos V. Kantartzis (Aristotle University of Thessaloniki, Greece)
The enhancement of a targeted ±1 harmonic using an array of time-varying graphene sheets and a reflector is presented in this paper. To this end, a semi-analytic framework based on the transfer matrix method is developed and verified via a modified finite-difference time-domain algorithm. By employing particle swarm optimization to tune the gaps between the sheets, we maximize a chosen Floquet harmonic. Simulations show up to 10x amplification while non-target sidebands remain suppressed.

8:40 The Brillouin Zone of Glide-Symmetric Structures: A New Definition and Its Implications

Martin Petek and Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Guido Valerio (Sorbonne Université, France); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Francesca Vipiana
(Politecnico di Torino, Italy) In this work, we introduce a novel definition for the Brillouin zones (BZs) of glide-symmetric structures defined on a rectangular lattice. Glide symmetry, characterized by a half-period translation followed by a reflection, is shown to induce paired solutions in the dispersion relations. These pairs are inherently connected by a wavevector shift. We explore this new definition using a rectangular pin structure, revealing that incorporating glide symmetry transforms the BZ into a hexagonal shape, despite the rectangular definition domain. We also discuss how previous, less comprehensive approaches obscure a proper analysis of the structure's electromagnetic performance. Finally, we investigate the physical significance of the resulting solution pairs. Overall, this work offers a complete and profound overview, effectively bridging the analytical gap between glide and non-glide structures.

9:00 Experimental Verification of a Metaprism for Surface Wave-Based Routing and Frequency Multiplexing

Talha Arshed, Enrica Martini and Stefano Maci (University of Siena, Italy)
We present the design, fabrication, and experimental validation of a passive metasurface device called the Metaprism (MTP). It routes non-line-of-sight wireless energy by converting an incoming space wave into a guided surface wave, carrying it across an obstruction, and re-radiating it through a frequency-dispersive leaky-wave section. The synthesis uses a penetrable impedance boundary condition (PIBC) with non-uniform reactance modulation to achieve efficient space-wave to surface-wave conversion while accounting for dispersion losses. An annular-ring unit cell printed on Rogers TC600 was selected after eigenmode analysis to balance frequency scanning and attenuation. The fabricated prototype divides the transmitter into six sub-apertures to

9:20 An Ultra-Thin Self-Triggered Diode-Integrated Energy-Selective Surface for Front-End Protection Against High-Power Microwaves

Vincenzo Violi (CNIT, Lab. RaSS, Italy); Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (Pisa University & CNIT, Sweden); John Booske and Nader Behdad (University of Wisconsin-Madison, USA)

In this work, we present an ultra-thin, self-triggered, diode-integrated energy selective surface (ESS) operating in the S-band as a band-stop limiter under high incident fields while maintaining low-loss transmission at low power. The design consists of a single, bias-free PCB layer on a 0.2-mm-thick (≈0.20% λ_0) FR-4 substrate. In the stopband configuration, the dog-bone ESS unit cell achieves a -10 dB fractional bandwidth of 37%, with rejection up to 45 dB in full-wave simulations. We discuss the equivalent circuit retrieval, Schottky ON/OFF behavior, and the agreement between measured and simulated results over 2.2-3.8 GHz. Waveguide measurements on the fabricated prototype showed a stable passband with reduced insertion loss at -28 dBm, and self-actuated limiting at +25 dBm without detectors or bias networks. This work demonstrates a compact, fabrication-friendly approach for microwave front-end protection, offering enhanced survivability and performance within a single passive layer.

Wednesday, April 22 8:00 - 9:40

P10a Sensing, Localisation and ISAC - Part I 1

TO5 Positioning, localization, identification & tracking / / Propagation
Chairs: Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France), Thomas Dallmann (Technische Universität Ilmenau, Germany)

Room: Dusseldorf

8:00 Simulation and Validation Study of Rain Scattering Effects in 77 GHz Automotive Radar

Sonakshi Gupta (TU Ilmenau, Germany); Thomas Dallmann (Technische Universität Ilmenau, Germany)

This work presents a comprehensive simulation framework for modeling and analyzing rain back-scattering and reflectivity clutter in 77 GHz automotive radar systems. The model integrates multiple physical phenomena, including Mie scattering, spatial raindrop simulation, and the influence of the radar detector, to emulate realistic rain clutter behavior. Each stage of the back-scattered signal formation and detection process is examined to understand its influence on the overall clutter characteristics perceived by the radar. Simulated results are compared against measured reflectivity data, showing strong agreement and validating the physical consistency of the model.

8:20 Anchor-Free RSS Localization Under Real Multi-Floor Propagation Conditions

Nour Zaarour (Université Du Québec En Abitibi Témiscamingue, Canada); Nadir Hakem (Université du Québec en Abitibi Témiscamingue, Canada); Nahi Kandil (Université du Québec en Abitibi-Temiscamingue, Canada)

Anchor-free localization techniques are increasingly relevant for large-scale Internet of Thing (IoT) deployments in smart buildings, warehouses, and underground facilities, where anchor installation is infeasible. They offer the potential for scalable indoor positioning without the need for pre-deployed reference nodes. However, their practical performance in real-world environments remains underexplored. In this study, we conduct an evaluation of our contextual received signal strength anchor-free approach (CRSSA) for internode distance estimation using an open-access multi-floor testbed. Absolute inter-node distance estimation errors are analyzed per floor using boxplots, cumulative distribution functions (CDFs), and median statistics. Median absolute errors remain below 4 meters across all floors, while the 75th and 90th percentiles confirm robustness against environmental variability. These results highlight the practical feasibility and reliability of our anchor-free proposed approach in an indoor environment, providing quantitative evidence from a publicly accessible testbed.

8:40 Compressive DoA Estimation Based on a Reconfigurable Metacavity Antenna with Selected Measurement Modes

Mengran Zhao (Queen's University Belfast, United Kingdom (Great Britain) & Xi'an Jiaotong University, China); Shitao Zhu (Xi'an Jiaotong University, China); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

In this paper, we present a compressive direction-of-arrival (DoA) estimation technique using a single-port reconfigurable metacavity antenna (RMA) with selected measurement modes. The RMA is an electrically over-sized metacavity with its back wall replaced by an 1-bit reconfigurable metasurface and its top surface etched with leaky cross-shaped irises. By manipulating the on/off states of the PIN diodes loaded on the metasurface, the excitations to the leaky cross-shaped irises are altered, resulting in spatio-temporally random radiated fields that can serve as measurement modes in compressive DoA estimation. Simulated experiments are conducted to validate the feasibility of the proposed RMA-based compressive DoA estimation method with three far-field sources. Additionally, a comparison experiment using both the selected and randomly generated measurement modes is conducted. It is demonstrated that employing the measurement mode selection method can significantly improve the DoA estimation accuracy without sacrificing the efficiency.

9:00 Derivation of 3D Flight Path of Tagged Insects from a Millimeter-Wave MIMO Radar Imaging System

Etienne Dedic (LAAS-CNRS, France & University of Toulouse, France); Dominique Henry (LAAS-CNRS & CRCA-CNRS, Toulouse University, France); Mathieu Lihoreau (CRCA-CNRS, Toulouse University, France); Hervé Aubert (Laboratory of Analysis and Architecture of Systems & Institut National Polytechnique de Toulouse, France)

This paper describes how the three-dimensional (3D) flight paths of bumblebees flying outdoors can be derived using a 3D millimeter-wave radar imaging system. We report the tracking of individual bumblebees as they fly freely between a nest and a feeder, using a network of three millimeter-wave frequency-modulated continuous-wave radar beam scanning systems scanning a total volume of 9.2m3. This preliminary experimental demonstration paves the way for future research into tracking tagged insects navigating in natural 3D conditions.

9:20 Monostatic mmWave 6G ICAS: Comparing Sensing Capabilities of Cylindrical Phased Arrays and Virtual Uniform Circular Arrays

Altug Kaya, Alper Schultze and Melih Ciftci (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Germany); Aline Friedrich and Indra Ghosh (IMST GmbH, Germany); Mathis Schmieder (Fraunhofer Heinrich Hertz Institute, Germany); Ramez Askar (Fraunhofer HHI, Germany); Sven Wittig (Fraunhofer Heinrich Hertz Institute, Germany); Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany)

This paper presents the sensing capabilities of an integrated communication and sensing (ICAS) capable cylindrical phased array (CPA) prototype and proposes a super-resolution azimuth angle of arrival (AAoA) estimation algorithm to perform accurate sensing and localization. The CPA operates at 26.5GHz, supports full 360deg azimuth coverage by electronic beamforming with 48 overlapping beams and a directivity of 18dBi. To verify the sensing capabilities of the CPA, controlled experiments are conducted both in an anechoic environment with corner reflectors and an indoor open office. Then, to enable comparison, the experiments in the anechoic environment are repeated using an established setup that employs a uniform circular array and a variant of MUSIC for AAoA estimation. The experiments demonstrate time-of-flight/ranging estimation accuracy on the order of 0.1ns and localization accuracy on the order of 1deg for both arrays. Thus, the CPA prototype can perform monostatic 6G ICAS in real-world.

Wednesday, April 22 8:00 - 9:40

SW6a Innovative Methods for Enhancing Antenna Measurement Accuracy and Data Interpretation

/ / Measurements

Room: Firenze

Janet O'Neil (ETS-Lindgren) and David Knight (NPL)
Dennis Lewis (Boeing)
Stuart Gregson (Next Phase Measurements and Queen Mary University of London)
Zhong Chen (ETS-Lindgren)
David Knight (NPL)
Stéphane Faure (Anyfields)
Guillaume Andrieu (XLIM Institute - University of Limoges)

This workshop explores emerging techniques and practical approaches to improving the reliability of antenna measurements. Presentations address topics ranging from traceability and accuracy factors to uncertainty budgets in 5G massive MIMO systems, post-processing methods for refining gain measurements, and tools for uncertainty propagation in time-domain S-parameter analysis. Attendees will see a live demonstration with antennas and VNAs, learn how infrared thermography can serve as a diagnostic tool for electromagnetic field accuracy, and examine statistical methods for estimating independent samples in virtual reverberation chambers. Together, these sessions share innovative strategies for advancing measurement precision and data interpretation in modern antenna testing.
Workshop outline: We have invited several excellent speakers from industry, government/defense, and academia who are well-known researchers in the EuCAP and AMTA communities. Each speaker will present for approximately 20 minutes followed by a LIVE demonstration to make the workshop very interactive between the speakers and the attendees. Two of the speakers (Chen and Gregson) were nominated for or received a EuCAP Best Measurement Paper Award.

08:00 - 08:05 Janet O'Neil (ETS-Lindgren) and David Knight (NPL) Welcome and Workshop Scope
08:05 - 08:40 Dennis Lewis (Boeing) Overview of Antenna Measurement Traceability and Factors Effecting Measurement Accuracy
08:40 - 09:10 Stuart Gregson (Next Phase Measurements and Queen Mary University of London) On the use of Range Assessments and Uncertainty Budgets with Plane Wave Generator EIRP Measurements of 5G Massive MIMO antennas
09:10 - 09:40 Zhong Chen (ETS-Lindgren) Assessing Test Environment Uncertainties Through Post-Processing for Improved Antenna Gain Measurements (includes live demonstration with antennas and VNA)
10:10 - 10:50 David Knight (NPL) An uncertainty propagation tool for time-domain and time-gated S-parameter measurements
10:50 - 11:20 Stéphane Faure (Anyfields) Infrared Thermography as a Diagnostic Tool for Electromagnetic Field Measurement Accuracy
11:20 - 11:50 Guillaume Andrieu (XLIM Institute - University of Limoges) On the estimation of the number of independent samples in a VIRC over long time sequences

BIOGRAPHIES: Guillaume Andrieu earned his Master's in radiofrequencies and optical communications from the University of Limoges in 2003 and a Ph.D. in electronics from the University of Lille in 2006. He worked at Renault Technocentre in 2003 and joined Xlim Laboratory as a postdoctoral fellow in 2006. Since 2009, he has been an associate professor at Xlim. His research focuses on cable coupling and EMC testing, including reverberation chambers and bulk current injection. He chairs the French IEEE EMC Chapter since 2021 and edited a reverberation chamber book published by IET in 2020.
Zhong Chen, ETS-Lindgren, Chief Engineer, is located in Cedar Park, Texas. He has over 25 years of experience in RF testing, anechoic chamber design, EMC antenna and field probe design and measurements. He is Vice-Chairman of ANSC C63® responsible for the antenna calibration (ANSI C63.5) and chamber/test site validation standards (ANSI C63.4 and ANSI C63.25 series). His interests include measurement uncertainty, time domain measurements for site validation and antenna calibration, and development of novel RF absorber materials. Zhong Chen received his M.S.E.E. degree in Electromagnetics from the Ohio State University at Columbus. Mr. Chen was a candidate for the EuCAP 2024 Best Measurement Paper Award.
Stéphane Faure, Senior Engineer at Anyfields (Toulouse, France), received his Ph.D. in Condensed Matter Physics from the University of Montpellier in 2001. He has over 10 years of experience in infrared thermography applied to antenna characterization. Formerly at ONERA (the French Aerospace Lab), he contributed to advancing IR thermography and developed a visible-spectrum variant. At Anyfields, his work focuses on phase retrieval algorithms, far-field and gain determination, and measurement metrology adapted to IR imaging. Stuart F. Gregson is Director of Operations and Research at Next Phase Measurements and honorary visiting professor at Queen Mary University of London. With 30 years in aerospace, space, and communications, he specializes in near-field antenna measurements, computational electromagnetics, and 5G OTA testing. Professor Gregson has authored two IET books, published over 130 papers, and received multiple AMTA awards. He presents industrial and academic courses, including AMTA and IET short courses. A Fellow of AMTA, IET, and IoP, he served on the AMTA Board and received its Outstanding Service Award in 2022. He holds a PhD from Queen Mary University of London.

David Knight, NPL, graduated in 1990 with BSc (Hons) Physics from Imperial College (London). After work at British Aerospace Space Systems designing satellite control systems, he completed an MSc in control theory in 1993. He joined NPL (Teddington, UK) where he is a senior research scientist, responsible for the VHF/UHF free field group, with focus on bespoke methods for novel antenna design projects. He has developed improvements in the calibration of standard types of antenna, for which he won an NPL Innovation Award. He contributes to national/international standard committees, such as the BSI GEL/210 (UK) and IEC CISPR/A (international).
Dennis Lewis, The Boeing Company, received his BS EE degree with honors from Henry Cogswell College and his MS degree in Physics from the University of Washington. He has worked at Boeing in Seattle, Washington, for 35 years and is recognized as a Technical Fellow, leading the enterprise antenna measurement capability for the Boeing Test and Evaluation Electromagnetics group. Dennis holds 12 patents and received the 2013 and 2015 Boeing Special Invention Awards. Speaker is an AMTA Fellow.
Yahya Rahmat-Samii, UCLA, is a Distinguished Professor, holder of the Northrop-Grumman Chair in electromagnetics, member of the US National Academy of Engineering (NAE), winner of the 2011 IEEE Electromagnetics Field Award and the former chairman of the Electrical and Computer Engineering Department at UCLA. Dr. Rahmat-Samii was the 1995 President of the IEEE Antennas and Propagation Society and 2009-2011 President of the United States National Committee (USNC) of the International Union of Radio Science (URSI). Dr. Rahmat-Samii has authored or co-authored over 1000 technical journal articles and conference papers and has written over 40 book chapters and six books.

Wednesday, April 22 8:00 - 9:40

SW5 Emerging mm-Wave and sub-THz antenna arrays: recent technological advances and applications

/ / Measurements
Room: Firenze
Antonio Clemente (CEA Leti)
Luis Guerrero (UC3M)
Ronan Sauleau (IETR/Université de Rennes)
Guillaume Ducournau (IEMN)
Nuria Llombart (TU Delft)
M. Sajjad Ahmad (Barkhausen Institut)
Antonio Clemente (CEA Leti)
Future 6G networks will rely on millimeter-wave and sub-THz technologies to enable ultra-high-capacity links, joint communication-and-sensing, and new reconfigurable antenna and metasurface paradigms. This workshop brings together leading experts in integrated photonics, gradient and modulated metasurfaces, active and passive phased arrays, THz communications, and emerging measurement methodologies. Together, they will explore breakthroughs enabling scalable, energy-efficient, and high-resolution antenna systems from 90 GHz to 300 GHz and beyond. The workshop will highlight recent results from European research initiatives and discuss open challenges on hardware, system integration, and real-world deployment.
The workshop is structured around six invited talks from internationally recognized experts, and brings together results from 7 projects covering key antenna, metasurface, and measurement innovations for mm-wave and sub-THz systems. The session will address novel bonding strategies and on-chip metasurfaces, photonic-enabled phased arrays, gradient and modulated metasurfaces, THz communication hardware and measurements, high-capacity 300-GHz link architectures and ISAC design trade-offs. A concluding open panel will connect hardware, propagation, and system-level perspectives, identifying research challenges for future 6G nodes and sensing platforms.
08:00 - 08:15 Antonio Clemente (CEA Leti) Bridging PCB and III-V Technologies: Novel Bonding Strategies and On-Chip Metasurfaces for D-band Antenna Arrays (TERRAMETA/SYSTERA/FUNTERA)
08:15 - 08:30 Luis Guerrero (UC3M) Photonic-enabled Broadband Phase Array Antennas Operating in the Millimeter-Wave Range (Tera6G)
08:30 - 08:45 Ronan Sauleau (IETR/Université de Rennes) Compact Sub-Terahertz Antennas Using Folded Flat Optics
08:45 - 09:00 Guillaume Ducournau (IEMN) Measurements for THz Communications: Active Devices and RIS (FUNTERA/SYSTERA/TIMES)
09:00 - 09:15 Nuria Llombart (TU Delft) Towards High Capacity and Efficient Communications Links at 300GHz (TeraGreen)
09:15 - 09:30 M. Sajjad Ahmad (Barkhausen Institut) ISAC/JCAS, Antenna and Beamforming Challenges, Solutions, and Performance Trade-offs (6G-SENSES/HiCONNECTS)
09:30 - 09:40 Antonio Clemente (CEA Leti) Wrap-Up and Outlook
BIOGRAPHIES Antonio Clemente - CEA Leti Antonio Clemente received his B.S. and M.S. in telecommunication engineering from the University of Siena, Italy, in 2006 and 2009, and a Ph.D. in signal processing from the University of Rennes 1, France, in 2012. Since 2013, he has worked as a Research Engineer at CEA-Leti. His research focuses on reconfigurable antennas, millimeter-wave technology, and antenna measurement. Dr. Clemente has authored over 40 journal papers, 150 conference publications, and holds 30 patents. Dr. Clemente received several awards such as the Young Scientist Award and the Best Paper Award from high-impact international conferences.
Guillermo Carpintero - University Carlos III of Madrid Prof. Guillermo Carpintero leads the Optoelectronics and Laser Technology Group at UC3M and is a pioneer in integrated microwave photonics and photonic integrated circuits for broadband wireless links. He has coordinated major European projects (FP7/H2020), authored more than 80 journal papers and 250 conference papers, and supervised numerous doctoral theses. His work underpins the spin-off LEAPWAVE Technologies. He is the recipient of several international awards including the SPIE Heather Williamson Young Investigator Award.
David González-Ovejero - University of Rennes / CNRS Dr. González-Ovejero is a CNRS tenured Researcher at IETR Rennes, working on computational electromagnetics, phased arrays, periodic structures, and metasurfaces for mm-wave/sub-THz antennas. He has held positions in Belgium, Italy, and at NASA JPL. He is the recipient of multiple best-paper awards, a Marie Curie Fellowship, and has served as Associate Editor and Track Editor for IEEE Transactions on Antennas and Propagation and IEEE Transactions on THz Science and Technology.

Wednesday, April 22 10:10 - 11:50

A11b Antennas for Satellite Communication 2

TO3 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Steven Shichang Gao (Chinese University of Hong Kong, China), Stefania Monni (TNO Defence Security and Safety, The Netherlands)
Room: Barcelona

10:10 Design of a Dual-Band Dielectric Resonator Antenna for Satellite Communication

Edson R. Schlosser (Universidade Federal do Pampa, Brazil); Simon P Hehenberger (DLR- German Aerospace Center, Germany & TU Delft, The Netherlands); Stefano Caizzone (German Aerospace Center (DLR), Germany)
In this paper, a dual-band linearly polarized antenna operating in the K and Ka bands is proposed for satellite communication. The single element consists of a dielectric resonator antenna (DRA) that operates from 18.2 to 21.8 GHz and from 27.6 to 30.3 GHz, corresponding to bandwidths of 3.6 GHz and 2.7 GHz for the Rx and Tx links, respectively. The DRA is used to form a 2x2 symmetrical subarray that radiates circularly polarized electromagnetic fields with a high cross-polar discrimination level. The structure's optimization parameters were determined using HFSS software. The model was developed using commercial laminate and dielectric structure that will be fabricated with a 3D printing machine.

10:30 Low-Cost Dual-Band Stacked Microstrip Antenna for GPS Application

Herick R. da Silva Rodrigues (UNIPAMPA, Brazil); Gabriel P Paulena (Instituto Tecnológico de Aeronáutica (ITA), Brazil); Abdou-Halique A. A. Bouari (Unipampa, Brazil); Juner M Vieira (Universidade Federal Do Pampa (Unipampa), Brazil); Edson R. Schlosser and Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil)

This paper presents a dual-band square microstrip antenna designed to operate with right-hand circular polarization (RHCP) in the L1 (1.575 GHz) and L5 (1.176 GHz) bands of the Global Positioning System (GPS). The proposed antenna employs two FR4 laminate layers and two truncated patches stacked and excited by a single coaxial probe. A series capacitor is introduced to achieve impedance matching in both bands. The antenna was designed in Ansys HFSS and the performance validated with measurements. In addition, a planar array composed of four proposed dual-band elements was analyzed, employing a beamforming technique to steer the main beam and ensure a high cross-polarization discrimination (XPD) level. The results obtained demonstrated good performance in both operating bands for the single antenna and for the antenna array.

10:50 Sequential Rotation Feed Network Implemented in Gap Waveguide MLW (GMLW) Coaxial Line Technology for Circularly Polarized Ka-Band Arrays

Sebastian Diaz-Beiza (Universidad Carlos III de Madrid, Spain); Raha Roosefid (Chalmers University of Technology & Satcube AB, Sweden); Jose-Luis Vazquez-Roy (University Carlos III of Madrid, Spain); Ashraf Uz Zaman (Chalmers University of Technology, Sweden); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

A sequential rotation feed network implemented in multilayer gap waveguide (GMLW) coaxial line technology is presented. The design extends the use of GMLW for CP generation by integrating linearly polarized arrays and using the entire feed structure within a single GMLW layer, preserving the advantages of contactless and low-loss propagation while avoiding complex assembly and additional transitions. Each radiating element of the array consists of a 2x2 subarray of linear slots fed through a cavity to achieve uniform amplitude and phase distribution. The proposed feed network provides four outputs with the required phase shifts of 0°, 90°, 180°, and 270° and corresponding sub-arrays rotation to implement sequential rotation. Full-wave simulations show an axial ratio bandwidth of 10.5% and an impedance bandwidth of 14.5% in the Ka-band, centered at 28 GHz, with stable broadside radiation patterns, confirming the feasibility of implementing sequential rotation feed networks in GMLW arrays for millimeter-wave applications.

11:10 A Novel Multi-Periodic Line-Wave-Waveguide Antenna with Open-Stopband Mitigation

Mikhail Madji (Sapienza University of Rome, Italy); Paolo Baccarelli, Alessio Monti and Alessandro Toscano (Roma Tre University, Italy); Filiberto Bilotti (ROMA TRE University, Italy); Paolo Burghignoli (Sapienza University of Rome, Italy)

Line waves belong to the category of edge waves predicted and observed to propagate at the interface of surfaces described by impedances with opposite sign. In this contribution, we exploit the peculiar features of such waveguides to realize power leakage through space waves. This effect is obtained by perturbing a line-wave mode through a periodic load set along the direction of propagation. The resulting radiator exhibits frequency-dispersive radiation properties, with a far-field pattern scan around 20 GHz of an elliptically polarized beam. The scan degradation around the broadside due to the open-stopband region is efficiently mitigated through a fine tuning of the unit-cell architecture. The overall design constitutes a first model for efficient, planar, periodic radiators based on the line-wave technology, exhibiting a frequency-driven scan of the elevation plane.

11:30 Latest Evolution on High-Performance SatCom Rotating Metascreens with Extreme Grating Lobe Control

Francesco Caminita (Wave-Up SRL, Italy); Cristian Della Giovampaola, Massimo Nannetti and Gabriele Minatti (Wave Up Srl, Italy); Nicola Bartolomei (Wave Up srl, Italy); Enrica Martini (University of Siena, Italy); Benedikt Byrne (European Space Agency, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Stefano Maci (University of Siena, Italy)

This paper reports the next step in the development of a Ka-band SatCom terminal that uses rotatable Metascreen apertures to realize wide-angle electronic beam steering with strongly suppressed grating lobes and broadened operational bandwidth. Spherical near-field measurements in an anechoic facility confirm robust scan performance over ~2 GHz in the receive band and ~2.5 GHz in the transmit band. The beam scans to ±65° from broadside in both bands while maintaining radiation efficiencies above 80%. Even at extreme scan angles (≥60°), the radiation patterns remain clean, with no observable grating lobes-representing a marked advance over earlier implementations.

Wednesday, April 22 10:10 - 11:50

A12b Array Antenna Deployments and Interactions 2

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Astrid Algaba-Brazález (Technical University of Cartagena, Spain), Vasilii Semkin (New York University Abu Dhabi, United Arab Emirates)

Room: Gothenburg

10:10 Dual-Directional Beam Steering and Fan-Beam Radiation Management Using a Unified Identical Aperture Phased Array

Jeonghyo Lee (POSTECH, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))

This paper presents a compact phased array concept that achieves dual-directional beam steering and fan-beam radiation control within a unified identical aperture (UIA). The proposed architecture is based on a single patch antenna integrated with port-selective boundaries (PSB), formulated from cavity analysis and the Duality principle. This configuration enables selective or simultaneous port excitation to realize broadside, endfire, and fan-beam radiation without active components or multiple radiator types. The impedance bandwidths are 26.0 to 28.2 GHz and 27.1 to 30.0 GHz for the broadside and endfire modes, respectively, while high port isolation is maintained across the bands. At 28 GHz, the 1 by 4 array achieves realized gains of 10.8 dBi and 9.6 dBi with wide 3 dB scan angles for the broadside and endfire modes, and forms a fan-beam under dual-port excitation. The results validate a unified phased array platform enabling seamless ISAC integration with orientation-free and frequency-coexistent operation.

10:30 Quasi-Optical MIMO Antennas for Realizing Tbps near-Field Communication Links

Huasheng Zhang (Delft University of Technology, The Netherlands); Daniel Swist (TU Dresden, Germany); Alexandros Bechrakis Triantafyllos (Delft University of Technology, The Netherlands); Meik Dörpinghaus (TU Dresden, Germany); Maria Alonso-delPino (Delft University of Technology, The Netherlands); Gerhard P. Fettweis (Technische Universität Dresden, Germany); Nuria LLombart (Delft University of Technology, The Netherlands)

Future 6G applications demand for larger than 100 Gbps link capacity, which is currently achieved by optical fibers. However, the deployment and maintenance of networks could be complex and expensive. Here, we explore how to solve this problem by using wireless near-field links with the goal of Tbps capacity. This work presents a quasi-optical (QO) MIMO system that can reach such capacity up to 100 m. The proposed MIMO architecture has dual polarization and 16×16 transmitter/receivers, leading up to 32×32 MIMO. The link coupling and interference levels are analyzed using a field-correlation method in reception. Then, a dual-polarized QO lens antenna is considered to evaluate realistic link performance. The SINR is reported for the best 8×8 MIMO configuration for short-range connections. The QO MIMO system is combined with 1-bit quantization and zero-crossing modulation to estimate the aggregated link capacity in the order of 1 Tbps while ensuring high energy-efficient operation.

10:50 On the Beamforming Abilities of 18-Port Multi-Polarized Multi-Mode Antenna

Tran-Hien Bui (University of Queensland, Australia); Sasan Ahdi Rezaeieh (The University of Queensland, Australia); Christophe Fumeaux (University of Queensland, Australia)
This paper presents the investigation and discussion on dual-beam scanning and advanced null-steering capability of an 18-port multi-polarized multi-mode antenna. The antenna and its accompanying control algorithm, recently proposed by the authors, have previously demonstrated the capability to scan simultaneously a main beam and two nulls over the entire upper hemispherical space. Its main beam showed a realized gain greater than 7.5 dB for any predefined direction and polarization. In the present investigation, the focus is on its dual-beam scanning capability with polarization diversity, as well as its ability to generate multiple arbitrary null regions with null depths higher than 20 dB. This investigation highlights the antenna's flexibility, where its characteristics, i.e., radiation patterns and polarization states, can be readily tailored to meet the requirements of several applications and adapt to dynamic environments.

11:10 A Wideband Tri-Band Shared-Aperture Antenna Array for 5G and 6G Applications

Shangyi Sun (University of Technology Sydney, Australia); Can Ding (University of Technology Sydney (UTS), Australia); Haihan Sun (University of Wisconsin-Madison, USA); Alessio Monti (Roma Tre University, Italy); Y. Jay Guo (University of Technology Sydney, Australia)
This work presents a wideband tri-band shared-aperture antenna array covering the 5G mid-band and 6G centimetric band. The challenge of scattering and coupling suppression is holistically addressed across wide bands. Guided by characteristic mode analysis (CMA), a segmented spiral is developed to mitigate high-frequency scattering while maintaining low-frequency radiation. Compared with a tube, the spiral achieves a reduced radar cross-section (RCS) over 4.7-21.5 GHz (128.2%). The segmented-spiral dipole achieves impedance matching in low band (LB, 3.05-4.68 GHz, 42.2%) with serial resonators, covering the 5G band (3.3-4.2 GHz), while additional suppressors reduce cross-band coupling. The middle band (MB) and high band (HB) antennas operate at 6.2-10.0 GHz (46.9%) and 10.0-15.6 GHz (43.8%), covering the 5G-Advanced and 6G bands (6.425-15.35 GHz). Both antennas employ a planar magnetoelectric (ME) dipole to avoid common-mode resonances and minimize scattering. The proposed array maintains undistorted radiation patterns and better than 20 dB isolation across three bands.

11:30 Dual-Polarized, Wideband, Double Stacked Coplanar Patch Antenna for Array Application in C-Band

Michael Pircher (German Aerospace Center, Germany); Markus Limbach (German Aerospace Center (DLR), Germany); Tobias Rommel (German Aerospace Centre (DLR), Germany); Ulf Johannsen (Eindhoven University of Technology, The Netherlands)
Dual-polarized array antennas are of increasing interest, for example in synthetic aperture radar (SAR) imaging, where polarimetric observations improve the detection and classification of targets. The design of dual-polarized array antennas, requires high integrated unit cells. For this purpose the paper proposes an unit cell design of a double stacked coplanar patch antenna. The stacked patch configuration improves the bandwidth and allows a direct feeding with a 50 Ω grounded coplanar line. This feeding topology simplifies the use of integrated circuit or lumped components, leading to a high integration density. Based on the simulation results a prototype was manufactured and tested. The antenna is operating at the C-band and has a bandwidth of 550 MHz. The measured gain is 5.3 dBi

Wednesday, April 22 10:10 - 11:50

A15b **Control and Evaluation of RIS and LIS Systems 2**

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain), Sergio Matos (Iscte-IUL / Instituto de Telecomunicações, Portugal)

Room: Krakow

10:10 Experimental End-to-End near-Field Link Using Smart Electromagnetic Skin in mmWave Scenarios: Evaluation and Positioning Tolerances

Sergio Menéndez Feito and Álvaro Pendás-Recondo (University of Oviedo, Spain); Álvaro F. Vaquero and Marcos R. Pino (Universidad de Oviedo, Spain); Manuel Arrebola (Universidad Politécnica de Madrid, Spain)
This work presents a Smart Electromagnetic Skin (SES) designed to extend coverage in indoor millimeter-wave (mmWave) communication scenarios within the 5G FR2 frequency band. The proposed SES is synthesized in the near-field to redirect and broaden the beam radiated by a base station (BS) toward its blind-spot regions. A realistic indoor environment was experimentally reproduced, and the SES performance was validated by comparing measured and simulated field distributions. The results show good agreement, confirming the effectiveness of the design. To assess the robustness of the proposed solution for practical large-scale deployment, the influence of installation inaccuracies was analyzed by considering different position and orientation errors of the SES. The results demonstrate that the SES maintains stable performance under moderate misalignments, preserving the intended field distribution. Furthermore, an end-to-end communication link was evaluated. Although the SES provides optimal performance when perfectly aligned, acceptable link rates are still achieved under positioning errors.

10:30 On Properties of Phase-Conjugation Focusing for Large Intelligent Surface Applications - Part I: Vertical Polarization

Jiawang Li and Buon Kiong Lau (Lund University, Sweden)
Large intelligent surface (LIS) is one promising path to leverage 6G performance in sub-10 GHz bands. This two-part paper explores the properties of phase-conjugation focusing for a simplified LIS setup with a circular antenna array and a user antenna located within the array aperture in the same plane. In Part I, we assume vertical polarization for all array elements, whereas Part II assumes horizontal polarization. In Part I, we focus on the effect of array radius on the peak gain, 3 dB focusing width, and sidelobes for two types of circular arrays. The numerical results show that the gain minimum is located at the array center. The peak gain varies by less than 0.5 dB for focal points located within 2 wavelengths from the array center. Similarly, the focal width and sidelobe level are stable in this region, irrespective of array radius. Full-wave simulations validate part of the numerical results.

10:50 On Properties of Phase-Conjugation Focusing for Large Intelligent Surface Applications - Part II: Horizontal Polarization

Jiawang Li and Buon Kiong Lau (Lund University, Sweden)
Near-field focusing (NFF) forms the basis for multiple 6G applications of large intelligent surface (LIS) in sub-10 GHz bands. In this two-part paper, Part I analyzed the properties of phase conjugation NFF for vertically polarized antennas, in a circular array configuration. Here in Part II, we continue to study these properties, but for horizontally polarized circular array elements in two distinct configurations. The numerical results show that the first configuration with co-polarized array elements offers significant better performance in terms of peak gain, 3 dB focal width and sidelobe level than the second configuration with the broadside of the elements facing the array center. This result shows that it is beneficial for the user to have an orthogonally oriented horizontally polarized dual-element for flexible polarization alignment with the fixed array orientation. Full wave simulations were used to validate part of the numerical results.

11:10 Passive and Reconfigurable Reflecting Intelligent Surfaces (RIS) for mm-Wave 5G Based on Reflectarray Concept

Eduardo Carrasco (Universidad Politécnica de Madrid, Spain); Robert Guirado (Universitat Politècnica de Catalunya, Spain); Randy Verdecia-Peña, Daniel Martinez-de-Rioja, Gerardo Perez-Palomino and José I. Alonso (Universidad Politécnica de Madrid, Spain)
Reflecting Intelligent Surfaces (RIS) are a cutting-edge technology to enhance wireless communication systems making them more efficient. These devices can be implemented passive or allowing dynamic reconfiguration. In the former, the reflected wave on the surface is optimized and remains fixed once the RIS is implemented, while in the second case the reflection features can be reconfigured, according to the demand of the system, by implementing electronic reconfiguration using liquid crystal technology. In this contribution, both cases are demonstrated significantly improving the quality of a 5G indoor link at the band of 27 GHz.

11:30 A D-Band Experimental Platform for the Characterization and Demonstration of RIS-Based Point-to-Point Links

Jose Luis Gonzalez Jimenez (Université Grenoble-Alpes/CEA-Leti, France); Sergio Matos (Iscte-IUL / Instituto de Telecommunicações, Portugal); Evangelos Pikasis and Dimitrios S. Kritharidis (Intracom Telecom, Greece); Sean Ahearne (Dell Technologies, Ireland); Giacomo Ulisse (Johann Wolfgang Goethe-Universität, Germany); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Luis M. Pessoa (INESC TEC & Faculty of Engineering, University of Porto, Portugal); Antonio Clemente (CEA-Leti, France)
This paper presents a flexible experimental platform for the investigation and demonstration of D-band point-to-point links including reflective and transmissive electromagnetic surfaces. It is used to demonstrate an 8.5 Gb/s transmission at 140 GHz using 128-QAM over a 1.4 m RIS-assisted NLoS link and 7.1 Gb/s over 4.2 m in a LoS link

Wednesday, April 22 10:10 - 11:50

A29b Reconfigurable Antennas 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Pablo Padilla (University of Granada, Spain), Richard W Ziolkowski (University of Arizona, USA)

Room: Madrid

10:10 Design of an mmWave Reconfigurable Dielectric Resonator MuPAR for Indoor Access Points

Kristian Drizari, Leonidas Marantis, Yorgos Stratakos and Athanasios G. Kanatas (University of Piraeus, Greece)
This paper focuses on the design of a Multi Port Parasitic Array Radiator (MuPAR) antenna using Dielectric Resonator (DR) elements, operating at 27GHz and serving as the front-end antenna system of a 6G indoor network Access Point (AP). A testbed transceiver with hybrid beamforming capabilities is proposed, including software-defined radios (SDR), up/down converters, and beamformers. The suggested MuPAR exhibits pattern reconfigurability, low cost, reduced complexity, and demonstrates an excellent impedance matching and wide bandwidth for all antenna states. The antenna can perform a continuous beam scanning from -50° to 50° on the azimuth plane and beam switching at -31°, 0° and 30° on the elevation plane at 27GHz.

10:30 Three Element Frequency-Reconfigurable Super Directive Parasitic Array Design

Abdellah Touhami, Marwan Jadid and Christophe Delaveaud (CEA-LETI, France)
This paper presents the design of a frequency-reconfigurable superdirective parasitic array. The array consists of three Top-loaded dipoles, spaced by 0.144 λ at 878 MHz. To enable frequency reconfigurability of the radiated beam, the parasitic dipoles are loaded with varactors acting as tunable capacitors. Adjusting the varactors capacitances within an optimized range shifts the frequency of maximum directivity over a wide band. To match the antenna across different sub-bands, a reconfigurable L-matching circuit based on two varactors was integrated into the driven dipole. Varying the capacitances of the matching varactors shifts the antenna operating sub-bands, enabling operation over a wide frequency band. The designed array exhibits a tunable directivity bandwidth of 470 MHz, from 824 MHz to 1294 MHz with directivity and gain greater than 9 dBi and 8 dBi, respectively. Furthermore, the antenna achieves a -10 dB matched tunable bandwidth of 382 MHz from 834 MHz to 1216 MHz.

10:50 Reconfigurable Analog Beamforming for GNSS Applications

Stefano Caizzone (German Aerospace Center (DLR), Germany)
The use of antenna arrays for satellite navigation applications can have multiple advantages, e.g. for multipath suppression, jamming mitigation and reflectometry applications. Their use is however limited by their complexity and costs as well as the need for a multiantenna-capable receiver. In this paper, we present a different approach, making use of a multiband, reconfigurable, analog beamformer. A 14-channel beamformer employing analog phase shifters and attenuators is presented, which caters to these applications. We will then show an exemplary use of it, by synthesizing a given radiation pattern and validating it through measurements in an anechoic chamber.

11:10 An All-Dielectric Dual-Beam 2-Bit Reconfigurable Transmitarray Antenna Enabled by Lego Brick Concept

Xinlian Du and Yu Shao (Chongqing University of Posts and Telecommunications, China); Yu Yao (University of Plymouth, United Kingdom (Great Britain)); Jie Zhang (Ranplan Wireless Network Design Ltd, United Kingdom (Great Britain))
This paper presents an all-dielectric dual-beam 2-Bit reconfigurable transmitarray antenna (RTA). The RTA is based on a dielectric reconfigurable unit cell consisting of two types of particles: the roof and root particle, and the phase-shifting particle. A 2-bit phase control is realized by adding or removing the phase-shifting particles. The particles can be seamlessly assembled through mechanically interlocking based on Lego brick concept. The dielectric particles are fabricated by 3-D printing, and one single-beam transmitarray and two dual-beam transmitarrays operating at K band are designed, assembled, and measured. The single-beam transmitarray generate a pencil beam with a gain of 25.6 dBi, an aperture efficiency of 39.2% and a 1-dB gain bandwidth of 19.1%. The two dual-beam transmitarrays generate beams pointing at (0°, -30°) (0°, 30°) and (90°, -30°) (0°, 30°), with peak gains of 18.4 dBi and 17.8 dBi, and 1-dB gain bandwidth of 16.8% and 12.7%, respectively.

11:30 Pixel Antenna Frequency Tuning Using Characteristic Mode Analysis

Leo Lahti and Pasi Ylä-Oijala (Aalto University, Finland)
This paper proposes novel way of obtaining initial solutions for optimization of pixel antennas using characteristic mode analysis (CMA). Furthermore, we adapt perturbation sensitivity analysis based optimization with network CMA for pixel antenna switch states when feeding ports are yet to be decided. This is showcased together with existing feeding port search strategies to find multiple pixel antennas operating in 2.4GHz and 5.9GHz frequencies respectively.

Wednesday, April 22 10:10 - 11:50

CS30b New progress in AI-driven antenna design 2

T08 Fundamental research and emerging technologies / Convened Session / Measurements
Chairs: Nelson Fonseca (Anywaves, France), Bo Liu (University of Glasgow, United Kingdom (Great Britain))

Room: Paris

10:10 Large Language Model-Based Intelligent Antenna Design System

Tao Wu (University of Glasgow, United Kingdom (Great Britain)); Kexue Fu (City University of Hong Kong, Hong Kong); Qiang Hua (University of Huddersfield, United Kingdom (Great Britain)); Xinxin Liu and Bo Liu (University of Glasgow, United Kingdom (Great Britain))
Antenna simulation typically involves modeling and optimization, which are time-consuming and labor-intensive, slowing down antenna analysis and design. This paper presents a prototype of a large language model (LLM)-based antenna design system (LADS) to assist in antenna simulation. LADS generates antenna models with textual descriptions and images extracted from academic papers, patents, and technical reports (either one or multiple), and it interacts with engineers to iteratively refine the designs. After that, LADS configures and runs an optimizer to meet the design specifications. The effectiveness of LADS is demonstrated by a monopole slotted antenna generated from images and descriptions from the literature. To improve gain stability across the 3.1-10.6 GHz ultra-wide band, LADS modifies the cross-slot into an H-slot and changes substrate material, followed by parameter optimization. As a result, the gain variation is reduced while maintaining the same gain level.

10:30 Smartphone Antenna Design Using Circuit-Network-Field Collaboration Mechanism

Wenjian Gong and Qi Wu (Southeast University, China); Haiming Wang (Southeast University, China & Purple Mountain Laboratories, China); Wei Hong (Southeast University, China)
This paper introduces a novel machine learning-assisted circuit-network-field co-optimization (MLA-CNFCO) method to mitigate the strong coupling between geometric and circuit variables in smartphone antenna design. Using the knowledge of the microwave network (MN), the proposed approach improves the quality of the initial solution through prescreening and accelerates convergence by constraining the search space. Furthermore, a dynamic elimination-based update mechanism is utilized to reduce computational overhead while adeptly handling the high sensitivity of circuit variables. The advantages of the proposed method are demonstrated on a metal-bezel smartphone antenna.

10:50 Towards Diffusion-Driven Synthesis of Dipole Elements for Base Station Antenna Design

Kirill Kurskiy, Xiantao Yang, Guangliang Cheng and Yi Huang (University of Liverpool, United Kingdom (Great Britain))
The design of antenna elements for modern base stations is becoming increasingly challenging as requirements on bandwidth, efficiency, and adaptability intensify in 5G and beyond-5G networks. Conventional parametric optimization approaches are constrained by a limited number of design variables and predefined initial geometries, limiting the discovery of unconventional solutions. This paper introduces a conceptual framework for diffusion-driven synthesis of dipole antenna elements, where the antenna surface is represented as a binary 256x256 grid with over 65,000 independent parameters generated directly from random noise. The model employs a diffusion process conditioned on the reflection coefficient S11 and the distance from the ground plane to synthesize viable geometries without iterative optimization. Within approximately 20 seconds of sampling, the framework produces physically meaningful dipole structures consistent with the desired electromagnetic responses, demonstrating the feasibility of diffusion-based generative modeling for rapid and scalable antenna design.

11:10 ML-Assisted Design of Dual-Band Modulated Metasurfaces

Hanieh Kiani Amiri (University of Toronto, Canada); Hoda Nematollahi (Ecole Polytehnique Montreal, Canada); Sean V Hum (University of Toronto, Canada)
Modulated metasurface antennas (MMAs) are compact, lightweight radiators that integrate excitation and radiation on a single surface. However, conventional MMA design workflows are limited: they often target single-frequency operation and rely on small sets of predefined unit cell geometries. These constraints make achieving dual-band operation challenging. In this work, we present a data-driven, machine learning-assisted design framework for synthesizing single-layer metasurfaces capable of dual-band performance. Our method expands the conventional design space by employing a generative adversarial network. By learning the mapping between geometry and surface impedance, the model generates novel unit cell patterns that simultaneously satisfy complex impedance requirements at two distinct frequency bands, a capability difficult to achieve with conventional unit cell libraries. Compared to traditional parametric sweeps and geometry-based searches, the proposed framework significantly reduces design time, explores a broader range of scatterer topologies, and produces more optimal dual-band MMA designs.

11:30 Detection of Antenna Radiation Anomalies Using AI-Enhanced Infrared Thermography Measurements

Adrien Laffont, Manon Bruneau, Clément Megemont and Antoine Balayssac (Anyfields, France)
This paper presents a novel approach for validating antenna radiation using infrared thermography (IRT) based measurement combined with deep learning. IRT provides a simple, fast, and frequency-independent method to measure the electric field radiated by an antenna. In this study, 208 measurements were performed from 52 identical broadband PCB UWB antennas, along with 60 additional measurements from 15 of these antennas incorporating simulated defects. Two unsupervised deep learning models based on Variational Autoencoders were trained exclusively on compliant data to learn standard radiation behavior. The first model employs fully connected layers, while the second uses convolutional layers. After training, both models were evaluated on test data, including defective cases. Results demonstrate that the models can effectively cluster measurements by frequency and identify anomalies in radiation behavior. This approach offers a promising pathway toward fast, automated, and non-intrusive antenna testing for industrial

Wednesday, April 22 10:10 - 11:50

CS44b Pre-Clinical and Clinical Microwave Devices - from Diagnosis to Treatment 2

T06 Biomedical and health / Convened Session / Propagation
Chairs: Raquel C. Conceição (Universidade de Lisboa, Portugal), Jorge A. Tobon Vasquez (Politecnico di Torino, Italy)

Room: Prague

10:10 Microwave Endoscopic Imaging: Clinical Results and Remaining Challenges

Marta Guardiola Garcia (MiWEndo Solutions, Spain); Alejandra Garrido (Universitat Politècnica de Catalunya, Spain); Luz María Neira, Alvaro María Yago and Gloria María Fernandez-Esparrach (MiWEndo Solutions, Spain)
This paper critically analyses the initial clinical results obtained with MiWEndo, a microwave endoscopic imaging system designed to assist colonoscopy by detecting polyps through dielectric contrast. The study discusses the main challenges that must be addressed for its extensive clinical use, including motion, manufacturing tolerances, or limited calibration possibilities. To overcome the scarcity of clinical data for training automatic detection algorithms, a comprehensive phantom-based validation campaign was carried out. These anatomically and dielectrically realistic colon phantoms enabled controlled data acquisition and algorithm improvement, supporting the development of robust detection models for future clinical deployment.

10:30 Repeatability Assessment in Medical Microwave Imaging: A Systematic Review Protocol

Henrique V Lopes, Daniela M Godinho and Raquel C. Conceição (Universidade de Lisboa, Portugal)
Medical microwave imaging (MMWI) is a promising technology for non-invasive diagnostics and monitoring of several medical conditions. For MMWI systems to be effectively integrated into clinical practice, it is crucial that the images and signals they produce demonstrate repeatability. However, there is a lack of standardised approaches to evaluate repeatability in MMWI, with existing studies employing diverse metrics and methodologies. This paper represents a protocol for a systematic review aimed to synthesise the current practices for evaluating repeatability in MMWI. The review identified quantitative metrics used, contexts of assessment, study designs, and reported sources of variability. By clarifying current practices and gaps, the review provides a foundation for developing consistent evaluation frameworks and encourages the systematic assessment of repeatability in newly developed MMWI systems-an essential step towards robust experimental validation and reliable clinical translation.

10:50 Fibroglandular Response Mitigation Exploring Polarization Diversity for Microwave Breast Imaging

Raquel A. Martins (Lisboa, Portugal); Joao M Felicio (Instituto Superior Técnico, Portugal & Instituto Telecomunicacoes, Portugal); Gaia Guida (Tor Vergata, University of Rome, Italy); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal)
Microwave breast imaging is based on the dielectric contrast between healthy and malignant tissues. However, when this contrast is low, tumor detection becomes challenging. This paper analyzes a technique to reduce clutter from fibroglandular tissue in microwave imaging, exploring polarimetry. To this end, we simulated a balanced antipodal Vivaldi antenna, operating between 1.5-5 GHz, oriented both vertically and horizontally relative to the breast in Computer Simulation Technology. Results indicate that fibroglandular tissues have a similar response regardless the polarization; on the contrary, tumor response can be up to 10x larger in vertical polarization than for horizontal polarization. As a result, the images obtained with vertical and horizontal polarizations can be combined to mitigate the response from fibroglandular tissue, thus enhancing the response of the tumor. Future work includes testing this concept with our pre-clinical experimental setup.

11:10 Progress on a Two-Stage Ultrasound-Microwave Breast Imaging System

Skylar M Trudeau, Wanting Zhang, Ian Jeffrey, Colin Gilmore, Vahab Khoshdel and Joe LoVetri (University of Manitoba, Canada)
Recent progress on the development of a two-stage ultrasound-microwave imaging system for breast imaging is reported. We validate the two-stage procedure using synthetic experiments on MRI-derived numerical breast phantoms converted to both sound-speed phantoms and complex-valued permittivity phantoms. Ultrasound and microwave scattered-field data is obtained by positioning these phantoms inside accurate numerical models of our dual-mode breast imaging system. Ultrasound data is obtained using the opensource k-wave software whereas microwave data is generated using our in-house high-order finite-element code. The ultrasound data is inverted using a novel radial-basis function algorithm to reconstruct a 3D image of the sound-speed which is then converted the complex-valued permittivity that is used as prior information for the microwave inversion. Results show that the performance of tumour detectability approaches that of a two-stage procedure where perfect prior information is provided for the microwave imaging.

Wednesday, April 22 10:10 - 11:50

CS5b Propagation for Smart Mobility Scenarios 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Ke Guan (Beijing Jiaotong University, China), Ibrahim Rashdan (German Aerospace Center (DLR), Germany)

Room: London

10:10 Evaluation of 5G Networks for Mobile Manipulators in Industrial Assembly Environments

Kazim Bayramov (Ikerlan, Spain & University of Basque Country (UPV/EHU), Spain); Jorge Elizalde (Ikerlan & BRTA, Spain); Xabier Eguiluz (Ikerlan, Spain & BRTA, Spain); Aitor Sanchoyerto (Ikerlan, Spain); Jon Montalban Sanchez and Eneko Iradier (University of the Basque Country, Spain); Sabtiago Gonzalez de la torre (Aldakin, Spain)

Industrial environments pose significant challenges due to harsh electromagnetic propagation conditions. In this paper, a ray-tracing-based channel emulation model is employed to capture the distinctive propagation characteristics of such environments and estimate their large-scale parameters. The model's results were validated against real-world measurements and analyzed using the Close-In (CI) Path Loss Model, a widely used empirical approach known for its simplicity and versatility in predicting path loss under Line-Of-Sight (LOS) and Non-Line-Of-Sight (NLOS) conditions. Additionally, we examined the relationship between the measured path loss exponent and the empirical model in a scenario where an Automated Guided Vehicle (AGV) is equipped with a 5G modem. The results demonstrate the potential of private 5G networks and provide a methodology to predict signal propagation in manufacturing environments with multiple reflective materials.

10:30 Terahertz Signal Coverage Enhancement in Hall Scenarios Based on Single-Hop and Dual-Hop Reconfigurable Intelligent Surfaces

Ben Chen, Zhangdui Zhong, Ke Guan, Danping He, Yiran Wang and Jian-wen Ding (Beijing Jiaotong University, China); Qi Luo (University of Herfordshire, United Kingdom (Great Britain))

Terahertz (THz) communication offers ultra-high data rates and has emerged as a promising technology for future wireless networks. However, the inherently high free space path loss of THz waves significantly limits the coverage range of THz communication systems. Therefore, extending the effective coverage area is a key challenge for the practical deployment of THz networks. Reconfigurable intelligent surfaces (RIS), which can dynamically manipulate electromagnetic wave propagation, provide a solution to enhance THz coverage. To investigate multi-RIS deployment scenarios, this work integrates an antenna array-based RIS model into the ray-tracing simulation platform. Using an indoor hall as a representative case study, the enhancement effects of single-hop and dual-hop RIS configurations on indoor signal coverage are evaluated under various deployment schemes. The developed framework offers valuable insights and design references for optimizing RIS-assisted indoor THz communication and coverage estimation.

10:50 A Channel Parameter Estimation Algorithm Based on Taylor-Series Expansion Models for Slightly-Distributed-Scatterers

Zhang DaLin (Tongji & TongjiUniversity, China); Qi Wang, Pengqi Zhu, Xuefeng Yin and José Rodríguez-Piñeiro (Tongji University, China)

With the rapid development of the sixth-generation (6G) communication systems, integrated sensing and communication (ISAC) has emerged as a significant application. Traditional specular-scatterer (SS) models face inherent limitations in capturing the complex dispersive characteristics of scatterers. To address this, we propose a slightly distributed scatterer (SDS)-based signal model and derive an n-th order generalized array manifold (nGAM) in the delay domain to characterize channel dispersion characteristics. Furthermore, leveraging the framework of the subspace-alternating generalized expectation-maximization (SAGE) algorithm, the so-called n-th order GAM-SAGE (nGAM-SAGE) is introduced, allowing for efficient channel reconstruction and accurate nominal delay and delay spread estimation. Simulation and experimental results exhibit that the proposed estimator significantly outperforms conventional models in channel reconstruction and parameter estimation.

11:10 Delay-Refined OMP-Based Multipath Parameter Estimation for 6G High-Mobility Channels

Peijie Liu, Pan Tang, Boyang He and Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Qixing Wang (CMCC, China)

Future 6G communication systems will operate under highly dynamic propagation conditions, where accurate estimation of multipath parameters is critical for reliable transmission and channel characterization. This paper proposes a delay-refined OMP-based iterative algorithm that constructs accurate delay-domain templates using the autocorrelation of the transmitted pseudo-noise (PN) sequence. The algorithm performs local delay refinement and least-squares amplitude estimation to improve sub-sample accuracy without relying on large overcomplete dictionaries. Simulation results at a 4 GHz carrier frequency show that the proposed method achieves superior precision in estimating path delay, amplitude, and Doppler power spectrum compared with conventional peak detection. Experimental measurements further validate its robustness and effectiveness in reconstructing realistic time-Doppler characteristics. The proposed framework provides a practical and efficient solution for high-resolution channel parameter estimation in 6G high-mobility environments.

11:30 UWB-Based Vulnerable Road Users Protection System at Intersections: Concept, Measurements and First Results

Ibrahim Rashdan, Martin Schmidhammer, Fabian de Ponte Müller and Stephan Sand (German Aerospace Center (DLR), Germany)

Multipath-enhanced device-free localization (MDFL) leverages user-induced fading in the received power of both line-of-sight (LoS) and multipath components (MPCs) to localize unequipped vulnerable road users (VRUs). In this paper, we report real-world measurement campaign at a busy intersection to evaluate the feasibility of MDFL for sensing VRUs in complex outdoor environments. We describe the measurement setup, the processing pipeline, and characterize pedestrian-induced power changes on LoS and MPCs across links, showing repeatable, geometry consistent power changes along the pedestrian trajectory. The results confirm that a sensing repetition rate of 8 Hz is sufficient in order to detect a pedestrian at walking speed. Overall, the measurements demonstrate the feasibility of using MDFL at road intersections for VRU sensing and localization.

Wednesday, April 22 10:10 - 11:50

CS8b Advanced Quasi-Periodic Electromagnetic Structures for Metasurface, Transmitarray, and Reflectarray Applications 2

T08 Fundamental research and emerging technologies/processes / Convened Session / Electromagnetics
Chairs: Antonio Clemente (CEA-Leti, France), Enrica Martini (University of Siena, Italy)

Room: Rome

10:10 A Wideband 1.5-Bit Unit Cell for Reconfigurable Reflectarray Design

Leiyuan Qin and Wei Hu (Xidian University, China); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

This paper presents a low-complexity, wideband unit cell design suitable for reconfigurable reflectarrays (RRAs). To overcome the challenges of high implementation complexity associated with high-bit quantization, and the performance degradation resulting from one-bit quantization, a 1.5-bit phase quantization approach is proposed. The developed unit cell can operate in multiple modes to realize reflection phase delay, resonance tuning, and true-time delay, controlled by two PIN diodes. By switching the states of these diodes, the unit cell provides four reflection states. Wideband operation is achieved by selecting appropriate states across the frequency range to ensure continuous phase coverage. To validate the proposed concept, a unit cell was designed and simulated. The simulation results demonstrate stable three-phase responses with low reflection amplitude variation under different incidence angles across the 13.4-19.2 GHz frequency band.

10:30 2-Bit Reconfigurable Reflectarray with Wide Gain-Bandwidth and High-Efficiency Beam Steering for 6G Wireless Systems

Quoc Duy Nguyen, Tung Duy Phan and Ping Jack Soh (University of Oulu, Finland)

A wideband, 2-bit reconfigurable reflectarray (RRA) is proposed for 6G applications. The unit cell (UC) employs an aperture-coupled magnetoelectric (ME) dipole and achieves 2-bit phase quantization using an efficient design with only two integrated p-i-n diodes on a microstrip delay line. The UC features a phase difference of 90°±20°, while maintaining a reflection loss below 1.8 dB across 6.35-7.2 GHz (12.5% fractional bandwidth). The RRA demonstrates a 1-dB gain bandwidth of 18.5%, a 3-dB gain bandwidth of 35%, and a peak aperture efficiency of 38.5%. Furthermore, it demonstrates wide-angle beam steering up to ±50° from 6 to 7.5 GHz (22.2% fractional bandwidth), with a scan loss below 3 dB. Crucially, the scan loss remains under 1.5 dB across the entire targeted 6G band (6.4-7.1 GHz). These wideband, high-efficiency characteristics confirm the proposed RRA as a strong candidate for future 6G wireless communication systems.

10:50 Ka-Band, Dual Polarization, Multibeam Bifocal Reflector with Wide Scan Angle for Next Generation of LEO Satellites

Gabriele Minatti (Wave Up Srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Massimo Nannetti and Cristian Della Giovampaola (Wave Up Srl, Italy); Serena Assefa Asfaw (Università degli Studi di Siena, Italy); Andrea Menichelli (Pasquali Microwave Systems, Italy); Nazzareno Mandolesi (Pasquali Microwave Systems, Firenze - Università di Ferrara, Italy); Enrica Martini (University of Siena, Italy); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Stefano Maci (University of Siena, Italy)

We report the design of a multibeam reflector system operating in the Ka-band with dual circular polarization capable to steer a cluster of 37 beams within an angular range of about ±40°, providing a minimum gain coverage of 40 dBi in the Rx band and of 36.5 dBi in the Tx band. The reflectors (Tx and Rx) are properly shaped and covered with metasurfaces to obtain two exact foci and good performance in all intermediate positions. This allows one to obtain a high aperture efficiency and minimal scan loss. In the proposed implementation, the beam cluster is steered by mechanically rotating the reflectors keeping the feeds cluster fixed. The scanning performances of the proposed architecture, conceived for low Earth orbit satellites platforms, is successfully compared, at simulation levels, with other more conventional single reflector solutions. A demonstrator is currently being manufactured, and measurement results will be shown at the conference.

11:10 Modulated FSS Radome for RCS Reduction Applications

Andreas Ericsson Ahlgren, Pasquale Giuseppe Nicolaci, Mustafa Murat Bilgic, Mark Whale, Oscar Borries and Min Zhou (TICRA, Denmark)

We present a modulated frequency-selective surface (FSS) radome designed for radar cross section (RCS) reduction while maintaining high transmission performance in the antenna operational band. The proposed design employs an electrically thin checkerboard configuration of modulated unit cells to redirect the scattered energy away from the monostatic direction. Simulation results obtained using QUPES demonstrate a wideband monostatic RCS reduction exceeding 10 dB in C- and X-band at 6.1-11.5 GHz, corresponding to a 61% fractional bandwidth, while providing excellent transparency in the Ka-band at 20.2 GHz. The radome concept was further validated with a Ka-band patch array, confirming that the FSS maintains the antenna's radiation characteristics with minimal degradation. These results highlight the effectiveness of the proposed modulated FSS approach for achieving simultaneous wideband RCS reduction and high-frequency transparency in advanced radome applications.

11:30 Advances on Reflectarray Cells Leveraging Resonant SIW Cavities

Andrés Gómez-Álvarez (Universidad de Oviedo, Spain); Nicolò Delmonte (University of Pavia, Italy); Lorenzo Silvestri (Università di Pavia, Italy); Maurizio Bozzi (University of Pavia, Italy); Manuel Arrebola (Universidad Politécnica de Madrid, Spain); Marcos R. Pino (Universidad de Oviedo, Spain)

We present recent advances on single-layer reflectarray (RA) unit cells based on resonant substrate-integrated waveguide (SIW) cavities. The incident field couples through a slot into a uniform SIW cavity; shorting vias placed inside the cavity set the resonance and the phase shift. We review the evolution from a basic rectangular-slot cell to a refined dual-resonance H-slot design with independently tunable half-mode resonances. A Ku-band demonstrator validates this concept, achieving a remarkable 1-dB gain bandwidth of 33.3% (12.5-17.5 GHz) and maximum gain of 29 dBi, with excellent agreement between simulation and measurement. The results confirm the viability of the presented low loss, compact cells and the excellent match with the predicted performance attest to their reduced sensitivity to local periodicity effects. These features make SIW-based unit cells a competitive option for broadband planar reflectarrays.

Wednesday, April 22 10:10 - 11:50

EO7b Electromagnetic theory: Components 3

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Angelo Freni (University of Florence, Italy), Kamil Karacuha (Istanbul Technical University, Turkey)

Room: Copenhagen

10:10 Analysis and Design of an Air-Filled Gap Ridge-to-Microstrip Transition

Juan J. Flórez Rodríguez and Luis Fernando Herran (University of Oviedo, Spain)
The study and design of transitions between different transmission technologies plays an important role when it comes to implement a communications system. One particular type of waveguide, called ridge waveguide (RW), has been very popular among novel RF designs because it provides a higher bandwidth than conventional rectangular waveguides (RWG). This is why numerous transitions to RW technology has been studied. However, this paper presents the design of a contactless transition from RW to microstrip technology, where an air-filled gap is placed between both technologies. The transition is characterized through a series-impedance circuit model and simulated on a back-to-back configuration demonstrating that it is possible to make contactless transitions between ridge and microstrip technology while keeping insertion losses below 1 dB between 18 and 23 GHz.

10:30 Design and Development of SU-8 Based mm-Wave Bandpass Filter Using Grayscale Photolithography

Abu Nasar Ghazali (University College Cork, Ireland); Dmitry Kozlov (Tyndall National Institute, Ireland); David Nugent (University College Cork, Ireland); Senad Bulja (Tyndall National Institute, Ireland); Riley Gatensby (Trinity College Dublin, Ireland)
The purpose of this paper is twofold. First, a new technique for the fabrication of mm-wave devices is presented. The method is based on grayscale photolithography, which unlike standard binary photolithography, allows for the creation of features of variable heights, depending on the amount and intensity of light the photoresist was exposed to. Second, the paper introduces a novel resonator, termed Multiple Split-Concentric Ring Resonator (MSCRR), which reduces the resonator profile by introducing multiple coupled split-ring resonant elements within the resonator cavity, thereby controlling the number of elements and the coupling among them; the resonator heights can be kept almost arbitrarily low. As a first demonstrator of both the new resonator and the fabrication technique, a 2-pole mm-wave bandpass filter operating at 34 GHz was fabricated using grayscale photolithography. The height of the presented filter is significantly lower than any other mm-wave air-filled filter cavity solution available in the literature.

10:50 Passive Emulation of Non-Foster Components

Younes Radi, Pardha Sourya Nayani and Morteza Moradi (Syracuse University, USA)
The rapid advancement of next-generation defense and telecommunications has imposed strong demand for broadband electromagnetic components. Non-Foster elements, such as negative capacitors and negative inductors, have emerged as one of the most promising solutions, offering the potential to overcome fundamental bandwidth limitations. However, existing realization methods of non-Foster components face substantial challenges: active implementations constrained with stability, and noise, while passive approaches are limited by narrow range of achievable values and lack systematic design methodologies. Here, we introduce a novel design concept that enables the realization of non-Foster components with arbitrary reactance values at any desired frequency and bandwidth within passive, linear, time-invariant (LTI) framework. As a proof-of-concept, we demonstrate a wideband negative inductor based on this concept. These non-Foster components can be realized as integrated chips, serving as practical counterparts to conventional inductors and capacitors. This paves the way for commercial integration of non-Foster elements into standard electronic components.

11:10 Wilkinson Power Divider in Printed Ridge Gap Waveguide with Enhanced Insertion Loss for mm-Wave Applications

Miguel Angel Fuentes-Pascual (Universidad Politécnica de Valencia (UPV) & Antennas and Propagation Laboratory (APL), Spain); Enlin Wang and Yongrong Shi (Nanjing University of Aeronautics and Astronautics, China); Jose I. Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Alejandro Valero-Nogueira and Mariano Baquero-Escudero (Universidad Politécnica de Valencia, Spain)
This paper presents the design of a Wilkinson Power Divider (W-PD) implemented in Printed Ridge Gap Waveguide (PRGW) technology for mm-wave antennas and devices at 30~GHz. At this frequency, conventional printed implementations such as microstrip suffer from significant dielectric losses, which become critical when scaling up to larger arrays or devices. PRGW technology offers considerably lower losses and can be implemented on more affordable substrates without a major degradation in performance. In this work, a lumped resistive element is integrated within PRGW technology for the first time through the design of a W-PD. To assess its performance, a counterpart W-PD in microstrip technology is also developed and compared, demonstrating the advantages of PRGW in overall performance.

11:30 Complementary Topological Metasurfaces for Robust Power Divider Performance Enhancement

Ali Ali and Maryam Khodadadi (University of Surrey, United Kingdom (Great Britain)); Hesam Zaravashan (5G and 6G Innovation Centres University of Surrey, United Kingdom (Great Britain)); Pei Xiao (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain))
Line-waves (LWs), highly confined one-dimensional electromagnetic modes that propagate along the interface between complementary metasurfaces, offer a promising platform for overcoming the inherent limitations of conventional power dividers. Traditional structures, such as Wilkinson power dividers, often suffer from narrow bandwidth, high insertion loss, and limited power handling capability, which restrict their performance in modern radio frequency (RF) and microwave systems. In this work, we propose a compact topological T-shaped 1×2 power divider that leverages complementary inductive-capacitive metasurfaces in conjunction with dielectric loading. The complementary metasurfaces enable the coexistence of TM and TE surface modes, while the dielectric loading significantly enhances field confinement and impedance matching across a broad frequency range. Therefore, the proposed design achieves low loss, high power transfer efficiency, and broadband operation. The presented structure offers a scalable solution that addresses key challenges in RF and microwave circuitry, providing an effective approach for next-generation signal distribution networks.

Wednesday, April 22 10:10 - 11:50

P10b Sensing, Localisation and ISAC - Part I 2

T05 Positioning, localization, identification & tracking / / Propagation
Chairs: Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France), Thomas Dallmann (Technische Universität Ilmenau, Germany)

Room: Dusseldorf

10:10 Triangular Arrays of Frequency-Scanned Antennas for Efficient Fully-Azimuthal 1D and 2D Direction Finding Using Bluetooth Beacons

Alejandro Gil Martinez (Universidad de Murcia, Spain); Rubén Pedreño Martínez and David Cañete-Rebenaque (Universidad Politécnica de Cartagena, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain); Antonio Skarmeta Gomez (University of Murcia, Spain); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain)
Two triangular antenna array topologies formed by three frequency-scanned microstrip leaky-wave antennas (MLWAs) are investigated, with potential application for single-anchor fully-azimuthal direction finding using Bluetooth Low Energy (BLE) beacons. The first topology combines three single-port MLWAs along their longitudinal plane forming a triangular array, demonstrating the synthesis of nine scanned beams covering 360° in the azimuthal plane when using the two more distant BLE advertising channels #37 and #39. The second configuration arranges three dual-port MLWAs along their transverse plane, demonstrating the synthesis of twelve beams covering 360° in azimuth and 90° in elevation using the same two BLE channels. Simulated results show the successful synthesis of amplitude-comparison monopulse functions which can be used for fully-azimuthal one-dimensional and two-dimensional amplitude-only direction finding, using a single BLE anchor point and RSSI (Received Signal Strength Information) data.

10:30 The Halo Antenna for Collocated over-the-Horizon Radar Transmit and Receive Sites

Simon Henault, Alain Joyal and Tony Laneve (Defence Research and Development Canada, Canada)
The halo antenna is evaluated as a potential element of a receive over-the-horizon radar array to be collocated with the transmit array in the Canadian Arctic. To prevent saturation of the receiver due to the direct signal of the transmitter, a null in the vertically polarized radiation pattern of the halo antenna is exploited. Using an unbalanced transmission line to connect this antenna introduces imbalances in the halo that need to be mitigated using proper balun and common-mode choke devices. Different combinations of a balun and chokes are evaluated using measurements and numerical modeling. Drone-based measurements are used to validate the effectiveness and criticality of the balun and chokes. It is determined that direct signal levels lower than -30 dBm at the receivers are achievable with an 8 km separation between the halo receive elements and a notional transmitter of 32 log-periodic elements with 1.28 MW of power.

10:50 Use of Orientation Diversity to Improve DoA Estimation with an Array of Incomplete Vector Sensors

Evelyn Lisseth Rojano Fernandez (CNES, France); Christophe Morlaas (ENAC, France); Vincent Laquerbe (CNES, France); Julien Lesouple (ENAC & TéSA Laboratory, France)
The aim of this paper is to show how exploiting orientation diversity on an array of incomplete electromagnetic vector sensors (each with only three out of six elementary dipoles) can improve the theoretical performance of the array to localize sources, approaching that of a full electromagnetic vector sensor. The Cramer-Rao bound (CRB) is evaluated for various array configurations with different sensor orientations. A key issue with incomplete vector sensors is the poor performance at elevation angles close to 90 degrees, which is here addressed by maximizing the orientation diversity among the elements. Finally, the calculated CRB is validated using the maximum likelihood estimator (MLE) applied to one of the diversely oriented arrays.

11:10 Dual-Radar Sensing for Automated Clinical Mobility Assessment: Toward Contact-Free Evaluation of the 10-Meter Walking Test

Xiaoxuan Dong and Phichamon Sakdarat (Chalmers University of Technology, Sweden); Gunilla Kjellby Wendt (Sahlgrenska University Hospital, Sweden); Xuezhi Zeng (Chalmers University Technology, Sweden)
Contactless gait measurement is desirable in many application scenarios, especially in clinical settings. Millimeterwave radar has demonstrated great potential for quantitative gait measurement, but it faces challenges in achieving accurate measurement over long distances due to complex multipath propagation effects. In this work, we present a novel dual-radar approach for reliable long-distance gait measurement, aiming to automate the 10-meter walking test for parkinson's disease assessment. A robust signal processing pipeline was developed to preprocess, fuse, and analyze radar data, enhancing measurement quality. This approach was validated in a simulated real-life environment at two different walking speeds, achieving a relative error reduction exceeding 20 % in step time estimation compared with a single-radar-based approach, and the improvement was statistically significant ($p < 0.01$).

11:30 Modeling and Compensation of GNSS Synchronization Errors for 5G TDoA Localization in Maritime Environments
Robin Byl (Université Libre de Bruxelles, Belgium); François Quitin (Université libre de Bruxelles, Belgium)
Accurate localization is a key requirement for maritime applications relying on 5G networks, such as autonomous navigation, situational awareness, and search and rescue operations. This paper investigates the performance of 5G-based positioning in maritime environments under Global Navigation Satellite System (GNSS)-synchronized networks. The study combines theoretical modeling of 5G signal propagation in maritime scenarios with real-world measurements of GNSSbased synchronization errors. Furthermore, an autoregressive model is proposed for the synchronization errors. Finally, a novel compensation algorithm capable of mitigating the impact of synchronization errors on localization accuracy is proposed, and its performances are assessed.

Wednesday, April 22 10:10 - 11:50

SW6b Innovative Methods for Enhancing Antenna Measurement Accuracy and Data Interpretation

// Measurements

Room: Firenze

Janet O'Neil (ETS-Lindgren) and David Knight (NPL)
Dennis Lewis (Boeing)
Stuart Gregson (Next Phase Measurements and Queen Mary University of London)
Zhong Chen (ETS-Lindgren)
David Knight (NPL)
Stéphane Faure (Anyfields)
Guillaume Andrieu (XLIM Institute - University of Limoges)

This workshop explores emerging techniques and practical approaches to improving the reliability of antenna measurements. Presentations address topics ranging from traceability and accuracy factors to uncertainty budgets in 5G massive MIMO systems, post-processing methods for refining gain measurements, and tools for uncertainty propagation in time-domain S-parameter analysis. Attendees will see a live demonstration with antennas and VNAs, learn how infrared thermography can serve as a diagnostic tool for electromagnetic field accuracy, and examine statistical methods for estimating independent samples in virtual reverberation chambers. Together, these sessions share innovative strategies for advancing measurement precision and data interpretation in modern antenna testing.
Workshop outline: We have invited several excellent speakers from industry, government/defense, and academia who are well-known researchers in the EuCAP and AMTA communities. Each speaker will present for approximately 20 minutes followed by a LIVE demonstration to make the workshop very interactive between the speakers and the attendees. Two of the speakers (Chen and Gregson) were nominated for or received a EuCAP Best Measurement Paper Award.

08:00 - 08:05 Janet O'Neil (ETS-Lindgren) and David Knight (NPL) Welcome and Workshop Scope
08:05 - 08:40 Dennis Lewis (Boeing) Overview of Antenna Measurement Traceability and Factors Effecting Measurement Accuracy
08:40 - 09:10 Stuart Gregson (Next Phase Measurements and Queen Mary University of London) On the use of Range Assessments and Uncertainty Budgets with Plane Wave Generator EIRP Measurements of 5G Massive MIMO antennas
09:10 - 09:40 Zhong Chen (ETS-Lindgren) Assessing Test Environment Uncertainties Through Post-Processing for Improved Antenna Gain Measurements (includes live demonstration with antennas and VNA)
10:10 - 10:50 David Knight (NPL) An uncertainty propagation tool for time-domain and time-gated S-parameter measurements
10:50 - 11:20 Stéphane Faure (Anyfields) Infrared Thermography as a Diagnostic Tool for Electromagnetic Field Measurement Accuracy
11:20 - 11:50 Guillaume Andrieu (XLIM Institute - University of Limoges) On the estimation of the number of independent samples in a VIRC over long time sequences

BIOGRAPHIES: Guillaume Andrieu earned his Master's in radiofrequencies and optical communications from the University of Limoges in 2003 and a Ph.D. in electronics from the University of Lille in 2006. He worked at Renault Technocentre in 2003 and joined Xlim Laboratory as a postdoctoral fellow in 2006. Since 2009, he has been an associate professor at Xlim. His research focuses on cable coupling and EMC testing, including reverberation chambers and bulk current injection. He chairs the French IEEE EMC Chapter since 2021 and edited a reverberation chamber book published by IET in 2020.
Zhong Chen, ETS-Lindgren, Chief Engineer, is located in Cedar Park, Texas. He has over 25 years of experience in RF testing, anechoic chamber design, EMC antenna and field probe design and measurements. He is Vice-Chairman of ANSC C63® responsible for the antenna calibration (ANSI C63.5) and chamber/test site validation standards (ANSI C63.4 and ANSI C63.25 series). His interests include measurement uncertainty, time domain measurements for site validation and antenna calibration, and development of novel RF absorber materials. Zhong Chen received his M.S.E.E. degree in Electromagnetics from the Ohio State University at Columbus. Mr. Chen was a candidate for the EuCAP 2024 Best Measurement Paper Award.
Stéphane Faure, Senior Engineer at Anyfields (Toulouse, France), received his Ph.D. in Condensed Matter Physics from the University of Montpellier in 2001. He has over 10 years of experience in infrared thermography applied to antenna characterization. Formerly at ONERA (the French Aerospace Lab), he contributed to advancing IR thermography and developed a visible-spectrum variant. At Anyfields, his work focuses on phase retrieval algorithms, far-field and gain determination, and measurement metrology adapted to IR imaging.
Stuart F. Gregson is Director of Operations and Research at Next Phase Measurements and honorary visiting professor at Queen Mary University of London. With 30 years in aerospace, space, and communications, he specializes in near-field antenna measurements, computational electromagnetics, and 5G OTA testing. Professor Gregson has authored two IET books, published over 130 papers, and received multiple AMTA awards. He presents industrial and academic courses, including AMTA and IET short courses. A Fellow of AMTA, IET, and IoP, he served on the AMTA Board and received its Outstanding Service Award in 2022. He holds a PhD from Queen Mary University of London.
David Knight, NPL, graduated in 1990 with BSc (Hons) Physics from Imperial College (London). After work at British Aerospace Space Systems designing satellite control systems, he completed an MSc in control theory in 1993. He joined NPL (Teddington, UK) where he is a senior research scientist, responsible for the VHF/UHF free field group, with focus on bespoke methods for novel antenna design projects. He has developed improvements in the calibration of standard types of antenna, for which he won an NPL Innovation Award. He contributes to national/international standard committees, such as the BSI GEL/210 (UK) and IEC CISPR/A (international).
Dennis Lewis, The Boeing Company, received his BS EE degree with honors from Henry Cogswell College and his MS degree in Physics from the University of Washington. He has worked at Boeing in Seattle, Washington, for 35 years and is recognized as a Technical Fellow, leading the enterprise antenna measurement capability for the Boeing Test and Evaluation Electromagnetics group. Dennis holds 12 patents and received the 2013 and 2015 Boeing Special Invention Awards. Speaker is an AMTA Fellow.

Yahya Rahmat-Samii, UCLA, is a Distinguished Professor, holder of the Northrop-Grumman Chair in electromagnetics, member of the US National Academy of Engineering (NAE), winner of the 2011 IEEE Electromagnetics Field Award and the former chairman of the Electrical and Computer Engineering Department at UCLA. Dr. Rahmat-Samii was the 1995 President of the IEEE Antennas and Propagation Society and 2009-2011 President of the United States National Committee (USNC) of the International Union of Radio Science (URSI). Dr. Rahmat-Samii has authored or co-authored over 1000 technical journal articles and conference papers and has written over 40 book chapters and six books.

Wednesday, April 22 10:10 - 11:50

IW5 Industrial Workshop - Next-Gen Antenna Array Systems: Design, Simulation, and Optimization (3DS)

// Electromagnetics

Room: Stockholm

Sajid Asif, 3DS

This workshop explores advanced methodologies for developing next-generation antenna array solutions. Participants will learn how to leverage CST Studio Suite's high-performance solvers for large antenna arrays, including array synthesis through Antenna Magus, automated design workflows in CST Studio Suite, and non-parametric optimization using Tosca. The session also highlights SIMULIA IVCAD tools, demonstrating unified modelling and simulation of antenna arrays integrated with active front-end circuits to improve overall system performance. Attendees will gain practical insights into state-of-the-art design and optimization for modern antenna array technologies. Workshop Outline: This workshop features three expert-led presentations. The first talk covers modelling and simulation of antenna arrays, demonstrating CST Studio Suite's built-in array tools, array synthesis with Antenna Magus, and CST's advanced solvers for large arrays. The second presentation focuses on Tosca and its integration with CST, enabling next-generation optimization methods-such as topology and shape optimization-that were previously not achievable. The final talk highlights SIMULIA's IVCAD Suite, showcasing its integration with CST and itsability to evaluate overall system performance, including nonlinear effects from active RF front-end components like power amplifiers. Together, the sessions provide a comprehensive view of modern phased-array design.

Sajid Asif, with over 17 years of experience, is an Industry Process Consultant at Dassault Systèmes, driving SIMULIA technical engagements in the Electromagnetics domain across multiple industries. A seasoned RF & Antenna Engineer, he has designed and tested advancedRF/microwave circuits and phased array antennas for Satcom and terrestrial applications. Alongside his industry work, he has contributed as a researcher and lecturer at several academic institutions. Dr. Asif holds a Ph.D. in Electrical & Computer Engineering from North Dakota StateUniversity, and is a senior member of IEEE and member of IET.

Wednesday, April 22 12:00 - 12:40

IN05 Christian Fager - Modeling and compensation of nonlinear effects in MIMO transmit arrays

/ / Antennas

Chair: Stefania Monni

Christian Fager received his Ph.D. degree from Chalmers University of Technology, Sweden, in 2003. He became a Full Professor at Chalmers in 2019 and currently serves as Head of the Microwave Electronics Laboratory. He has authored or coauthored more than 250 publications in international journals and conferences, making significant contributions to the development of linear and energy-efficient power amplifiers and transmitter architectures for wireless communication Dr. Fager has served as Associate Editor for both IEEE Microwave Magazine and IEEE Microwave and Wireless Components Letters. He is a member of the Board of Directors of the European Microwave Association (EuMA) and has been elected General Chair of the 2028 European Microwave Week to be held in Göteborg, Sweden. Dr. Fager is a Fellow of the IEEE.

Room: Edinburgh

12:00 Modeling and Compensation of Nonlinear Effects in MIMO Transmit Arrays

Christian Fager (Chalmers University of Technology, Sweden)

The design of active antenna transmitters for highly integrated 5G/6G and sensing systems brings together a complex interplay of factors - from antenna radiation behavior and circuit nonlinearities to thermal interactions and digital signal design. Understanding and managing these interactions are key to unlocking the next generation of efficient and intelligent wireless systems. In this presentation, we introduce a comprehensive yet computationally efficient multi-physical modeling framework that unifies communication/sensor signal characteristics, circuit behavior, antenna self- and mutual coupling, and radiation effects into a single framework for analysis and optimization. Building on this framework, we also explore advanced digital signal processing techniques for identifying and compensating these impairments. A variety of simulations and experimental demonstrations will highlight the validity and practical use of the proposed methods, illustrating how such integrated modeling can accelerate the development of transmitters and antenna systems for future wireless systems.

Wednesday, April 22 12:00 - 12:40

IN06 Balasubramaniam Shanker - Computational Electromagnetics; past, present and future (?)

/ / Electromagnetics
Chair: Oscar Quevedo-Teruel
B. Shanker received his B'Tech from the Indian Institute of Technology, Madras, India in 1989, M.S. and Ph.D in 1992 and 1993, respectively, from The Pennsylvania State University. From 1993 to 1996 he was a research associate in the Department of Biochemistry and Biophysics at Iowa State University where he worked on the Molecular Theory of Optical Activity. From 1996 to 1999 he was with the Center for Computational Electromagnetics at the University of Illinois at Urbana-Champaign as a Visiting Assistant Professor, and from 1999-2002 with the Department of Electrical and Computer Engineering at Iowa State University as an Assistant Professor. From 2017, he was a University Distinguished Professor (an honor accorded to about 2% of tenure system MSU faculty members) in the Department of Electrical and Computer Engineering at Michigan State University, and the Department of Physics and Astronomy. Currently, he is a Professor and Chair of Electrical and Computer Engineering at The Ohio State University. From 2015-2018, he was appointed Associate Chair of the Department of Computational Mathematics, Science and Engineering, a new department at MSU and was a key player in building this Department. Earlier he served as the Associate Chair for Graduate Studies in the Department of Electrical and Computer Engineering from 2012-2015, and currently is the Associate Chair for Research in ECE. He has authored/co-authored around 450 journal and conference papers and presented a number of invited talks. His research interests include all aspects of computational electromagnetics (frequency and time domain integral equation based methods, multi-scale fast multipole methods, fast transient methods, higher order finite element and integral equation methods), propagation in complex media, mesoscale electromagnetics, and particle and molecular dynamics as applied to multiphysics and multiscale problems. He was an Associate Editor for IEEE Antennas and Wireless Propagation Letters (AWPL), IEEE Transactions on Antennas and Propagation, and Topical Editor for Journal of Optical Society of America: A. He is a full member of the USNC-URSI Commission B. He is Fellow of IEEE (class 2010), elected for his contributions to time and frequency domain computational electromagnetics. He has also been awarded the Withrow Distinguished Junior scholar (in 2003), Withrow Distinguished Senior scholar (in 2010), the Withrow teaching award (in 2007), and the Beal Outstanding Faculty award (2014).

Room: Berlin

12:00 Computational Electromagnetics; Past, Present and Future (?)
Balasubramaniam Shanker (The Ohio State University, USA)
The solution to Maxwell's equation has been the basis of a slew of development over the past eight decades. These range from early radar systems to modern applications that are capturing imagination of engineers today: wearable sensors or antennas, antennas and sensors for driverless vehicles, threat detection scanners, non-invasive medical devices, advanced electromagnetic (EM) and acoustic materials. In exploring these applications, the state of art has advanced to an extent that it computational electromagnetics has become a routine part of the design eco-system. Indeed, more often than not, it is not uncommon for designers to ask whether measured data agrees with HFSS, a simulation software. It was not always this way. A couple of decades ago, the state of art of simulations was at its infancy. Problem that could be solved were electrically small and geometrically not sophisticated. The gradual transformation of the state of art happened in late 1990's. The transformation was largely driven by both advances in computational horsepower as well new algorithms. In concert, we have achieved remarkable capabilities. That said, the richness of our electromagnetic environment implies that there are a range of problems that are still beyond the reach of our simulation capabilities. Challenges arise due to increase in frequency, behavior of materials at these frequencies, shape and topology optimization, transient physics, multi-physics challenges, packaging in relation to new circuit architectures, and so on. In this talk, I will walk through some the grand challenges (biased perspective, of course) that the community has overcome and our group's role in these efforts. I will also diverge onto interesting intellectual forays into the intersection of computer graphics and computational electromagnetics as well as particle in cell methods for plasma physics. I will walk through some of the interesting topics that our group has embarked upon as well as pose a set of open interesting problems.

Wednesday, April 22 12:40 - 13:30

WG10 Lunchtime Meeting of EurAAP Working Group Chairs

Room: Dusseldorf
This is a lunchtime meeting for all chairs of EurAAP Working Groups.

Wednesday, April 22 13:30 - 14:40

CMSIG Characteristic Modes Special Interest Group Annual Meeting

Room: Firenze
CM-SIG was set up in 2014 to bring together those interested in developing the theory and applications of characteristic modes, currently with 118 member groups from academia/industry. We will report/discuss the progress of our various initiatives at the annual meeting. All are welcome to attend

Wednesday, April 22 13:30 - 14:40

WG6 EurAAP Working Group on Education

Room: Madrid

Wednesday, April 22 13:30 - 14:40

BPA1 **Best Student Paper - Poster Session 1**

Room: Poster Area

Best Student Paper Award

Committee:
Assoc. Prof. Enrica Martini (University of Siena, Italy)
Prof. Max Ammann (Technological University Dublin, Ireland)
Assoc. Prof. Dr.-Ing. Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok, Thailand)
Dr. Raffaele D'Errico (CEA-LETI, France)
Dr. Tian Hong Loh (National Physical Laboratory, UK)

Short list:
(1571213581) Yupeng Wang, Keita Nishi and Minseok Kim (Niigata University, Japan) - "Multi-Link Micro-Doppler Signature Measurements for ISAC Human Activity Recognition"

(1571212288) Xinyi Y. I. Xu (Zhejiang University, China); Yang Yan and Jinpeng Yuan (Shanxi University, China); Wei E. I. Sha (Zhejiang University, China) - "Rydberg-Atom Superheterodyne 3×3 Receiver Array for Two-Dimensional Direction-of-Arrival Estimation"

(1571215896) Qinghao Zhang, Yongzhong Li and Piero Triverio (University of Toronto, Canada) - "Adaptive Mesh Refinement for a Multiscale Electromagnetic Solver Accelerated with MultiAIM"

(1571215132) Jacob Linden (University of Chicago, USA); Felipe Vico (Universidad Politécnica de Valencia, Spain); Jeremy Hoskins (University of Chicago, USA); Manas Rachh (Indian Institute of Technology Bombay, India) - "Efficient BIE-Based Shape Optimization for the Design of mm-Wave Lenses"

(1571215578) Viktor Chernikov (Chalmers University of Technology, Sweden); Goran Granstrom (GOTMIC, Sweden); Marcus Gavell (Gotmic AB, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden) - "Characterization of Variable Phase Resolution and Cross-Channel Amplitude Imbalance Effects in 100GHz Active Beam-Steering Phased Array"

Wednesday, April 22 13:30 - 14:40

P2-AO1 **Adaptive and reconfigurable antennas**

TO1 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 3

3.01 An Arbitrary Linear Polarization Generation Method Based on Dual-Polarization Reconfigurable Reflectarray

Zhifeng Pan (Anhui University, China); Zhi Li (China Electronics Standardization Institute, China); Hang Yu (Anhui University, China); Yang Lixia (Jiangsu University, China)

In this paper, we propose an arbitrary linear polarization generation method that can be achieved with a unit cell possessing 1-bit phase modulation capability for both horizontal and vertical polarization waves. This method combines far-field modulation technology with a sparse approach to achieve simultaneous control of dual circular polarization (CP) waves. Then, a desired linear polarization (LP) wave is generated in the desired direction. As verification, an array with a scale of 16×16-element is designed and fabricated. Measurement results show that the desired LP wave is successfully generated in the desired direction.

3.02 Assessment of the Trade-off Between Efficiency and Bandwidth in Aperture Tuned Antennas

Sergei Kosulnikov, Jussi Rahola, Jaakko Juntunen and Mikko Honkala (Optenni Ltd, Finland)

Aperture tunable antennas are widely used in portable wireless devices to meet the requirements for the wide range of operating frequency bands. The aperture port is connected to a switch which selects the suitable aperture component to be used in the particular frequency range. In the design, the input matching network and the values of the aperture components must be optimized simultaneously. In this paper we show that there is a trade-off between radiation efficiency and mismatch losses of the antenna system related to the aperture component value. If the radiation efficiency is maximized, the antenna system has small inherent bandwidth and is difficult to match efficiently, resulting in large mismatch losses.

3.03 Reconfigurable Intelligent Surface Based on Slots for Wireless Communications

Andres D Prieto Martinez and Josep Parrón Granados (Universitat Autònoma de Barcelona, Spain)

This work presents the design, simulation, and experimental validation of a 1-bit Reconfigurable Intelligent Surface (RIS) based on slot elements controlled by PIN diodes. It also extends the concept to 2-bit by introducing an asymmetric slot. In both cases, the phase of the reflected wave is digitally controlled through the diode switching states. Unlike solutions based on MEMS, varactors, or other devices, the proposed approach offers a simpler and easily scalable architecture, that enables increasing in the number of bits without major structural modifications. The fabricated 1-bit prototype demonstrates the RIS capability to control beamforming and signal steering. In the 2-bit version, validated through simulations, a significant reduction in secondary lobes is also observed.

3.04 Study and Design of a Reconfigurable Unit Cell with Optical Switching Using PIN Diode and Photodiodes Biasing

Ikra Ahmed (University of Limoges, France & Toulouse-INP, France); Hamza Kaouach (LAPLACE & Toulouse INP-ENSEEIHT & Université Férérale Toulouse Midi-Pyrénées, France); Olivier Daniel Bernal (LAAS-CNRS, Université de Toulouse, France); Olivier Pigaglio (Institut National Polytehcnique de Toulouse, INPT-ENSEEIHT, France)

Reconfigurable transmitarray antennas (RTAs) are key enablers for high-gain, beam-steerable performance in future communication and radar systems. While PIN diodes provide rapid switching capabilities, their dependence on electrical biasing networks introduces additional complexity and insertion loss. This work explores an optically controlled phase reconfigurability for RTAs in the X band and compares the insertion loss to a conventional voltage-biased PIN diode. The approach uses photodiodes to optically bias a PIN diode, offering reduced insertion loss while preserving isolation. Simulation results indicate that, in ADS, both the voltage-biased and photodiode-biased PIN diode achieve comparable ON-state insertion losses of approximately 0.7 dB. Experimental validation further shows that, at the expense of higher optical power, the photodiode-assisted approach can reduce insertion loss below the electrically biased case while maintaining effective isolation. These findings confirm that optically controlled switching provides a viable path to reduce insertion loss and simplify biasing in reconfigurable RF systems.

3.05 A New Approach to Reconfigure Antipodal Vivaldi Antennas

Lidiane S Araujo and Alessandro Girardi (Universidade Federal do Pampa, Brazil)

In this paper, we propose a novel technique for developing frequency-reconfigurable antipodal Vivaldi antennas (AVA) capable of operating as multiband, wideband, or ultra-wideband (UWB). The new approach adds notches to the original antenna on the inner edge of one of the radiating plates, combined with filamentary conducting bridges placed transversally at suitable positions across each notch. Layouts of the antenna and computer simulation results (HFSS ANSYS software) are produced for three examples of reconfigurable AVA, covering the 2.8 to 15 GHz band.

3.06 Non-Volatile Printed MoS2 Enabled Reconfigurable MSRR Metasurface for Improved Decoupling in a Joint Communication and Sensing System

Zizhen Zhang (University of Manchester, United Kingdom (Great Britain)); Zixing Peng and Xiaoyu Xiao (The University of Manchester, United Kingdom (Great Britain)); Cinzia Casiraghi and Zhirun Hu (University of Manchester, United Kingdom (Great Britain))

This paper proposes a non-volatile MoS2 enabled reconfigurable MSRR metasurface to reduce inter-antenna coupling in Joint Communication and Sensing (JCAS) systems. By adjusting the switch states, the metasurface achieves frequency-dependent isolation control, providing optimal decoupling across different operating bands. Full-wave simulations on a 2x2 array verify that the design effectively suppresses coupling and improves SINR. The simulated results confirm that the metasurface enables adaptive, tunable decoupling, offering a flexible hardware solution for future 6G JCAS applications.

3.07 Single-Layer Dual-Mode Circular Patch Filtenna

Sara Javadi (Graz Uuniversity of Technology & CD Lab, Austria); Behrooz Rezaee (Graz University of Technology, Austria); Wolfgang Bosch (Graz University of Technology & Institute of Microwave and Photonic Engineering, Austria)

In this paper, a compact single-layer Filtenna based on a circular patch and fusion method is presented. By etching a semicircular λg /4 slot on the patch, dual-mode excitation is achieved, enabling the antenna to perform radiation and filtering functions simultaneously. Additionally, a λg /2 edge slot intro- duces a radiation null that enhances frequency selectivity. The proposed structure exhibits a measured impedance bandwidth of 200 MHz, a center frequency of 3.45 GHz, and a realized gain of 6.5 dBi. The total size of the Filtenna is 0.28λ0 ×0.28λ0 ×0.018λ0, where λ0 is the free-space wavelength at 3.45 GHz. Owing to its compact geometry and intrinsic filtering capability, the design presents a promising solution for modern sub-6 GHz wireless communication systems

Wednesday, April 22 13:30 - 14:40

P2-AO2 Fundamental research and emerging technologies/processes

TO8 Fundamental research and emerging technologies/processes / / Antennas

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 3

3.08 Design and Fabrication of a Microstrip Antenna Using Aerosol Jet Printing Technology

Pasquale Naclerio and Adriano Cimini (University of Trieste, Italy); Nicholas Sesto Gorella (Picosats, European Union); Federico Dogo, Paolo Camerini, Giacomo Contin, Laura Gonella and Giulia Buttazzoni (University of Trieste, Italy)

In this work, we present the design, fabrication and validation of a low-cost rectangular microstrip antenna, fed by a 50 Ohm quarter-wave impedance transformer and operating at 18.5 GHz for satellite communications. The study was carried out in the laboratories of the University of Trieste, as a collaboration between the Department of Physics and the Department of Engineering and Architecture. Following the theoretical design and numerical optimization, the antenna was fabricated using Aerosol Jet Printing (AJP) technology, employing nanomaterial-based conductive silver ink on a Rogers RO4725JXR substrate. Both the reflection coefficient and radiation pattern of the printed antenna were experimentally characterized in an anechoic chamber under far-field conditions, showing good agreement with the simulation results. These findings not only highlight the advantages of implementing AJP-printed antennas for satellite applications, but also demonstrate the effectiveness of the overall design process as a rapid prototyping tool for both research and educational purposes.

3.09 A Single-Layer Dual-CP Antenna Array Based on Gap Waveguide Technology

Ali Farahbakhsh (Gdansk University of Technology, Poland & Graduate University of Technology, Iran); Davood Zarifi and Michal Mrozowski (Gdansk University of Technology, Poland)

A novel dual-circularly polarized (dual-CP) antenna sub-array operating in the X-band (10.5-12.5 GHz) based on E-plane groove gap waveguide (GGW) technology is presented. The proposed sub-array incorporates a septum polarizer and a horn flare with an integrated splitting grid to suppress grating lobes. The sub-array achieves excellent impedance matching and an axial ratio below 2.5 dB across the entire band (17.4% bandwidth), supporting both LHCP and RHCP radiations. The design features single-layer feeding network enables low-loss, contactless assembly and simplified fabrication, making the design highly suitable for satellite communication.

3.10 Angularly Selective Electromagnetic Absorbers: Tailoring Transmission and Absorption

Martin Olguin Lopez and Nathaniel J. Riehl (University of Delaware, USA); Quang M Nguyen (DEVCOM ARL, USA); Mark Mirotznik (139 The Green & University of Delaware, USA); Mario Junior Mencagli (University of Delaware, USA)

This work presents a systematic methodology for designing electromagnetic absorbers with tailored angular absorption profiles and minimized reflection within a prescribed angular sector. The proposed approach enables the realization of structures that exhibit strong absorption for oblique incidence while remaining highly transparent near normal incidence. A representative design is demonstrated based on a unit cell composed of two back-to-back parallel-plate waveguides loaded with a lumped resistive element. Full-wave simulations of the periodic absorber confirm the effectiveness of the proposed design methodology. Such angularly selective absorbers may find application in radome systems to reduce the radar signature of antennas while preserving high transmission and reception efficiency along the main beam direction.

3.11 A Comparison of Metallization Methods in Additive Manufacturing for Rapid Prototyping of Microwave Structures

Anouk Nees (Eindhoven University of Technology, The Netherlands); Teanette van der Spuy (Chalmers University of Technology, Sweden & Satcube AB, Sweden); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands); Rob Maaskant (CHALMERS, Sweden)

This paper presents an investigation into additive manufacturing with 3D-printed structures and metallization methods for microwave structures and antennas. It explores the use of copper electroplating and silver electroless plating with a modified version of Tollens' reagent. Preliminary tests were conducted with a 10cm long WR-42 waveguide. The loss per centimeter varies from 0.2dB/cm to 1.2dB/cm due to surface roughness. A more detailed loss analysis was performed using an iris resonator within the same frequency band, resulting in Q-factors of 540 and 1550. Although the metallized prototypes are more lossy than their fully metallic counterparts, these results provide a reliable basis for first-order prototype validation of microwave structures.

3.12 Effectiveness of Dielectric Rod Antenna on Image Resolution for W-Band Radiometric Imaging System

Ilhami Unal (University College Dublin, Ireland); Sergiy Panin (Millimeter Wave and Terahertz Research Laboratories (MİLTAL), Turkey); Mustafa Tekbaş (Tron Electronic Systems, Turkey)

In this study, dielectric rod antennas of different shapes were investigated for utilization as quasi-optics feed for passive radiometric imaging in the W-band to obtain better image resolutions. The influence of rod shape on the antenna performance was revealed. The dielectric rod waveguide antenna, possessing not complicated design for manufacturing. was proposed to get acceptable and better image resolution compared to an available commercial W-band rectangular horn antenna. It possesses at 94 GHz measured gain about 17.6 dBi, and almost circular symmetric radiation pattern with 10-dB beamwidth around 38 degrees and return loss less than -13.5 dB in the frequency range of 90-100 GHz.

3.13 Feasibility Studies on Plasma-Based Reflective Surfaces

Mirko Magarotto, Mohammad Ali Shameli, Lorenzo Tonon, Federico Cescon, Renwei Tan, Luca Schenato and Antonio-D. Capobianco (University of Padova, Italy)

The numerical design of two plasma-based reflective surfaces operating in the X band is presented. One design enables beam-forming, while the other supports beam-steering. Both configurations incorporate an illuminating horn antenna. In parallel, the plasma discharges forming the reflective surfaces have been experimentally realized and characterized in terms of plasma density using a microwave interferometer. The numerical analysis explores the sensitivity of the proposed designs to variations in plasma properties and operating frequency. For instance, when operating at 8 GHz, the beam-forming capability is maintained over a bandwidth of approximately 1 GHz, with side lobe levels remaining below -7 dB. Experimental tests conducted with a geometry matching the simulated configuration confirm that the assumed plasma properties are achievable in practice, thereby supporting the feasibility to the proposed designs.

3.14 Water and Oil Emulsion Antennas for Compact Low Frequency Applications

Pedro Vazquez (Universidad Politécnica de Madrid, Spain); Ahmed El Yousfi (King Fahd University of Petroleum and Minerals, Saudi Arabia); Vicente González Posadas (Polytechnic University of Madrid, Spain); Daniel Segovia-Vargas and Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain)

Water-in-Oil (W/O) and Oil-in-Water (O/W) emulsions may be used to economically manufacture high permittivity compact dielectric resonator antennas. Compact antennas for low-frequency applications allow for the efficient deployment of massive Multiple Input Multiple Output (MIMO) solutions within the sub-GHz bands as well as elevated levels of power transfer in Microwave Power Transfer (MPT) applications. In order to achieve such miniaturization, Dielectric Resonator Antennas (DRAs) may be used alongside high-permittivity materials. Nonetheless, such materials require complex manufacturing, elevated costs and allow for discrete permittivity selection. Emulsions permit for the selection of an arbitrary value of permittivity, continuously ranging between those of the components at furthest extremes. In this work, the dielectric properties of several emulsions are characterized and modeled in order to simulate a miniaturized DRA. The simulation demonstrates the validity of such emulsions as substitutes for state-of-the-art high-permittivity dielectrics at low frequencies, achieving an extremely low cost and simple manufacturing.

3.15 Towards Lightweight Miniaturized ESPAR Antennas: 3D-Printed High Permittivity Dielectric Overlays

Bartosz Kamecki, Benedykt Sikorski and Luiza Leszkowska (Gdansk University of Technology, Poland); Mateusz Rzymowski (Gdansk University of Technology & WiComm Center of Excellence, Poland); Krzysztof Nyka and Lukasz Kulas (Gdansk University of Technology, Poland)

This paper investigates the use of additive manufacturing for the fabrication of dielectric overlays aimed at miniaturizing reconfigurable electronically steerable parasitic array radiator (ESPAR) antennas. The study examines the influence of relative permittivity, infill density, and the number of outer walls in Acrylonitrile-Butadiene-Styrene (ABS) composites with ceramic powder additives on antenna impedance matching and radiation performance. The results show that antenna resonance can be tuned effectively by controlling the printing parameters, without degrading radiation efficiency or beam-steering capabilities. In addition, by employing materials with higher dielectric permittivity in combination with reduced infill and added outer walls, the mass of the overlay was reduced by approximately 18% compared to a fully solid reference, while maintaining comparable performance. To the best of our knowledge, this is the first demonstration of an optimized balance between material permittivity and infill density for lightweight ESPAR antenna overlays.

3.16 LED-Induced Photoconductive HR Silicon for Reconfigurable Antennas: Modeling and Experimental Study

Fatma Elhouni, Yi Huang and Yaochun Shen (University of Liverpool, United Kingdom (Great Britain))

We present a combined experimental and simulation study on using high-resistivity silicon (HR-Si) as a tunable photoconductive material for reconfigurable antennas. Illumination by high-power LEDs is used to induce photoconductivity in the HR-Si, dynamically altering its conductivity. Four-point probe measurements under various LED intensities show that the silicon's conductivity can be tuned over several orders of magnitude. These measured conductivity values are used as models by defining illuminated regions of silicon with different conductivities. This work demonstrates that high power LED can serve as an effective, fast, and reprogrammable method for contactless RF reconfiguration. The proposed approach offers a scalable and accessible mechanism for next-generation reconfigurable antennas, with the potential for software-defined optical control of antenna patterns and frequency bands.

3.17 Mass Reduction of a Dual-Band Folded-Shorted Patch Antenna for Compact Platforms Enabled by Additive Manufacturing and Electroplating

Alasdair D. I. Christie and Alexander T Don (University of Edinburgh, United Kingdom (Great Britain)); Bandar R Alshammari (The University of Edinburgh & King Abdulaziz City for Science and Technology, United Kingdom (Great Britain)); Yuepei Li (Imperial College London, United Kingdom (Great Britain)); Faezeh Shalchy (Heriot-Watt University, United Kingdom (Great Britain)); Sam Tammas-Williams and Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A low cost and lightweight dual-band folded-shorted patch (FSP) antenna is developed by plastic additive manufacturing (AM) techniques and electroplating, for utilization on size and mass restricted platforms. The intricate design operates in the S- and L-bands and uses a meandered top layer for miniaturization. Moreover, the manufactured prototype was compared to an identical monolithic copper 3D AM prototype. Beam pattern measurements are primarily in agreement with a slight decrease in the peak realized gain, likely due to the manufacturing process. Also, a minor downward shift in the operating frequency for both antenna models was observed when compared to simulations, but good matching is still observed for the plated prototype. Also, the manufactured structure has an 80% mass reduction when compared to the monolithic counterpart and is a fraction of the cost.

3.18 Electromagnetic Characterization of Screen-Printed Carbon-Based Dipole Antennas

Nicola Curreli, Matteo Bruno Lodi and Andrea Melis (University of Cagliari, Italy); Marco Simone and Loreto Di Donato (University of Catania, Italy); Alessandro Fanti (University of Cagliari, Italy)

This paper presents the electromagnetic characterization of dipole antennas fabricated by screen printing a carbon-based conductive paste. The paste, composed of high-reactivity carbon mixtures and a cellulose binder, was deposited on paperboard substrates to realize lightweight and low-cost radiating elements. Prototypes with lengths of 10 cm and 14 cm were designed, simulated, and experimentally tested. The effective conductivity of the printed traces was extracted through comparison between simulations and measurements, yielding a value of approximately 6 × 10^3 S/m. Despite the lower conductivity compared to copper, the printed dipoles exhibited broader bandwidths and stable radiation patterns with toroidal distribution. These results demonstrate the feasibility of carbon-based pastes for radiofrequency applications, particularly in low-cost and disposable devices.

3.19 Study of the Photoconductive Effect in Germanium for High-Frequency Applications

Ines Larrayoz-Arrigote (Universidad Publica de Navarra, Spain); Miguel Ángel Armendáriz-Armenteros and Beñat Sanz-Ambustegui (Public University of Navarra (UPNA), Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain)

This paper investigates the photoconductive effect in germanium (Ge) as a basis for high-frequency optoelectronic applications. A mathematical framework is developed to describe the generation, recombination, and transport of photoexcited carriers in Ge under near-infrared excitation (1550 nm). The analysis provides quantitative insight into carrier dynamics and their impact on the transient conductivity response relevant to high-frequency regimes. In parallel, the complete cleanroom fabrication process of Ge-based photoconductive structures is detailed, including deposition, lithography, and metallization steps. This combined theoretical and technological study serves as a preliminary exploration of germanium in the context of telecom-compatible THz devices, acknowledging its known limitations within PCA applications and paving the way for future experimental validation with alternative materials.

3.20 Modular K/Ka Front-End Antennas via Additive Manufacturing for Spaceborne Phased Arrays

Adrian Fonseca (Celestia TTI, Spain); Carlos Suárez García (TTI, Spain); Alberto Pellón and Manuel J. Gonzalez (Celestia TTI, Spain)

This paper presents the design and validation of a modular K/Ka-band phased array developed within Multispace Project for next-generation LEO satellite payloads. The architecture relies on a modular Building Block (BB) concept, enabling scalable array synthesis across SATCOM K/Ka frequency bands (17.7-31 GHz). Each BB integrates a fully additive-manufactured dual polarization radiating chain composed of a quad-ridge septum polarizer working as radiating element, a high-selective waveguide filter, and a Bow-Tie PCB-to-waveguide transition. The components are manufactured using Selective Laser Melting (SLM) - a Laser Powder Bed Fusion (LPBF) process - in AlSi10Mg. The proposed design ensures polarization purity, low mutual coupling, and broadband operation while maintaining full compatibility with additive manufacturing (AM) constraints. Manufactured hardware has been experimentally characterized, showing strong agreement with simulations. These results confirm the suitability of the presented approach for scalable, high-performance K/Ka-band phased arrays in LEO communications payloads.

3.21 Fully Metallic Wideband Monoconical Antenna Embedded in 3D Printed Capacitive Impedance Surfaces

Karina Vieira Hoel (FFI, Norway & University of Oslo, Norway); Stein Kristoffersen (FFI, Norway)

We have designed a broadband monocone on a circular metallic capacitive loaded ground plane to lift the omnidirection elevation angles between 30o - 70o with minimum multipath interference. Finite standard ground planes propagate surface waves causing ripples in the radiation patterns due to the edge diffraction. Periodic surfaces such as Bed of Nails (BON) improve the radiation patterns over a broad frequency band (2:1). Simulation and measurement results show that surface currents are reduced, the radiation patterns are improved, while VSWR remains unchanged. This metal solution is possible with 3D printing, which avoids dielectric material that can be detrimental in space applications.

3.22 Monolithically-Integrated Coaxial Transmission Lines Enabled by Multi-Material Multi-Process Additive Manufacturing

Konstantinos Kermanidis (University College Cork, Ireland & Tyndall National Institute, Ireland); Ghassen Brinis and Deepal Deepak Patil (Tyndall National Institute, Ireland); Dimitra Psychogiou (University College Cork and Tyndall National Institute, Ireland)

This paper reports on a novel integration concept for the realization of monolithically-integrated 3D square coaxial transmission lines (SCLs) using multi-process digital additive manufacturing (DAM) technologies. The proposed manufacturing approach is based on the combination of three manufacturing processes, namely fused filament fabrication (FFF), piezo jetting, and laser sintering, alongside 5-axis manufacturing, that are uniquely combined within a single in-house DAM platform. For proof-of-concept validation purposes, the dielectric insulator of the SCL was made from a low loss Acrylonitrile Butadiene Styrene (ABS) filament whereas a highly conductive silver ink was used for the manufacturing of the inner and the outer conductor. The SCLs demonstrated ultrawide operational bandwidth up to approximately 46 GHz. The average attenuation factor of the SCLs was measured around 0.33 dB/cm at 10 GHz and is in close agreement with the one predicted by full-wave electromagnetic simulations. Dimensional analysis was also performed, confirming minimal deviations.

3.23 Narrowing the Received Intensity Profile in an Optical Wireless Power Transfer System Using Ring-Free Bessel-Gaussian Laser Beams

Masato Suzuki, Natsuha Ochiai, Yukiko Suzuki, Kazuto Kashiwakura, Sho Aonuki, Yuka Oshima and Yohei Toriumi (NTT, Inc., Japan); Madoka Takahashi (NTT, Inc. , Japan)

This study numerically investigates optical wireless power transfer (OWPT) using ring-free Bessel-Gaussian (RFBG) beams and demonstrates narrowing of the received intensity profile and a consequent reduction in receiver panel area. Under the assumption that the beam periphery is truncated and a circular panel intercepts only the high-intensity central area, an RFBG beam can collect the same energy as a Gaussian beam with a smaller receiving area. Under our computed conditions, we obtained up to an 11% reduction in area. These results suggest potential space-saving in OWPT systems.

3.24 Reconfigurable Solution with Slotted Ground Planes for Antenna Booster Technology

Sabrina Arus (Universitat Ramon LLull, Spain); Jaume Anguera (Ignion & Universitat Ramon Llull, Spain)

The rapid growth of Internet of Things (IoT) devices has increased the demand for compact, efficient, and flexible antennas. This work presents a strategy to enhance antenna performance on a 60 mm × 65 mm PCB by integrating a slotted ground plane with a reconfigurable SP4T (Single-Pole-Four-Throw) switch architecture. A small, 30 mm × 3 mm × 1 mm antenna booster element is used to excite the radiating modes of the ground plane. The combination of both techniques yields a 4.4 dB improvement over the reference design across the 698 - 960 MHz band. These results demonstrate that integrating structural modifications with reconfigurable matching network effectively enhances the radiation performance of compact IoT devices.

Wednesday, April 22 13:30 - 14:40

P2-A03 **Lens antennas and transmitarrays**

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)
Room: Poster Level 4

4.28 3D Printed GRIN Lens with Continuous Refractive Index Gradient for the Emerging 26-GHz Applications

Matthieu Egels (Aix Marseille University, IM2NP, France); Cedric Djaou (Aix Marseille Univ, CNRS, Im2np, France); Chaouki Hannachi (Aix Marseille University, IM2NP, France); Philippe Pannier (IM2NP, France)

In this article, a 3D-printed gradient-index (GRIN) lens featuring a continuous refractive index profile is proposed. The index variation is achieved by modifying the G-code using a custom Python script. By adopting this technique, a GRIN lens with a radius of 35 mm, a thickness of 10 mm, and a focal length of 35 mm was fabricated in 7 hours and 11 minutes, instead of the expected 15 hours required for a standard 5-zone discretized lens. Matching layers were also integrated at the input and output surfaces to minimize multiple reflections. The lens was printed using ultra-low-loss Zetamix 7.5 and Zetamix 2.2 filaments. Experimental measurements, conducted with WR34 waveguide illumination, demonstrate a gain ranging from 22 dB to 24.6 dB over the 22-33 GHz frequency band. The measured results are in good agreement with simulations, validating the effectiveness of the proposed fabrication method.

4.29 Compact Pillbox Antenna Based on a Geodesic Lens

Dayan Pérez-Quintana (KTH Royal Institute of Technology, Sweden); Qiao Chen (Nanjing University of Science and Technology, China); Jose Rico-Fernandez (Northern Waves AB, Sweden); Miguel Beruete (Universidad Publica de Navarra, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

We present a compact antenna system operating at 60GHz that integrates a pillbox structure with a dual-layer geodesic lens. The complementary solution to the Luneburg inverse problem was employed to achieve a more compact antenna system. The first layer of the lens directs the waves toward a parabolic reflector, which connects the edges of both layers. The reflected waves then enter the second layer to illuminate the radiation aperture. By generating a virtual focus, the lens allows the reflector to operate as if it were fed directly from this point, enabling a more compact overall design. Furthermore, by exploiting the rotational symmetry of the geodesic lens, 11 feeding points are proposed to achieve beam scanning capability. A comparison with a classical parabolic reflector shows a size reduction of approximately 30% and a beam scanning range of 18deg.

4.30 Modelling Interactions Between an Antenna Array and a Radome in near Field

Hugo Bouisson (XLIM, France); Marc Thevenot (XLIM-UMR CNRS 7252, University of Limoges, France); Cyrille Menudier (XLIM Université de Limoges, France); Nicolas Mezieres (Centre National d'Etudes Spatiales, France); Romain Contreres (CNES, France); Pascal Cousin and Christophe Melle (Safran Data Systems, France)

The simulation of the interaction between antennas and radomes is a difficult and cumbersome task that commercial tools struggle with. This article presents an initial analysis of the electromagnetic (EM) performance of a single-layer radome, evaluated in interaction with a fictitious source representing a unit cell of a large array antenna. To this end, the principles of an original hybrid method combining Geometric Optics (GO) and Physical Optics (PO) are presented, along with the initial results obtained. The ultimate goal of this approach is to extend it to the scale of a complete array in order to evaluate the influence of the radome on the radiation performance of the source.

4.31 A 3D-Printed Hemispherical GRIN Dielectric Lens

Giacomo Muntoni, Gabriele Marras, Marco Murgia, Gabriele Atzeni, Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)

A novel optimized 3D-printed hemispherical GRIN dielectric lens is presented in this paper. The presented lens is comprised of four hemispherical regions whose dielectric permittivity and radii have been optimized to maximize realized gain, front-to-back ratio and minimize side-lobe levels. This result is achieved through an optimization algorithm that combines the effect of a GRIN configuration with a hemispherical dielectric lens, a layout fairly known in the scientific literature. The presented simulated results show that the proposed lens has higher gain and front-to-back ratio and lower side-lobe levels with respect to a canonical GRIN lens.

4.32 Evaluation of Foaming Materials and Infill Patterns for 3D Printed Dielectric Lens Antennas

Leonard Ihns (Technische Hochschule Köln, Germany); Oscar Moschner and Rainer Kronberger (TH Cologne University of Applied Sciences, Germany)

In this work, we present a detailed evaluation of recently developed active foaming 3d printing materials in comparison with traditional materials for the creation of additively manufactured gradient index (GRIN) lens antennas. We examine the impact of different infill patterns and contrast it with the uniform structure produced by foaming materials. To achieve this, we carried out a detailed material characterization for all materials and infill densities using a split-resonator, manufactured two GRIN lenses with the same gradient using different infill patterns (grid and comb) and compare it to the foamed lens. We simulated and measured the gain difference introduced by the different lenses from 18-40 GHz using open-ended waveguides.

4.33 A Multi-Lens Quasi-Optical System with Two Octave of Instantaneous Bandwidth and Wide Field-of-View for (Sub)-mm Wave Astronomy

Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands); Wouter Gregoor and Cor Meijneke (TU Delft, The Netherlands); Akira Endo (Delft University of Technology, The Netherlands)

Quasi-optical (QO) systems with wide instantaneous bandwidths and large field-of-views (FoVs) are being considered at (sub)-millimeter wavelengths for future generation of ground-based astronomy. Such systems are desired in the astronomical community to generate 3D (2D in FoV plus spectral dimension) images of large cosmic volumes with a fast mapping speed. TIFUUN is an imaging spectrometer for ground-based astronomy targeting this need with a flexible QO system covering 90-360 GHz with two sub-bands aiming for a wide range of astronomical surveys. In this work, we present TIFUUN's QO system based on refractive optics to achieve a compact cryogenic system. The optimised design is generated by employing a sequential Geometrical Optics technique in combination with an antenna in reception analysis. The performance of the system is validated using a commercial Physical Optics based code showcasing a wide operation bandwidth while covering a significant portion of the FoV of its host telescope.

4.34 Direct Dielectric Waveguide Coupling for Two-Dimensional Mechanical Beam Steering in Lens-Antennas

Kristof Dausien and Tobias Körner (Ruhr University Bochum, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany); Ilona Rolfes (Ruhr University Bochum, Germany); Jan Barowski and Christian Schulz (Ruhr-Universität Bochum, Germany)

This paper presents a novel approach to millimeterwave beam steering through direct dielectric waveguide coupling to lens antennas with two-dimensional mechanical positioning. Unlike conventional metallic waveguide feeds constrained to discrete positions, the proposed system enables continuous xy translation of dielectric waveguides across the focal plane, achieving complete hemispherical coverage. The architecture employs low-cost 3D-printed antenna elements manufactured from recyclable high-impact polystyrene at costs under 30 cents per unit, transforming traditional mechanical reliability challenges into predictable replacement cycles. Experimental validation demonstrates steering angles up to ±15° as a proof of concept with minimal pattern degradation, while the all-dielectric construction not only eliminates ohmic losses but also inherently supports compatibility with FDA and ATEX safety considerations for operation in harsh industrial environments.

4.35 Sub-THz Parallel Plate Waveguide Lens Based on Gradient Index Dielectric Materials

Umair Rafique, Kimmo Rasilainen, Marko E Leinonen, Aarno Pärssinen and Ping Jack Soh (University of Oulu, Finland)

This paper presents a parallel plate waveguide (PPW) lens designed using gradient index dielectric materials for sub-terahertz (sub-THz) applications. The PPW is filled with materials having refractive indices close to the Lüneburg profile, which facilitates high gain beam-focusing in the H-plane between the frequency range of 220 and 330 GHz. Furthermore, the antenna produces three beams at 0 ◦ and ±50 ◦ angles, indicating its suitability for multibeam communication applications. The proposed gradient profile is compared with the ideal Lüneburg profile, showing that the proposed gradient profile offers better gain and radiation properties within the operating range. In addition, the proposed lens antenna structure is simple, low-profile, and can be fabricated using low-cost fabrication methods.

4.36 Tests and Design Validation of a 3D Printed Antenna System Based on Luneburg Lens for Grid of Beams Applications at mm-Waves Frequencies

Philippe Ratajczak (Orange Innovation, France); Eric Seguenot (Orange Labs, France)

In this paper, a 3D printed antenna system based on Luneburg lens fed by a 3D conformal array is presented and tested and its performance analyzed. The half Luneburg lens and the 3D focal array are 3D printed. The patches and ground plane are metallized by Laser Direct Structuring (LDS) technology. The measured radiation patterns and input impedances are compared to the simulations.

4.37 Theory and Design of Ultrawideband Flat Leaky Lenses

Erik Speksnijder and Cesare Tadolini (TU Delft, The Netherlands); Paolo Sberna, Riccardo Ozzola and Andrea Neto (Delft University of Technology, The Netherlands)

This paper presents the design guidelines for flat leaky lens antennas, which by exploiting the radiation of a slot with a small separation from a dense dielectric, allows for a wide bandwidth and integrated feed. Two preliminary designs are proposed. The first one is intended to be fabricated in alumina and operates from 4 to 40 GHz. The second antenna is realized with silicon micromachining and operates from 30 to 180 GHz.

4.38 Additively Manufactured GRIN Lenses for Millimeter-Wave 2-D LTCC Van Atta Arrays

Benedykt Sikorski, Kamil Trzebiatowski, Krzysztof Nyka and Lukasz Kulas (Gdansk University of Technology, Poland)

This paper presents the design of gradient-index (GRIN) lenses with spatially varying permittivity. The lenses are intended to enhance the readout range of two-dimensional 24 GHz Van Atta arrays fabricated using low temperature co-fired ceramics (LTCC) technology for potential use as chipless RFID tags in the millimeter-wave band. The lenses were manufactured via 3D printing using Acrylonitrile-Butadiene-Styrene (ABS) mixed with ceramic powder. The gradient permittivity was achieved by employing different material infill factors in the individual layers. The fabricated lenses improve the radar cross section (RCS) of the arrays in two incidence planes by up to approximately 7 dB and additionally provide mechanical protection against impacts and damage. To the best of the authors' knowledge, this is the first reported use of GRIN lenses to extend the readout range of two-dimensional Van Atta arrays.

4.39 Modified GRIN Luneburg Lens for High-Efficiency Millimeter-Wave Multi-Radar Sensing

Mohammad Omid Bagheri, Veronica Leong, Justin Chow and Joshua Visser (University of Waterloo, Canada); George Shaker (University of Waterloo & Spark Tech Labs, Canada)

This paper presents a high-efficiency modified spherical gradient-index (GRIN) Luneburg lens (LL) designed to enhance signal quality and efficiency in millimeter-wave (mm-wave) multi-radar sensing systems. The proposed design achieves a synthesized dielectric permittivity distribution optimized for compact radar integration, enabling multiple fixed high-gain beams. A 10 cm-diameter lens integrated with five Infineon radar modules operating in the 58-63 GHz band achieves a realized gain enhancement of approximately 13 dB per radar unit compared with standalone configurations.

Wednesday, April 22 13:30 - 14:40

P2-A04 **Sub-6 GHz Antennas for Mobile and Terrestrial Networks**

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)
Room: Poster Level 3

3.25 A Compact Wideband Circularly Polarized Antenna with Stable Gain

Zhipeng Hu, Shaowei Liao, Zhiheng Zhou and Quan Xue (South China University of Technology, China)

A compact wideband circularly polarized (CP) antenna with stable gain is proposed in this paper. The antenna is composed of four pairs of rotationally symmetric unequal-length dipoles, four sets of parallel-strip line, and a wideband 90° phase shifter. Unequal dipole lengths ensure stable impedance matching over a wide frequency range, while overlapping adjacent dipole arms enhances inter-element coupling to further extend bandwidth. Furthermore, four parasitic patches are introduced to equalize radiation amplitude and stabilize gain within the operation bandwidth. The fabricated prototype achieves an overlapped -10 dB impedance and 3 dB axial-ratio bandwidth of 2.5 - 6.7 GHz (91.3%), within which the gain variation is less than 3dB. The wide bandwidth and stable radiation performance make the design suitable for satellite communication, radar, and remote-sensing applications.

3.26 A Compact Wideband Microstrip Antenna Integrated with a Shunt Stub Tuner

Jeong-Ung Yoo (Agency for Defense Development, Korea (South)); Hae-Won Son (Jeonbuk National University, Korea (South))

A compact wideband microstrip antenna integrated with a shunt stub matching network is proposed. The antenna is a probe-fed single-layer rectangular patch with two parallel slots in the longitudinal direction from the center to one of the radiating edges of the patch. A shorting pin is placed at the center of the patch. The part between the two slots on the patch acts as an open-circuit shunt stub tuner, providing wideband impedance matching. An equivalent circuit model is presented and analyzed to explain the principle of wideband operation. A prototype antenna operating at 5.2 GHz is designed and fabricated. The measured bandwidth is 6.7% (VSWR < 2), which is more than two times wider than a traditional microstrip antenna of the same size. The antenna provides a symmetric broadside radiation pattern and a stable realized gain of 5.9 to 7.2 dBi over the impedance bandwidth.

3.27 Omnidirectional Folded Waveguide Antenna Based on Antenna Cluster Technique for Handset Devices

Yunfeng Dong (vivo Mobile Communication Co., Ltd., China); Yue Qin (vivo Mobile Communication Co., Ltd, China)

This paper presents a folded waveguide antenna that can be used for mobile phones and other handset devices. By utilizing antenna cluster technique, the proposed antenna not only achieves higher radiation efficiencies and larger bandwidths with dual-band operation but also exhibits nearly-ideal omnidirectional far-field radiation characteristics. When an extra feed is added to each antenna element, the radiation modes are enhanced while the resonant modes are restricted accordingly. Effective radiations are realized by the narrow gaps on the upper corners of the mobile phone. For proving the concept, an omnidirectional folded waveguide antenna is designed for WiFi applications. When the width of the radiating slots is 1 mm, the proposed antenna exhibits directivities of 1.1 dBi at 2.45 GHz and 4.5 dBi at 5.5 GHz. Meanwhile, the averaged radiation efficiencies are -2.30 dB and -2.04 dB within the operating frequency ranges of 2.4-2.5 GHz and 5.15-5.85 GHz, respectively.

3.28 High-Gain Coaxial Array Antenna with Enhanced Omnidirectional Performance

Tianqi Ao and Xinyue Zhang (University College Dublin, Ireland); Xingqi Zhang (University of Alberta, Canada); Yuandan Dong (University of Electronic Science and Technology of China, China)

This paper presents a novel omnidirectional array antenna based on a coaxial-line structure, designed for applications requiring wide communication coverage. The outer conductor of an air-filled coaxial line is used to design sleeve radiators, providing high-directivity omnidirectional radiation along the boresight direction at 3.5 GHz. Owing to the highly symmetric structure, this design achieves exceptional performance in terms of non-circularity, which is the key novelty of this work. To verify the performance of this design, simulated results are presented. The proposed antenna achieves a wide impedance bandwidth from 3.28 to 3.84 GHz (15.7%), high omnidirectional peak gain of 8 dBi, and low non-circularity of 0.16 dB.

3.29 A Hemispherical Conformal Magnetoelectric Dipole Array Antenna for 5G Frequency Bands

Han Hao (Southwest Jiaotong University, China); feng Quanyuan (Southwest JiaoTong University, China); Yan Wen and Yukang Chen (Southwest Jiaotong University, China)

As 5G deployments increasingly prioritize both visual unobtrusiveness and wide bandwidth, transparent, conformal antenna architectures have gained significant traction. This work proposes a hemispherical magnetoelectric (ME) dipole array tailored to the 5G n79 band. The antenna employs a 2mm-thick PET hemispherical substrate coated with a metalmesh conductive layer, achieves an effective balance between electrical conductivity and optical transparency. Each magnetoelectric dipole element provides stable radiation and high polarization isolation over the curved surface. The hemispherical configuration ensures wide beam coverage and reliable radiation while maintaining high transparency. The proposed design offers a lightweight, low-profile, and optically transparent solution that can be integrated on the surface of spherical surveillance devices, providing a new approach for future 5G conformal communication applications.

3.30 Dual-Functional Phase-Transforming Metasurface-Loaded Resonant Cavity Antenna for Mobile Satellite Communication (SatCom) Systems

Mohammad Nasrat Zaqumi and Syed Muzahir Abbas (Macquarie University, Australia); Fatima Ghulam (Zhejiang Normal University, China); Saleem Shahid (Graz University of Technology, Austria); Subhas Chandra Mukhopadhyay (Macquarie University, Australia); Wolfgang Bosch (Graz University of Technology & Institute of Microwave and Photonic Engineering, Austria)

An efficient technique for directivity enhancement of resonant-cavity antennas (RCAs) is presented using a near-field phase transformation method. The joint phase correction and beam steering structure, comprising spatially distributed printed unit cells, is positioned within the RCA near-field to transform its nonuniform phase distribution into a linear phase gradient, enabling beam tilting and focusing. A single dielectric phase transformation structure operating at 11 GHz is integrated with an RCA, where it can function as directivity enhancement along with beam tilting. The proposed configuration achieves a 15° beam tilt, 5dB directivity improvement, reduced 3 dB beamwidth, and 22% aperture efficiency, validating the effectiveness of near-field phase manipulation for compact high-gain antennas.

3.31 A Wide-Band Cavity-Backed Patch Antenna Array for Wide-Angle Scanning in X-Band

Dinh Son Nguyen (Viettel High Technology Industries Corporation, Vietnam); Minh Duc Hoang (Viettel High Technology Industries Corporation (VHT), Vietnam); Thi Huong Ngo, Van Phu Nguyen and Trung Duc Le (Viettel High Technology Industries Corporation, Vietnam); Thi-Hoa Nguyen (Viettel High Technology Industries Corporation, Vietnam & Hanoi University of Science and Technology, Vietnam)

In this paper, a wide-band cavity-backed patch antenna array suitable for X-band wide-angle scanning applications is proposed. The proposed antenna array consists of 256 elements and has a total size of 216 x 216 x 11 mm3. When this 16 x 16 antenna array scans to 60 degree on both E and H planes, the active standing wave ratio (VSWR) is less than 2 in a wide operating frequency range of 2.28 GHz (8.78 - 11.06 GHz). The measurement result shows that the proposed array has a maximum gain of 27.9 dBi and the half power beam width (HPBW) is less than 8.4 degree. The side lobe level (SLL) is greater than 10dB when the main beam scans to 60 degree on both planes and there is no grating lobe.

3.32 Power Consumption Optimization of Amplifier-Antenna Array with EIRP Constraint

Bing Xue and Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland); Mikko Valkama (Tampere University, Finland); Anu Lehtovuori (Aalto University, Finland)

This paper proposes a DC-bias-controlled power amplifier (PA)-antenna array model for minimizing total power consumption under a defined effective isotropic radiated power (EIRP) constraint. Harnessing a neural network model trained with practical measurements for PAs, a hybrid optimization method combining genetic algorithm (GA) and gradient descent (GD) is applied to determine the optimal DC bias voltages as well as the input amplitudes and phases of each PA element. A four-element linear array is analyzed as an example. The results show that the proposed method effectively reduces power consumption compared with classical constant-voltage and progressive-phase setups. For instance, a relative power reduction of up to 8.7 dB is achieved while maintaining the required EIRP. The optimized phases also differ from progressive ones due to mutual coupling among antenna elements, resulting in more accurate beamforming. The proposed approach offers a promising solution for energy-efficient phased-array radar and wireless communication systems.

3.33 Reducing Frequency-Dependent Beam Tilt in Broadside Series-Fed Arrays

Marco Simone and Davide Guarnera (University of Catania, Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy); Gino Sorbello (University of Catania, Italy)

Series-fed slot arrays in substrate-integrated waveguides or parallel-plate waveguides offer simple fabrication and high radiation efficiency, but suffer of frequency-dependent beam tilt. A novel feeding scheme with two counter-propagating waves produces a frequency-stable broadside main beam. The antenna is optimized using a numerical approach to tailor slots excitations and ensure high radiation efficiency.

3.34 A Low-Profile Wideband Circularly Polarized Tightly Coupled Dipole Arrays with Large Element Spacing

Xingdong Wu and Kejin Chen (University of Electronic Science and Technology of China, China); Feng Yang (University of Electronic Science and Technology of China & University of Electronic Science and Technology of China (UESTC), China); Shiwen Yang (University of Electronic Science and Technology of China (UESTC), China)

This paper presents a circularly polarized Tightly Coupled Dipole Arrays (CP-TCDA). The proposed antenna features two linearly polarized dipoles with overlapping phase centers, fed by a power divider and 90-degree phase shifter located at the bottom. A cross patch are incorporated between the dual arms of the dipoles to achieve large element spacing (0.56 of the highest frequency wavelength), thereby enhancing channel utilization efficiency. The profile is merely 0.33 of the highest frequency wavelength, facilitating antenna miniaturization. The operating frequency spans 1.3-3 GHz, while the scanning range encompasses the entire grating lobe-free space (±50°). Owing to its key advantages of large element spacing and low profile, the proposed antenna is particularly suitable for applications such as large-scale phased arrays and satellite communications.

3.35 Dual-Band Base Station Antenna Covering Sub-6 GHz and cmWave Bands for Future 6G Networks

Álvaro Martín-Núñez (Universitat Politècnica de València & Antennas and Propagation Lab (APL), Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Jose I. Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain); Eva Antonino-Daviu (Universitat Politècnica de València, Spain)

A compact dual-band base-station antenna covering both sub-6 GHz and centimetric-wave (cmWave) frequency bands is designed for future beyond-5G/6G networks. The structure integrates two PCB cavity-backed radiators on a single platform: a truncated-patch element for 2.75-4.60 GHz, fully spanning 5G NR n77/n78, and a circular-patch element operating from 7 GHz to 15 GHz to address emerging cmWave allocations. Fullwave simulations indicate wide impedance bandwidth in both bands, inter-element isolation better than -15 dB, and envelope correlation coefficients below 0.05, supporting MIMO operation with low pattern correlation. The proposed approach prioritizes low cost and simple manufacturing while enabling scalable array integration for future base-station deployments.

3.36 Wideband Planar Monopole Antenna Array for FR3/6G Applications

Ricardo Nunes (University of Aveiro, Portugal); Tiago Varum (Instituto de Telecomunicações, Portugal); Samuel Pereira (Instituto de Telecomunicações, IT, Portugal); Luís Almeida (Instituto de Telecomunicações, Portugal); Arnaldo Oliveira (Universidade de Aveiro - DETI / Instituto de Telecomunicações - Aveiro, Portugal)

This paper presents the design, fabrication, and experimental characterization of a wideband planar monopole antenna array operating at 10 GHz, within the Frequency Range 3 (FR3), targeting sixth-generation (6G) wireless applications. The array consists of 16 rectangular monopole elements arranged in a 4×4 configuration, each fed by a microstrip transmission line and coaxial probe. To enhance impedance bandwidth, an open rectangular slot is introduced in the ground plane of each element. The antenna was simulated, fabricated, and measured, achieving an average measured bandwidth of 2.04 GHz and a peak gain of 15.52 dBi. The proposed array offers a compact, scalable, and low-complexity solution for future FR3/6G systems, supporting wideband operation and enabling integration with digital beamforming platforms through individually accessible coaxial-fed elements.

3.37 Dual-Band Low-SAR Antennas for Smartphones

Si-Xin Dong, Quan Deng and Qing-Xin Chu (South China University of Technology, China)

Low specific absorption rate (SAR) antennas operating in LTE high-frequency band and Sub-6G band are proposed for smartphones. The antenna in the LTE band uses a T-shape power divider for feeding, the measured -6 dB bandwidth is 1.7-2.7 GHz with an efficiency of over 60%. Using T-shape coupling feeding in the Sub-6G band, the measured -6 dB bandwidth of the antenna can cover 3.3-3.8 GHz, and the efficiency is greater than 65%. The ground clearance of the antenna is 1.5 mm, and the normalized SAR values measured on each surface in each frequency band are all less than 1.2 W/kg. The antenna has both excellent radiation performance and low SAR values.

3.38 Miniaturized Multiband Antenna with Pattern Diversity

Abel Zandamela, Hossein Raghib Hokmabadi and Max James Ammann (Technological University Dublin, Ireland)

By combining the concept of multiband antenna design with the use of annular sectors, a compact antenna capable of operating in three frequency bands and exhibiting pattern diversity is developed. The antenna includes two separately fed sectors loaded with rectangular slots, and a parasitic scatterer for mutual coupling suppression. The antenna operates at f1 = 2.4 GHz, f2 = 3.76 GHz, and f3 = 5.15 GHz, with 0.26 × 0.26 × 0.01λ^3 (w.r.t. f1, electrical size ka = 0.83). Full-wave simulations demonstrate that the antenna can achieve radiation efficiency > 25% in each band, where more than 10 beam states with linear and elliptical polarization are synthesized. Due to its miniaturization, multiband pattern diversity, and efficiency characteristics, the design is considered to be a promising solution to enhance the performance of emerging on-/in-body medical applications.

Wednesday, April 22 13:30 - 14:40

P2-EO1 Inverse Problems

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 4

4.01 Discovering Target Properties via Failures of Microwave Inversion Inside of Conductive Enclosures

Seth Cathers and Colin Gilmore (University of Manitoba, Canada)

Imaging of dielectric targets inside of conductive enclosures with non-linear inversion is generally unsuccessful at the resonant frequencies of the background enclosure. This failure can be detected by large data error in the inversion results at the resonant frequency. Herein, we consider the idea that non-linear inversion may also fail at the loaded resonant frequencies of the enclosure, where the loading is a property of the dielectric target (size and permittivity) in the enclosure. The exact frequencies of these failures at the loaded frequencies will provide information about the dielectric target in the enclosure.

Using a 2D-scalar synthetic example, we show that large spikes in the data error occur both at the background resonances and lower frequencies that depend on the dielectric target in a systematic way. This means that some dielectric target properties can be inferred from the frequencies of the failure of the non-linear inversion process.

4.02 Enhanced Low-Resolution Contrast Operator Using Neural Networks for H-Polarized EM Scattering Problems

Daan van den Hof (Eindhoven, The Netherlands); Martijn van Beurden and Roeland J. Dilz (Eindhoven University of Technology, The Netherlands)

Solving Electromagnetic scattering problems, formulated as domain integral equations, generally involves a discretization step. A denser discretization generally leads to a closer approximation of the continuous problem while coarser discretizations result in larger errors. A large part of this error is specifically due to the discretization of the contrast operator. We present a modified contrast operator that is constructed via the use of a neural network. Using this operator, we achieve a higher accuracy on a coarse discretization while reducing computation time as compared to a finer discretization. We do this for vector-valued 2D scattering problems. The network is trained using synthetic data from a full-wave Maxwell solver for a set of polygonal scatterers.

Wednesday, April 22 13:30 - 14:40

P2-EO2 Metamaterials, Metasurfaces, Intelligent surfaces

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Area

4.03 A Surrogate Model for the Forward Design of Metasurface-Based Radar Absorbing Structures

Vineetha Joy (CSIR-National Aerospace Laboratories, India); Aditya Anand (Birla Institute of Technology and Science, Pilani, Rajasthan, India); Nidhi K (Centre for Electromagnetics, CSIR-National Aerospace Laboratories, Bangalore, India); Anshuman Kumar and Amit Sethi (Indian Institute of Technology Bombay, India); Hema Singh (CSIR-National Aerospace Laboratories, Bangalore, India)

Metasurface-based radar absorbing structures are highly preferred for stealth applications due to their capability to achieve tailored absorption characteristics with minimal thickness and reduced weight penalty. However, the conventional approach for the EM design and optimization of these structures relies on full wave simulation tools to predict EM responses. This process is computationally intensive, time consuming and requires exploration of large design spaces. To overcome this challenge, we propose a surrogate model that significantly accelerates the prediction of EM responses of metasurface-based RAS. A convolutional neural network based architecture with Huber loss function has been employed to estimate the reflection characteristics of the RAS. The proposed model achieved a cosine similarity of 99.9% and a mean square error of 0.001 within 1000 epochs of training. The efficiency of the model has been established via full wave simulations where it demonstrated significant reduction in computational time while maintaining high predictive accuracy.

4.04 Integration of a Circularly Polarized Array with a Holographic Metasurface Converter for Dual-Polarization

Subhadrita Ghosh (Queen's University Belfast, United Kingdom (Great Britain)); Chinmoy Saha (Indian Institute of Space Science and Technology, India & Royal Military College of Canada, Canada); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

This paper presents the integration of a circularly polarized (CP) patch antenna array (PAA) and a holographic metasurface (HMS) that serves as a polarization converter. The HMS is positioned in the far field (Fraunhofer) region of the PAA. By converting the beam generated by the PAA into horizontally and vertically polarized (HP and VP) beams, the proposed HMS configuration demonstrates effective polarization control. Both the antenna and the holographic metasurface operate at 2.4 GHz, achieving a maximum directive gain of approximately 18 dBi. The circular polarization performance is validated by an axial ratio (AR) below 3 dB and a co-cross polarization isolation of about 28 dB. The positional variation of the HMS enables the characterization of dual polarization (DP) behavior and influences other antenna parameters of the PAA. Detailed design methodology and results are presented to verify the proposed approach.

4.05 Non-Foster Angular Scattering by Transverse Periodically Modulated Metasurfaces

Jordan R. Dugan, Tom Smy and Shulabh Gupta (Carleton University, Canada)

We have recently demonstrated that spatially dispersive metasurfaces implemented through longitudinal stacking of lossless non spatially dispersive metasurfaces, are bound by an angular form of Fosters theorem. In this work, we show that such a limitation is lifted when the spatially dispersive metasurfaces are realized instead by periodically modulating local unit cell along the surface, i.e., in the transverse plane. This highlights their potential usefulness in applications such as cloaking over a wide angular bandwidth, thus increasing the angular scattering control.

4.06 Equivalent Circuit Modelling of Compact Dual-Band Reflective Surfaces Featuring Inductive Loading

Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)); Kenneth Lee Ford (University of Sheffield, United Kingdom (Great Britain))

A gridded compact dual-band reflective surface incorporating lumped capacitors and metallic structures for tunable resonant frequencies and controlled mutual coupling is presented. A novel Equivalent Circuit Model captures inter-band and inter-cell coupling, induced patch, grid, and substrate inductances. Parametric studies reveal that conductor width, substrate thickness, and periodicity strongly influence inductances, coupling factors, and band separation. The proposed reflective surface features a 0.09λ unit cell and achieves enhanced shielding, reduced mutual coupling, and precise dual-band tuning, with excellent agreement between ECM predictions and full-wave simulations, providing an effective methodology for designing compact, electrically small dual-band reflective surfaces.

4.07 Multi-Beam Reconfigurable Intelligent Surface with Adaptive Power Allocation for Multi-User Communication

Kumar Anmol and Akhila Gouda (Indian Institute of Technology Indore, India); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain)); Saptarshi Ghosh (Indian Institute of Technology Indore, India)

This work demonstrates a multi-beam reconfigurable intelligent surface (RIS) with an adaptive power allocation feature for different beams. The power levels of the beams can be controlled based on the distances of users at different locations. The proposed concept is validated by designing RIS structures with varying quantization levels (1-bit, 2-bit, and 3-bit). The 2-bit and 3-bit RIS are designed to generate two beams at $(\theta_1, \varphi_1) = (30°, 45°)$ and $(\theta_2, \varphi_2) = (30°, 135°)$, with both equal and unequal power distributions. The simulation results confirm that the designed RIS offers potential applications in multi-user communication systems, enabling dynamic power distribution and multi-beam steering.

Wednesday, April 22 13:30 - 14:40

P2-E03 Sensing and Tracking

T05 Positioning, localization, identification & tracking / / Electromagnetics

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 3

3.39 Analysis of the Impact of Positioning Errors and the Coherence Time on the Performance of a Millimeter-Wave Freehand Imaging System

Guillermo Alvarez Narciandi (University of Oviedo); María García Fernández (University of Oviedo, Spain); Jaime Laviada (Universidad de Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)

This contribution analyzes the impact of positioning errors on the quality of the images retrieved with a freehand imaging system considering a hybrid coherent-incoherent processing technique for different coherence time values. For this purpose, a measurement performed with a handheld millimeter-wave scanner is contaminated with positioning errors of different magnitude following a normal distribution. Results show that the use of the hybrid coherent-incoherent algorithm enables to mitigate the drastic image degration caused when significant positioning error values affect the measurements at the expense of a certain resolution loss. Furthermore, it is shown that the coherent time of the algorithm can be adjusted depending on the magnitude of the introduced positioning errors or, equivalently, depending on the accuracy of the tracking system employed by the imaging system.

3.40 Learning-Assisted Interpretation of B-Scan Radar Data for Through-Wall Surveillance

Rahul Sharma (Queen's University Belfast, United Kingdom (Great Britain)); Lokesh Bisht and Carmen Loew (Sapper Intelligence, Germany); Amir Masoud Molaei (Queen's University Belfast, United Kingdom (Great Britain)); Jiaming Zhang (Queen's University Belfast & Centre for Wireless Innovation, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Through-wall radar data interpretation remains challenging due to complex wall interactions, signal attenuation, and variations in target geometries. In this work, a deep learning-based framework for target classification and localization using B-scan radar images is proposed, where targets are positioned behind walls. The B-scan data, represented as two-dimensional time-trace targets, are used to train neural networks for classifying the presence of targets, while a regression-based neural network is introduced for estimating the spatial coordinates of targets within the radargrams, enabling effective localization. The proposed models are trained on a dataset comprising simulated B-scan images with varying wall and target configurations. This approach demonstrates robust performance on both the tasks, achieving high accuracy in classification and low localization error. These results highlight the potential of deep learning to automate and enhance the interpretability of B-scan data in non-invasive through-wall radar imaging scenarios.

3.41 Impact of the Switching Sequence in Spatial Sampling of a MIMO Radar Boarded on UAV

Pablo Alegría and Yuri Alvarez-Lopez (University of Oviedo, Spain); Jaime Laviada (Universidad de Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)

The use of multistatic sparse antenna arrays for SAR imaging applications enables fast acquisition while preserving image resolution. This is of special interest in airbone-based systems, where the goal is to maximize the scanned area per flight. The need for a densely sampled surface while moving the system with significant velocity generates the problem of selecting the best channel activation order to achieve a uniform distribution. By means of simulation, and comparing qualitatively and quantitatively the obtained results, the impact on the extracted images of the switching scheme and the degree of randomness applied is studied and analyzed, finding out that a repetitive fixed sequence for all the measurement cycles is the best option in terms of scanning efficiency, available resource exploitation, and output image quality.

3.42 Convolutional Neural Network-Based DOA Estimation for Multiple Incident Signals in Noisy Environments

Oscar Gutiérrez Blanco (Universidad de Alcalá, Spain); David Cabornero Pascual and Lorena Lozano (University of Alcala, Spain)

This paper presents a deep learning approach for direction-of-arrival (DOA) estimation using convolutional neural networks (CNNs). Building upon recent advances in neural architectures for signal processing, we propose a CNN model that directly estimates incident angles from raw temporal samples collected by non-uniform linear antenna arrays. The network is trained using synthetic data generated under varying conditions, including different numbers of signal sources and signal-to-noise ratios (SNRs). The proposed architecture demonstrates high accuracy in both single-source and multi-source scenarios, with robustness to noise and array geometry variations. Experimental results show that increasing the training dataset size significantly improves performance in complex environments. The model maintains reliable performance across SNR levels ranging from 30dB to 0dB. These findings highlight the potential of CNN-based methods for scalable and accurate DOA estimation in real-world applications.

3.43 Self-Healing Electromagnetic Beams for Robust Waveform Propagation Using a Metasurface

Narimane awada Mislmani (University of Gustave Eiffel & IFSTTAR-LEOST, France); Mohammed Kalaagi (Université Gustave Eiffel, Villeneuve D'ascq, France); Naman Baghel (Université Gustave Eiffel, France); Divitha Seetharamdoo (Univ Gustave Eiffel COSYS LEOST Univ Lille Nord de France & Univ Lille Nord de France, France)

In this paper the design and validation of a meta- surface capable of generating a three-dimensional curved beam operating at 5.9 GHz is presented. The metasurface phase distribution is synthesized using the generalized law of reflection combined with differential-geometry principles to shape the reflected wavefront along a prescribed trajectory. Full-wave simulations demonstrate the beam's self-healing property, where the field reconstructs after interaction with a metallic obstacle. Experimental far-field measurements using a metallic sphere confirm the correct beam formation and angular response. The demonstrated self-healing characteristics offer a promising route toward waveform-resilient communication systems, where main- taining amplitude and phase integrity enhances the robustness of advanced modulated signals specailly for applications in high-frequency wireless links, radar imaging, and reconfigurable beamforming architectures.

Wednesday, April 22 13:30 - 14:40

P2-MO1 **Measurement Topics 1**

TO8 Fundamental research and emerging technologies/processes / / Measurements

Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 4

4.08 An Alternative Magnetic Permeability Method Using CEM Inversion

John W Schultz (Compass Technology Group, USA)

Magneto-dielectric materials in radio frequency applications are used for shielding, antenna substrates, and microwave components. A traditional method to measure magnetic permeability of these materials is the high frequency permeameter, and a sensor geometry that has been successful is the electrically shorted strip transmission line or single loop coil. This method uses semi-empirical equations combined with calibration to 'known' materials to extract real and imaginary permeability. The presented work develops an alternative methodology that still employs a shorted strip transmission line but instead uses a computational electromagnetic (CEM) inversion method to extract permeability without the need for multi-step calibrations or magnetic standards. Furthermore, instead of inserting material into the transmission line, the described method treats the transmission line as a handheld device that non-destructively measures permeability of larger sheets. This paper presents the methodology along with computational and experimental results from a manufactured measurement probe.

4.09 Comparison of Several Two-Ports Calibration Methods for Antenna Measurement

Thibault Charlet (CEA CESTA, France); Guillaume Cartesi and Hanae Devos (CEA, France)

In this article, we compare three calibration methods for antenna measurement to obtain the gain and the impedance matching of an Antenna Under Test (AUT), performed in an anechoic chamber. The studied technique are Short-Open-Load-Through (SOLT), Short-Open-Load-Reciprocal (SOLR) with a cable and an innovative SOLR with the two AUT as Thru. Each method is implemented experimentally, by paying attention to the practical steps, requirements, and challenges encountered during calibration operations. The SOLR method, by using a cable as the Thru channel, emerges as the most practical and reliable method, minimizing error sources and simplifying the process. When the antennas themselves serve as the Thru channel, this SOLR original approach reveals phase uncertainty. Our comparative analysis evaluates the strengths and limitations of each method, offering practical insights to select the most suitable calibration technique based on their specific measurement needs, resources, and the balance between accuracy and ease of implementation.

4.10 Enhanced Accuracy of Radiometric Measurements of Sub-THz Thermal Radiation

Laurens F.E. Beijnen, Paolo Sberna, Marco Spirito and Andrea Neto (Delft University of Technology, The Netherlands)

The general validity of the second Kirchhoff law that states the emissivity of a body is equal to its absorptivity was tested via experiments in a previous work [1]. The thermal energy radiated by silicon wafers with different resistivities was characterized in the mm and sub-mm wave ranges. Surprisingly to some readers, the current standard theory in radiometry, based on Planck's Law in combination with the second Kirchhoff Law, was only able to predict the frequency dependence of the thermal radiation from highly doped (low resistivity) wafers, not for wafers with a low doping (high resistivity). In this work, we highlight a novel calibration strategy that we applied to a second measurement campaign. This second campaign, presented here, has an increased accuracy compared to before because of this calibration strategy but also due to other practical improvement that we emphasize in the current contribution.

4.11 Performance of Flexible Gasper-Curve Based Microwave Array Sensor for Non-Destructive Testing of CFRP Composites

Vimal Kumar Chaudhary (University of Glasgow, United Kingdom (Great Britain)); Muhammad Zubair (University of Leicester, United Kingdom (Great Britain)); Jalil ur Rehman Kazim, Muhammad Ali Imran and Qammer Abbasi (University of Glasgow, United Kingdom (Great Britain))

This paper outlines a novel Gasper curve (GC)-based microwave array sensor for non-destructive testing (NDT) composites made of Carbon Fiber Reinforced Polymer (CFRP). The affordable and flexible Taconic TLY-5 (0.51mm) material is employed for designing the suggested sensor. In addition, the performance of this sensor is examined by analyzing its E-Field distribution and transmission coefficient (S21) response. In the presence or absence of deformation on the surface of Sample Under Test (SUT), the proposed sensor acts as a bandstop and bandpass filter. The suggested GC-based sensor uses a fringing field sensing capacitor (FFSC) as a "sensing pad" that makes direct contact with the SUT to detect surface cracks. This sensor operates in the frequency range of 3-5.5 GHz and can detect deformation as small as 0.5 mm. The safety and integrity of vital infrastructure including pipelines, bridges, and aircraft, may be enhanced by using this sensor to detect surface cracks.

4.12 G/T Measurement Enhancements and Methods Comparison

Joel Dunsmore (1400 Fountaingrove Parkway & Keysight Technologies, USA); Mike Ballou and Hiroyuki Maehara (Keysight Technologies, USA)

Gain divided by Noise Temperature (known as G/T) is a key performance indicator for active phase-array antennas. Previous papers reported a novel active antenna G/T measurement using a VNA cold-source method and verifying results using known standards and composite devices. This paper introduces two new advances: 1) Improved calibration, and analysis and compensation for ambient temperature offsets and 2) detailed comparison between VNA and Y-factor measurement using this improved method on a spectrum analyzer as noise-figure analyzer.

4.13 Resonator-Based Oscillator Circuit with Enhanced Frequency Resolution to Detect Glucose and NaCl Solutions Under Eliminated Environmental Effects

Haneul Woo (Yonsei University, Korea (South)); Hee-Jo Lee (Daegu University, Korea (South)); Jong-Gwan Yook (Yonsei University, Korea (South))

In this paper, we propose a microwave resonator-based oscillator circuit with two resonators. One resonator senses only environmental variations, including temperature and humidity, while the other responds to both environmental changes and solution concentration. Reflection coefficient data from each resonator drive their respective oscillators, and the outputs are mixed to produce an IF signal that eliminates environmental effects and improves frequency resolution. Measurements indicated that the IF frequency varied by approximately 80 kHz for glucose concentrations of 0-400 mg/dL and by about 148 kHz for NaCl concentrations of 500-900 mg/dL.

4.14 A Fully Screen-Printed MIM Varactor for Flexible Microwave Applications

Aeron Jones (King Abdullah University of Science and Technology, Saudi Arabia); Mohammad Vaseem (King Abdullah University of Science and Technology (KAUST), Saudi Arabia); Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

This work presents a highly tunable fully screen-printed varactor fabricated at low temperatures (120 deg C) on a flexible substrate using a novel barium strontium titanate (BST) ink. The dense BST layer allows for a metal-insulator-metal (MIM) structure, overcoming a key limitation of printed ferroelectric films. This printed MIM architecture eliminates the need for micrometer-scale lateral gaps found in interdigitated capacitors (IDCs) while also improving electric field confinement. Microwave measurements demonstrate a high tunability of 15% at an electric field of 8 V/um surpassing that of previously reported fully printed IDC varactors and other hybrid thin-film (TF) devices. These results establish screen printing as a low cost, high performance choice for flexible and reconfigurable microwave components.

4.15 Amplitude-Only Measurement-Based RIS Diagnostics and Calibration with Space-Time Modulation

Shiyuan Li, Chi Zhang and Chong He (Shanghai Jiao Tong University, China)

This paper proposes a diagnostic and calibration technique for reconfigurable intelligent surfaces (RIS) using amplitude-only measurements. Firstly, fast diagnosis and amplitude calibration of the RIS are achieved by utilising the harmonic amplitudes generated through periodic space-time modulation of each RIS unit. Subsequently, both reference and test units undergo periodic phase modulation at the same frequency but with programmable delays. Phase calibration is achieved by monitoring the variation in the generated $+1$st harmonic power with respect to delay. Finally, a transmission-type 1-bit phase-reconfigurable RIS operating in the X-band is fabricated, diagnosed, and calibrated, validating the effectiveness of the proposed methodology.

4.16 Misalignment Compensation for Two Orthogonally Polarized Acquisitions in Planar near-Field Scanning

Juha Ala-Laurinaho and Jan H. S. Bergman (Aalto University, Finland); Freysteinn Vidar Vidarsson (KTH Royal Institute of Technology, Sweden); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

The polarization properties of an antenna can be determined based on two orthogonal linear polarization measurements. This paper discusses probe displacements between two orthogonally polarized acquisitions in planar near-field scanning. The effects of the probe displacements on the plane wave spectrum and far-field are studied. A simple compensation method based on the measured far-field phase is proposed. The method assumes symmetry of the phase pattern of the antenna under test.

Wednesday, April 22 13:30 - 14:40

P2-PO1 **Propagation Models**

T07 Electromagnetic modelling and simulation tools / / Propagation
Chairs: Tim Brown (University of Surrey, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Poster Level 4

4.17 Frequency-Dependent Channel Modeling and Ray-Tracing Accuracy Evaluation Based on Measurements in Industrial Environments

Azril Haniz and Hirokazu Sawada (National Institute of Information and Communications Technology, Japan); Takeshi Matsumura (National Institute of Information and Communications Technology (NICT), Japan & Kyoto University, Japan)

In this paper, propagation channel modeling in an industrial environment is performed using measured receiver (Rx) power and delay spread at five different center frequencies in the sub-6 GHz and mmWave bands based on the alpha-beta-gamma (ABG) model in non-line-of-sight (NLOS) scenarios. Furthermore, ray-tracing (RT) accuracy is also investigated by comparing predicted and measured values of Rx power and delay spread. Key RT parameters such as the order of reflections and angular spacing between rays were varied to assess their impact. Results show that increasing reflection order or decreasing ray spacing reduces delay spread error; however, this simultaneously increases Rx power error, with ray spacing having a greater influence on Rx power accuracy. These findings highlight the trade-offs between accuracy and computational cost when performing optimal RT parameter selection in complex industrial environments.

4.18 RadioSim Agent: Combining Large Language Models and Deterministic EM Simulators for Interactive Radio Map Analysis

Sajjad Hussain (National University of Sciences and Technology, Pakistan); Conor Brennan (Dublin City University, Ireland)

Deterministic electromagnetic (EM) simulators provide accurate radio propagation modeling but often require expert configuration and lack interactive flexibility. We present RadioSim Agent, an agentic framework that integrates large language models (LLMs) with physics-based EM solvers and vision-enabled reasoning to enable interactive and explainable radio map generation. The framework encapsulates ray-tracing models as callable simulation tools, orchestrated by an LLM capable of interpreting natural language objectives, managing simulation workflows, and visually analyzing the resulting radio maps. Demonstrations in urban UAV communication scenarios show that the agent autonomously selects appropriate propagation mechanisms, executes deterministic simulations, and provides semantic and visual summaries of pathloss behavior. The results indicate that RadioSim Agent provides multimodal interpretability and intuitive user interaction, paving the way for intelligent EM simulation assistants in next-generation wireless system design.

4.19 Improved Prediction of Mean and Variance for 1D Gaussian Surfaces Under Shadowing

Giacomo Melloni and Torbjörn Ekman (Norwegian University of Science and Technology, Norway)

This paper presents an improved model to predict the illuminated mean height and variance under shadowing for one-dimensional, Gaussian rough surfaces. The proposed model is obtained by applying additive correction factors to Smith's state-of-the-art theory. A method is provided to derive the systematic error between the estimated and predicted mean and variance using Smith's shadowing model for Gaussian rough surfaces. The model is applied for both monostatic and bistatic settings. The validation through Monte Carlo simulation shows improved prediction of the moments for different scenarios.

4.20 Verification of Synthesized Attenuation Method in Indoor Environments

Jarosław Wojtuń, Tomasz Grasza, Jan M Kelner and Cezary Ziółkowski (Military University of Technology, Poland); Radek Zavorka (Brno University of Technology, Czech Republic); Josef Vychodil (Brno University of Technology & BUT Brno, Czech Republic); Jiri Blumenstein and Tomas Mikulasek (Brno University of Technology, Czech Republic); Ales Prokes (Brno University of Technology & Sensor, Information and Communication Systems Research Centre, Czech Republic); Aniruddha Chandra (National Institute of Technology Durgapur, India); Niraj Narayan (National Institute of Technology, India)

Developing technologies utilizing millimeter-wave propagation and directional antenna systems necessitates research in diverse environmental conditions. Comparing research results from different research centers is significantly hampered by the antenna systems' varying direction and other parameters. This paper presents a method for transforming attenuation measurement results using directional antennas into those provided by an omnidirectional antenna system. This allows us to clearly assess the impact of various factors occurring in the propagation environment on the level of received signals. This approach allows us to analyze propagation phenomena based on a broad data set obtained in diverse measurement scenarios. In the developed method, attenuation transformation uses a multi-elliptical propagation model, and its effectiveness is assessed based on a comparative analysis of attenuation values resulting from measurements taken in a selected indoor environment.

4.21 EM Simulation Using Ray Tracing Technique to Analyze Multipath Fading in LEO Satellite-to-Ground Mobile Communications

Stefanos Lampiris, Aris Tsolis and Kyriakos N. Manganaris (NCSR Demokritos, Greece); Fotis Lazarakis (NCSR Demokritos, Institute of Informatics & Telecommunications, Greece); Theodore Zervos (NCSR "Demokritos", Institute of Informatics & Telecommunications, Greece); Antonis A Alexandridis (NCSR Demokritos, Greece)

this paper presents an analysis of ray tracing as a deterministic approach for generating input data to analyze multipath fading for Low Earth Orbit satellite-to-ground communication at 28 GHz. The study aligns the theoretical propagation models with realistic electromagnetic environments through detailed ray tracing analysis. The results provide valuable insights into the propagation behavior of high-frequency Low Earth Orbit communication links and establish a solid foundation for future research on channel modeling and performance optimization in next-generation satellite communication systems.

4.22 Simulation and Analysis of THz Channels Using Ultra-Wideband Ray-Tracing

Georg Jensen (TU Braunschweig, Germany); Christoph Herold, Tobias Doeker and Thomas Kürner (Technische Universität Braunschweig, Germany)

This paper presents a model for computing an ultra-wideband (UWB) channel transfer function (CTF) as well as the corresponding channel impulse response (CIR) in the terahertz (THz) range, based on simulation results from a ray-tracer. The model divides the frequency band into equally spaced subbands, calculates their channel information and combines them into a single CTF and CIR. Unlike existing works that focus mainly on results, this paper emphasizes a comprehensive description of the underlying concept and its implementation. The presented model allows frequency-selective effects resulting from reflection, free space path loss (FSPL), and gaseous attenuation to be investigated.

4.23 Deep Learning for Wireless Channel Prediction with Noisy Structured Log-Distance Models

Eran Greenberg (RAFAEL, Israel); Edmund Klodzh (Rafael, Israel)

This paper presents a deep learning approach to predict wireless channel parameters for noisy synthetic log-distance path loss models. We trained a deep neural network on data from 100 transmitters at different locations, generating radio coverage heatmaps to evaluate its ability to predict received power across receiver grids. We investigated network architectures and input features, focusing on the role of spatial correlation in the path loss exponent and the impact of additive Gaussian noise due to shadowing. Without spatial correlation, the model failed to generalize, with a model RMSE of ~18 dB, while correlated data enabled effective learning, achieving a model RMSE below 0.5 dB without noise and ~6 dB with significant noise (STD of 5 dB). These results on a synthetic model provide critical intuition on spatial correlation and noise, guiding the design of deep neural networks for sophisticated wireless channel prediction tasks, including future ray-tracing based urban modeling.

4.24 Environment-Aided Dynamic Channel Prediction Based on Visual Transformer and Time Fusion

Keying Guo, Ruisi He, Mi Yang, Yuxin Zhang, Chenlong Wang, Zhicheng Qiu and Xuejian Zhang (Beijing Jiaotong University, China)

Accurate prediction of dynamic evolution of wireless channels is essential for design and optimization of communication systems. Traditional prediction methods often struggle to capture the dynamic behavior caused by time-varying multipath propagation and complex environmental scattering. This paper proposes an environment-aided channel prediction framework that integrates scene perception into time-series modeling. The framework employs a Visual Transformer (ViT) to extract geometric and scattering features from environment images, and a Long Short-Term Memory (LSTM) network to capture temporal channel evolution. By fusing both modalities, the model performs recursive prediction of future power delay profiles (PDPs) while effectively mitigating error propagation. Experimental results demonstrate that the proposed method outperforms baseline approaches across all error metrics, and achieves superior reconstruction of key channel statistics, including path loss, shadow fading, RMS delay spread, and stationarity time. These results highlight the advantages of incorporating environmental information for accurate and robust long-horizon channel prediction.

4.25 An Analysis of Magnetic Field Modelling Techniques for Triaxial Electromagnetic Tracking

Kseniia Kosmynina (University College Cork, Ireland & Tyndall, Ireland); Herman Alexander Jaeger (Tyndall National Institute, Ireland & University College Cork, Ireland)

This work presents a comparative analysis of quasi-static electromagnetic field models for 6-DoF electromagnetic tracking. The classic tracking algorithm that uses triaxial sensors and transmitters often relies on the magnetic dipole approximation, which can introduce systematic errors in near-field scenarios due to model inaccuracies. To improve tracking accuracy, a more realistic field representation based on the Biot-Savart law was implemented and validated using commercially available finite element modeling. A rectangular Biot-Savart model was shown to offer a good balance between accuracy and computational cost. The results indicate that field mismatch errors remain below 2.5 mm across the tracking range and below 1 mm at distances greater than three times the transmitter's largest dimension. These findings confirm theoretical expectations and demonstrate that more accurate field modeling can reduce tracking errors without significantly increasing complexity.

4.26 Measurement-Driven Deep Learning for Uplink RF Exposure Assessment in Urban Environments

Qunfei Sun (Paris Cié University, France & LIPADE, France); Shanshan Wang (Polytechnic Institute of Paris, France); Yarui Zhang (University Paris-Saclay, France); Jiang Liu (CNRS, France); Joe Wiart (Télécom Paris, France); Farid Nait-Abdesselam (Université Paris Cité, France)

This paper presents a deep learning based framework for studying uplink radio-frequency (RF) exposure in urban environments. Large-scale outdoor uplink measurements were conducted using the Nemo device from Keysight Technologies. Key uplink related parameters were extracted, including transmit (Tx) power, frequency band, application type, and reference signal received power (RSRP). The proposed deep learning framework utilizes uniquely environmental features, publicly available datasets, i.e., map imagery and base station information, and actual measurements as model inputs, making it a purely measurement based approach. The proposed framework can predict both RSRP and Tx power, where extra information on the application and band are fed to the part predicting Tx power. Measurement locations were divided into separate sets for training and testing to ensure independent validation. The results demonstrate that the proposed framework achieves a prediction performance of RMSE=7.84 dB for downlink and RMSE=7.5 dB for uplink transmit power estimation.

4.27 Hybrid Deep Learning Model for VHF-Band Propagation Prediction Using ResNet Architecture and Attention Mechanism

Ahmad-mahbubul Alam (IETR, University of Rennes 1, France); Bernard Uguen (University of Rennes I, France); Thierry Marsault (DGA-MI, France)

This paper presents a novel deep learning framework for predicting received signal strength in the Very High Frequency (VHF) band (30-80 MHz) using approximately 30,000 real-world measurements collected across diverse French terrains. The proposed TriResNet architecture, a hybrid convolutional-feedforward neural network (CNN-FNN) with residual blocks, is specifically designed to address the challenges of long-range, terrain-dominated propagation inherent in the VHF band by integrating scalar metadata with encoded environmental profiles. The model employs deep residual blocks to enlarge the receptive field, enabling it to capture terrain-induced effects over distances of tens of kilometers. An integrated attention mechanism enables the network to dynamically focus on the most relevant terrain regions, improving both interpretability and prediction accuracy. We conducted a systematic and progressive integration of environmental profiles to quantify their individual and combined impact, demonstrating that our framework significantly outperforms metadata-only models and effectively handles complex VHF propagation scenarios.

Wednesday, April 22 14:40 - 15:20

IN07 Naoki Shinohara - Novel Beam Forming Antenna at Millimeter Wave for Advanced Radiative Wireless Power Transfer Business and for Sustainable Future

// Antennas

Chair: Davide Comite

Naoki Shinohara received the B.E. degree in electronic engineering, the M.E. and Ph.D (Eng.) degrees in electrical engineering from Kyoto University, Japan, in 1991, 1993 and 1996, respectively. He was a research associate in Kyoto University from 1996. From 2010, he has been a professor in Kyoto University. He has been engaged in research on Solar Power Station/Satellite and Microwave Power Transmission system. He is a Fellow of IEEE and URSI, IEEE MTT-S elected AdCom member (2022-2027), IEEE MTT-S Technical Committee 25 (Wireless Power Transfer and Conversion) former chair and member, IEEE MTT-S Standard Committee chair, IEEE MTT-S MGA (Member Geographic Activities) Region 10 regional coordinator, IEEE WPT Initiative member, IEEE Wireless Power Transfer Conference & Expo founder and Steering committee member, URSI commission D (Electronics and Photonics) former chair, the first chair and technical committee member on IEICE Wireless Power Transfer in Japan, Japan Society of Electromagnetic Wave Energy Applications former president and adviser, Space Solar Power Systems Society president, and was IEEE MTT-S Distinguish Microwave Lecturer (2016-18). He was the recipient of the 2025 IEEE Microwave Magazine Best Paper Award, the 2023 IEEE Journal of Microwaves Best Paper Award, the 2022 Award of Minister of Education, Culture, Sports, Science and Technology in Japan, and the 2023 IEICE Achievement Award in Japan, etc. His supervised students were the recipient of 100 awards from 2011 to 2025. He has been author of over 150 reviewed journal papers, over 130 keynotes and invited speakers in international conferences, and over 120 the other invited speakers including 55 DMLs. He has collaborated with totally over 150 companies for the WPT and microwave applications in 30 years. He is the co-inventor of 35 patents and 20 submitting patents. He has worked to harmonize academia and industry of the WPT. He organizes Wireless Power Transfer Consortium for Practical Applications (WiPoT), and Wireless Power Management Consortium (WPMc) in Japan as a chair from 2013 with over 40 companies to establish the WPT market and to encourage the WPT business. His books are "Wireless Power Transfer via Radiowaves" (ISTE Ltd. and John Wiley & Sons, Inc., 2014), "Recent Wireless Power Transfer Technologies Via Radio Waves (ed.)", (River Publishers, 2018), "Far-Field Wireless Power Transfer and Energy Harvesting", (Artech House, 2022), "Theory and Technology of Wireless Power Transfer: Inductive, Radio, Optical, and Supersonic Power Transfer" (CRC Press, 2024), and "Wireless Power Transfer: Theory, Technology, and Applications (2nd Edition) (ed.)" (IET, 2018 and 2014), and some English, Japanese, and Chinese translated text books of WPT.

Room: Edinburgh

14:40 Novel Beam-Forming Millimeter-Wave Antenna for Advanced Radiation Wireless Power Transfer Business and a Sustainable Future

Naoki Shinohara (Kyoto University, Japan)
In 2022, the ITU-R published the Recommendation on Radiative Wireless Power Transfer (WPT). Many startup companies providing radiative WPT have developed various WPT products, including battery-free sensors for the Internet-of-Things (IoT), wireless chargers for small electronics, etc. Most current WPT products are geared toward weak-power and multi-user applications. Novel beamforming technologies are required for increasing the receiving power at the user and suppressing interference at higher transmitting power. For advanced WPT transmitters, the frequency should be increased, considering the cost. Kyoto University developed a novel, low-cost, high-efficiency beam-forming antenna that operates at 28 GHz for simultaneous wireless information and power transfer (SWIPT). The system is based on a waveguided antenna. In this talk, current research and development related to radiative WPT and the global business status will be introduced, along with novel beamforming technology for advanced WPT businesses. Future perspectives for WPT will also be discussed.

Wednesday, April 22 14:40 - 15:20

IN08 Ana Benarroch - Statistics of event and inter-event duration of rainfall events applicable for Mission-Critical Communications and disaster relief systems

/ / Propagation

Chair: Lorenzo Luini

Ana Benarroch received the M.S. and Ph.D.degrees in telecommunication engineering from Universidad Politécnica de Madrid (UPM), Madrid, Spain, in 1985 and 1990, respectively. Since then she has been a research collaborator with Information Processing and Telecommunications Center (IPTC, UPM), taking part in a number of research projects, including Europen Union research projects COST Actions COST255, COST280 and COSTIC0802. She has authored various technical articles in international journals and conference proceedings. She participates regularly in the meetings of the Working Parties of Study Group 3 (Radiowave Propagation) of the Radiocommunication sector of the International Telecommunication Union (ITU-R). Her main research interests are in the areas of radiowave propagation and radio meteorology. In recent years she has carried out studies on the behaviour of various parameters such as rainfall rate, raindrop size distribution (DSD), 0°C Isotherm height and ERA5 cloud parameters.

Room: Berlin

14:40 Statistics of Event and Inter-Event Duration of Rainfall Events Applicable for Mission-Critical Communications and Disaster Relief Systems

Ana Benarroch, Domingo Pimienta-del-Valle and Jose M Riera (Universidad Politécnica de Madrid, Spain); Gustavo Siles (Universidad Privada Boliviana, Bolivia)
Nowadays there is broad interest in the development of mission-critical networks that will include public protection and disaster relief systems. The connectivity for such systems will be provided by 5G/6G technologies, leveraging the combination and future integration of terrestrial and Non-Terrestrial Networks (NTN, e.g. satellite systems). Relevant radio communication systems use high frequency bands, such as Ka and Q/V bands. These frequency bands are subject to rain-induced disruptions that may impact the operation of critical systems. Therefore, the effects of rain events on these systems must be fully understood. In particular, the expected time between events that exceed a given rainfall rate threshold can be of critical importance for such systems Our presentation will show the results of a statistical analysis on the durations and inter-event durations of rainfall events, including extreme events. Rainfall rate data recorded during 17 years with a disdrometer is available for this study.

Wednesday, April 22 15:50 - 17:30

ES1 European School of Antennas Meeting

Room: Madrid

Wednesday, April 22 15:50 - 17:30

A14 Array Antennas at Sub-THz and THz Bands

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Dongjin Jung (Samsung Electronics, Korea (South) & Skyworks Solutions, USA), Antti E. I. Lamminen (VTT Technical Research Centre of Finland, Finland)

Room: Paris

15:50 Silicon-Filled Waveguide Slot Antenna Array for Sub-THz and THz Integration Platform

Antti E. I. Lamminen, Vladimir Ermolov, Henri Ailas, Mikko Kantanen and Mikko Varonen (VTT Technical Research Centre of Finland, Finland)
This paper presents the design, fabrication, and characterization of a silicon-filled waveguide slot antenna array intended for sub-THz and THz integration platforms. The antenna array was manufactured using deep reactive ion etching (DRIE) micromachining and gold-to-gold (Au-Au) thermocompression wafer bonding technologies. The structure features radiating slots exposed through a gold layer atop a gold-plated silicon waveguide, with underlying cavities positioned beneath the slots. The measured peak antenna gain of the eight-element slot antenna array is 8.3 dBi at 302 GHz. The radiation efficiency of the antenna is 58%, which is significantly higher than that of a comparable antenna without cavities.

16:10 240 GHz Dielectric Resonator Antenna Array with Etch Profile Analysis in a BiCMOS BEOL Silicon Interposer Technology

Muhammad Faisal Bashir (IHP - Leibniz-Institut Fuer Innovative Mikroelektronik, Germany); Thomas Voß (IHP, Germany); Sascha Mehl, Jens Lehmann and Kanaka Joy (IHP - Leibniz-Institut Fuer Innovative Mikroelektronik, Germany); Elizabeth Bekker (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany); Akanksha Bhutani (Karlsruhe Institute of Technology, Germany); Matthias Wietstruck (IHP, Germany)
This paper presents a 240 GHz dielectric resonator antenna (DRA) array implemented within a silicon interposer technology. The 2x2 DRA array consists of silicon blocks which are fabricated using a so-called Bosch process. The accurate etch profile of the DRA array is analyzed and the influence on the input reflection ((S{11})) and the realized gain is evaluated. An insignificant change is observed for the (S{11}) whereas 0.5 dB variation in the realized gain can be observed due to etch profile tolerances. The DRA array is characterized and the measured and simulated (S_{11}) are in close agreement.

16:30 Development of a Focal Plane Array in BiCMOS Technology at Terahertz Frequencies

Martijn Hoogelander, Marco Spirito and Nuria LLombart (Delft University of Technology, The Netherlands); Corrado Carta (IHP - Leibniz Institut für Innovative Mikroelektronik, Germany & Technische Universität Berlin, Germany); Maria Alonso-delPino (Delft University of Technology, The Netherlands)

This contribution presents a chessboard FPA operating between 200GHz and 600GHz, to realize a THz camera with both state-of-the-art thermal and spatial resolution. The FPA is integrated in a state-of-the-art, 130nm SiGe BiCMOS technology. Each feed in the FPA is loaded by a direct detector consisting of heterojunction bipolar transistors, optimized to a achieve a noise-equivalent power sufficient for passive THz imaging. The direct detector and FPA were co-designed to optimize impedance matching and antenna losses. A prototype was fabricated and its responsivity, and radiation patterns were characterized using a quasi-optical setup. Responsivity and pattern measurements agree with simulation within 1 dB. The responsivity of the chessboard FPA camera is ten times higher than in our previous work and comparable to the state-of-the-art. While THz detectors with state-of-the-art sensitivity are limited to single-pixel designs, the presented work combines a multi-pixel implementation with competitive sensitivity.

16:50 A Focal Plane Array of Leaky Lens Antenna Coupled MKIDs with Integrated Polarizer at 3.75 THz for Polarimetric Observations of PRIMA

Alexandra Mavropoulou (Delft University of Technology, The Netherlands); Stephen J.C. Yates (SRON, The Netherlands); David Thoen (Kavli Institute of NanoScience, Delft University of Technology, The Netherlands); Jochem Baselmans (SRON, The Netherlands); Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands)

The PRIMAger Polarimetric Imager (PPI), as part of the Probe Far Infrared Mission for Astrophysics (PRIMA), is under development to provide polarization mapping, using Microwave Kinetic Inductance Detectors (MKIDs) coupled to sequentially rotated antennas, operating at 1.13-3.75 THz, in four sub-bands. In this work, the radiation coupling mechanism of this instrument is presented, which is based on a focal plane array of tapered-slot leaky wave lens antennas, connected to the detectors via coplanar waveguides (CPWs). Although the CPWs are optimized to minimize re-radiation, due to fabrication constraints and the high frequency of operation, the common mode is partially excited, increasing the cross-polarized component of each antenna. To enhance the polarization purity, which is critical in PPI due to the simultaneous detection of spatial and polarimetric information, an array of polarizing grids is integrated inside the lens array. A demonstrator is under fabrication and measurements will be presented during the conference.

17:10 Design and Characterization of a Photoconductive Connected Array Source Based on InGaAs: Fe

Martijn D. Huiskes (Delft University of Technology, The Netherlands); Alexander Dohms (Fraunhofer Heinrich Hertz Institute, Germany); Juan Bueno, Nuria LLombart and Paolo Sberna (Delft University of Technology, The Netherlands); Robert Kohlhaas (Heinrich-Hertz-Institut, Germany); Andrea Neto (Delft University of Technology, The Netherlands)

This work presents the design and modeling of a photoconductive connected array (PCCA) source based on iron-doped indium gallium arsenide (InGaAs: Fe) optimized for excitation with a 1550 nm laser with 3 W of average power. A time-domain Norton equivalent circuit is used to determine the optical pulse fluence that results in an impedance match between the photoconductive gap and the antenna impedance. The high-mobility InGaAs material used allows for a efficient THz generation. Simulations predict that the designed 33x33 array source radiates approximately 27 mW of THz power. A power measurement setup is developed for the experimental validation of the proposed array. The setup includes a membrane-based dielectric Bragg reflector (DBR) to reflect stray 1550 nm light, which is transparent for THz radiation from the PCCA. Measurements of the fabricated device will be presented at the conference.

Wednesday, April 22 15:50 - 17:30

A37 Wireless power transmission and harvesting

T04 RF sensing for automotive, security, IoT, and other applications / / Antennas
Chairs: Gholamhosein Moloudian (Tyndall National Institute, Ireland), Chaoyun Song (King's College London, United Kingdom (Great Britain))

Room: Krakow

15:50 A 13.56 MHz Wireless Power Transfer System for RFID Tag and Low Power Applications

Kodeeswaran Sankararaj and Maeve Duffy (University of Galway, Ireland)

This paper presents the design and analysis of a 13.56 MHz wireless power transfer system to supply additional sensor circuitry on an RFID tag during a standard RFID read operation using one coil on the receiver side. The challenge is to provide sufficient power for operation of the sensor, while ensuring robust RFID reading over its required reader-tag distance. An equivalent resonant circuit model is developed to study the impedance behavior, coupling characteristics, and harvested power for the RFID and sensors loads under constant voltage conditions. To maintain compatibility with standard RFID readers, the diameter and number of turns of the receiver coil are varied to increase power transfer. Analytical modeling using the Greenhouse formula provides accurate inductance estimation, followed by validation using finite element analysis (ANSYS Maxwell) and circuit-level verification using LTspice. The proposed design is well-suited for compact, battery-less RFID and IoT-based wireless energy harvesting applications.

16:10 Definition of the Q-Factor for Resonant Antennas in the near-Field Region and Estimation Methods for Propagation Characteristics

Takanori Washiro (NTT, Inc., Japan)

Different types of antennas are used in wireless power transfer (WPT) technology depending on the application. However, the evaluation criteria used for far-field antennas, such as return loss and radiation gain, cannot be applied to near-field resonant antennas. This study therefore proposes a new evaluation method for near-field resonant antennas, reporting measurement results obtained using a prototype antenna operating at 13.56 MHz. Furthermore, by defining the Q-factor for near-field electric field resonant antennas and demonstrating its relationship with propagation characteristics, this study shows that propagation characteristics can be estimated by measuring the Q-factor of individual antennas. This approach simplifies the evaluation of electric field resonant antennas, which previously required numerous measurements, and provides insights into their performance

16:30 RF Rectifier Using Diodes in Series with Inductive Matching Technique for High-Power Application

Muh-Dey Wei (RWTH Aachen University & High Frequency Electronics, Germany); Lukas Hüssen and Renato Negra (RWTH Aachen University, Germany)

This paper demonstrates the feasibility of a diode-in-series configuration for an RF rectifier, which aims to increase the dc output voltage and enable high input power. It is known that the dc output voltage of a rectifier is directly related to the reverse breakdown voltage of the diode..Therefore, when two diodes are connected in series, the dc output voltage of a rectifier can be doubled under high input power. However, having two identical diodes is impractical, and thus, the effect of mismatch between them is discussed. A prototype is implemented to demonstrate the concept. To have a compact design, the inductive matching technique is employed leading to a size of 32mm×46mm.Measured peak efficiency is 79.9% at 2.4GHz with an input power of 24.7dBm and the dc output voltage is 10V.

16:50 Simultaneous Wireless Power Transfer and Tracking with Orthogonally Polarized Self-Diplexing Antenna

Hassan Naseri Gheisanab (University of Alberta, Canada); Peyman Pourmohammadi (Polytechnique Montreal and Concordia University, Canada); Rashid Mirzavand (University of Alberta, Canada)

In this paper, a novel self-diplexing antenna operating at 2.45 GHz with orthogonally polarized elements is proposed and characterized. A 1×4 array of the antenna is constructed, forming two closely spaced 1×4 sub-arrays with orthogonal polarizations. One sub-array is connected to a WPT network capable of beam steering, while the other can be used for tracking. This configuration enables simultaneous WPT and tracking, which is essential for powering dynamic RF devices. Simulation results demonstrate good impedance matching at 2.45 GHz with inter-element coupling better than 17 dB. The proposed self-diplexing antenna features a compact profile of 0.38 × 0.19 λ0. The overall gain of the array, with an inter-element spacing of 0.5λ0, surpasses 9.5 dBi, making it suitable for long-range WPT applications.

17:10 A Screen-Printed Dual-Band Compact Antenna for 868 MHz Wake-Up Radio and 2.45 GHz RF Energy Harvesting

Sanjeev Kumar (Tyndall National Institute, Ireland & University College Cork, Ireland); Gholamhosein Moloudian, Dinesh R. Gawade and Javier Torres-Sanchez (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland); Brendan O'Flynn (Tyndall National Institude, Ireland)

This paper presents a compact, screen-printed dual-band antenna for integration into a low-power embedded wireless tracking device. The antenna is designed for operation at 868 MHz for wake-up radio (WuR) and 2.45 GHz for radio frequency energy harvesting (RF-EH). A dual-radiator design, combining a planar inverted-F antenna (PIFA) and a coplanar waveguide (CPW)-fed monopole, provides independent resonant and impedance response in both bands. Fabricated on the inner surface of a device enclosure using stencil-assisted screen printing with silver nanoparticle ink, the design eliminates the need for an additional PCB assembly. Measurements show -10 dB impedance bandwidths of 58 MHz and 577 MHz at 868 MHz and 2.45 GHz, with peak realized gains of -3.6 dBi and -0.58 dBi, and radiation efficiencies of 15.6% and 25.7%, respectively. The compact, integrated design demonstrates reliable dual-function performance for IoT sensor nodes, supporting both WuR communication and RF energy harvesting.

Wednesday, April 22 15:50 - 17:30

CS18 Advancements in Electromagnetic Field Exposure Research in 5G and Beyond

TO6 Biomedical and health / Convened Session / Electromagnetics

Chairs: Amina Fellan (Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany), Mario Pauli (Karlsruhe Institute of Technology, Germany)

Room: Prague

15:50 Low-Cost Approaches to 5G NR RF-EMF Exposure Assessment in Sub-6 GHz and mmWave Bands

Erdal Korkmaz and Derek Land (The Hague University of Applied Sciences, The Netherlands); Leila Gottmer (Delft University of Technology, The Netherlands); Jonathan Gnanadhas, Xavier van Rijnsoever and Sam Aerts (The Hague University of Applied Sciences, The Netherlands); Marco Spirito (Delft University of Technology, The Netherlands); John Bolte (The Hague University of Applied Sciences, The Netherlands)

Accurate assessment of RF-EMF exposure in 5G NR networks requires measurement solutions that operate across both sub-6 GHz and mmWave frequency ranges. Traditional high-end instruments provide reliable results but are costly, bulky, and unsuitable for large-scale distributed monitoring. This paper presents three complementary low-cost approaches for 5G NR RF-EMF exposure assessment. First, a dedicated FR1 sensor node is introduced, covering four frequency bands allocated in the Netherlands and validated in a pilot deployment. Second, a modified SDR platform (ADALM-Pluto) is calibrated and equipped with GPS for in-field exposimetry, enabling portable exposure mapping. Third, a novel FR2 sensor is proposed, integrating a dual-polarised leaky-wave antenna with a 3D-printed dielectric lens and low-noise electronics, achieving high sensitivity, wide dynamic range, and low power consumption. Together, these solutions demonstrate the feasibility of scalable, low-cost monitoring of 5G RF-EMF exposure, bridging the gap between simple trend analysis and high-precision laboratory measurements.

16:10 Sionna Ray-Tracing-Driven Analysis of RF-EMF and MIMO Channel Capacity in FR3 mmWave LOS Scenarios

Hongda Xu and Kun Li (The University of Electro-Communications, Japan)

This study employs the Sionna RT platform, an open-source ray-tracing library, to conduct a comprehensive evaluation of both wireless performance and RF-EMF (electromagnetic field) safety in a MIMO (multiple-input multiple-output) downlink channel operating under line-of-sight (LOS) conditions in the FR3 millimeter-wave band. Two downlink transmission schemes, regularized zero-forcing (RZF) precoding and no precoding, are compared, and the corresponding MIMO channel capacities of the mobile antenna and the incident power density created nearby mobile terminal are evaluated. The results demonstrate that, in a typical urban road scenario, RZF precoding improves MIMO capacity by approximately 40.6% compared with the no precoding case owing to its ability to suppress inter-user interference. Moreover, due to its beam-focusing capability, the RZF precoding scheme achieves a 20.7 dB reducing in power density at the target receiver and a 5.2 dB average reducing in the entire region.

16:30 RF-EMF and EIRP Trade-off in 6G Handset Multi-Antenna Systems at FR1 and FR3 Bands

Chunxiao Li and Kun Li (The University of Electro-Communications, Japan)

This study investigated the trade-off between total RF-EMF exposure and the effective isotropic radiated power (EIRP) of 6G handset antennas operating at FR1 and FR3 bands. A handset multi-antenna system is designed that integrates cross-band time division multiplexing (TDM) between 2.1 GHz and 3.5 GHz planar inverted-F antenna (PIFA) arrays and employs a 10 GHz patch array for carrier aggregation (CA). The objective is to maximize the overall EIRP while satisfying multi-band RF-EMF exposure limits. With a total antenna input power of 23 dBm, the specific absorption rate (SAR) and absorbed power density (APD) on a human forearm skin model are analyzed over the 6-minute averaging period under different TDM ratios. The results demonstrate that optimal EIRP can be achieved within the exposure limits by appropriately assigning power weighted coefficients across different frequency bands.

16:50 EMF-Aware Proportional Fair Scheduling for Non-Intended UEs in RIS-Assisted Networks

Xueyun Long (Karlsruhe Institute of Technology, Germany); Amina Fellan (Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany); Mario Pauli (Karlsruhe Institute of Technology, Germany); Yueheng Li (Shandong University, China); Hans D. Schotten (University of Kaiserslautern, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

As discussions about defining the sixth generation (6G) of communication networks unfold, an opportunity arises to design electromagnetic field (EMF)-aware networks that ensures that EMF exposure is minimal to users. In this work, we consider a network that employs multiple reconfigurable intelligent surfaces (RISs) to optimize its throughput while maintaining stringent EMF constraints. We consider the performance of proportional fairness (PF)-based scheduling algorithms under EMF constraints that protect bystanders, or non-intended users, from unnecessary EMF exposure, at the same time maximizing the data rate for intended user equipments (UEs) by proactively alleviating signal blockage. Our results are based on ray-launching (RL) simulations inspired by a real-world scenario.

17:10 Near-Field SAR Modelling for Wearable Antennas: A Simulation-Based Framework from 2.45 GHz to 5G and Beyond

Mariem Chemingui (University of Surrey, United Kingdom (Great Britain)); Ashwin Thelappilly Thelappilly Joy (5GIC and 6GIC, University of Surrey, United Kingdom (Great Britain)); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Ahmed Elzanaty and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))
This paper introduces a novel piecewise empirical framework for modelling near-field specific absorption rate (SAR) behaviour in wearable devices, explicitly distinguishing between reactive and radiative coupling regimes. Comprehensive full-wave simulations of planar inverted-F (PIFA) and patch antennas at 2.45 GHz reveal a critical transition in near-field coupling at an 8 mm separation, defining a distinct empirical transition region. The patch antenna demonstrates markedly superior near-field performance, achieving up to 44% lower SAR in typical wearable configurations. Extending the framework to 5G frequencies shows that the compressed reactive near-field at 3.5 GHz intensifies electromagnetic coupling constraints while further emphasizing the advantages of the patch antenna. The proposed model achieves a 32% reduction in RMSE compared with conventional single-region approaches and provides practical, quantifiable guidelines for the design of next-generation wireless and wearable antenna systems.

Wednesday, April 22 15:50 - 17:30

CS36 EuMA session: Active Antennas for Sensing and Communication

TO4 RF sensing for automotive, security, IoT, and other applications / Convened Session / Antennas
Chairs: Alessandra Costanzo (DEI, University of Bologna, Italy), Christian Fager (Chalmers University of Technology, Sweden)

Room: Gothenburg

15:50 A 2.4-GHz Doherty Amplifier-Antenna System with Power Combining on a Dual-Fed Antenna

Genedyn Gems S Mendoza, Guo Wei, Anu Lehtovuori and Kari Stadius (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)
Miniaturization of radio head electronics is a ubiquitous mission for our community. This paper focuses on the reduction of antenna-transceiver interface complexity. The paper proposes a co-design approach for a Doherty power amplifier-antenna transmitter that eliminates the need for a separate power combiner and output matching network, incorporating these functions into a dual-fed antenna structure. The paper presents a 2.4-GHz Doherty power amplifier design with two output alternatives: a reference design including a conventional on-PCB power combiner, output matching network and a single-fed patch antenna, and the proposed design which eliminates these networks altogether by utilizing the dual-fed antenna. The proposed solution was compared to the reference design, and the results show a significant 10% improvement in PAE while also being more area efficient. The results and gathered design know-how indicate that on-antenna power combining is a viable and efficient method to reduce the volume of a radio head.

16:10 Modeling and Analysis of Distortions in Amplitude-Tapered Active Phased Arrays Induced by Temperature and Mutual Coupling

Feza Turgay Çelik (Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands); Yanki Aslan (Delft University of Technology, The Netherlands)
An iterative electro-thermal modeling framework for active transmitters is presented. The proposed approach comprehensively accounts for antenna impedance matching, mutual coupling among array elements, and the self-heating effects of power amplifiers (PAs). The four-stage iterative procedure begins with the computation of the PA output signal from the input excitation and reflection coefficients, followed by the evaluation of dissipated power, estimation of junction temperature, and subsequent update of the PA signal model. The effectiveness of the method is demonstrated for a 16-element linear array of rectangular patch antennas employing Class-A amplifiers operating at 2.14 GHz. The coupled electromagnetic and thermal behaviors are analyzed under various inter-element spacings, scan angles, and amplitude tapering profiles. Results indicate up to a 3.82 dB reduction in radiated power and a 13 dB increase in peak side-lobe level (SLL) for a 40 dB Taylor taper, underscoring the importance of the proposed joint electro-thermal modeling approach.

16:30 Power-Handling Capabilities Investigation of a Time-Modulated Radiating System for WPT Scenarios

Lorenzo Bastia (Università di Bologna, Italy); Tommaso Tiberi (University of Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Diego Masotti (University of Bologna, Italy)
The exploitation of time-modulated arrays (TMAs) as smart RF sources in the wireless transmission of power is critically analyzed in this paper. The limitation in terms of power-handling capabilities of the control logic needed for the time modulation of the input RF signals is highlighted: the nonlinear/electromagnetic rigorous analysis is carried out for a multi-spoke radial array operating at 2.45 GHz connected to a control board adopting Mini-Circuits SAV-541 p-HEMT as switches. The obtained results can, however, be easily generalized for whatever TMA architecture thanks to the definition of a figure of merit able to univocally define the power range where the useful sideband radiation phenomenon is still effective.

16:50 GaN MMICs for in-Band Full-Duplex Active Antenna Arrays

Zoya Popovic (University of Colorado at Boulder, USA); Laila F Marzall and Seth J Johannes (University of Colorado Boulder, USA); Kenneth E. Kolodziej (MIT Lincoln Laboratory, USA)
This paper discusses gallium nitride integrated circuits (GaN MMICs) that help with interference suppression in active antenna arrays. We specifically address in-band full-duplex arrays in C and X bands. Each antenna element contains a transmit-receive front end, and at any given time a percentage of the elements in an array transmit, while the others receive. The coupling between transmit and receive elements results in self-interference at the receiver ends. This can be mitigated by including circuits at the front end that enable calibration of the array so that the digital interference cancellation is improved. The design and experimental validation is demonstrated with a transmit-observation (TXO) circuit at C-band for a narrowband 3-GHz array, as well as for a broader-band X-band array with Vivaldi antenna elements. Additionally, self-interference analog cancellation is demonstrated with an active circulator topology implemented in GaN at C-band and showing over 30dB of frequency-tunable self-interference suppression.

17:10 A 160 GHz on-Chip Antenna for Sub-THz Phased Arrays in a BiCMOS Technology

Lasse Cordes (Ruhr University of Bochum, Germany); Tobias T Braun (Ruhr University Bochum, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany)
This paper presents a differential bow-tie-shaped on-chip antenna designed for a 160-GHz on-chip phased array transmitter. The antenna is developed to provide the optimum load impedance to a power amplifier. Due to the amplifier being placed directly at the feed of the antenna, lossy matching networks and interconnect losses can be eliminated. Furthermore, utilizing a thinned silicon substrate with a thickness in the vicinity of a quarter wavelength, in conjunction with a metal block backing, allows for a simulated radiation efficiency of 18%, despite the lossy silicon substrate. Although operating close to the second resonance, the footprint of the antenna is only 740 um x 220 um, rendering it suitable as an antenna element for 2D phased arrays. The design is realized entirely within the standard back- end-of-line metal stack of Infineon's B12HFC BiCMOS process, without requiring additional packaging or advanced interconnect technologies.

Wednesday, April 22 15:50 - 17:30

CS46 Theory and Applications of Antennas for Biomedical Devices

T06 Biomedical and health / Convened Session / Antennas
Chairs: Mingxiang Gao (ETH Zurich, Switzerland & IT'IS Foundation, Switzerland), Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France)

Room: The Hague

15:50 Kirigami-Inspired Deformable Antenna for Breathing Monitoring

Jamal Abounasr and Mariam El gharbi (Universitat Politècnica de Catalunya, Spain); Raul Fernandez-Garcia (Universitat Politecnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain)

This study introduces a kirigami-inspired deformable antenna designed for non-invasive breathing monitoring. The antenna consists of a printed radiator on polyimide and a ground line with a co-located resonator, separated by two strategic cuts that enable out-of-plane deformation when stretched. This movement alters the near-field coupling between elements, causing a predictable resonance frequency shift correlated with respiration. Bench tests and full-wave simulations targeted 2.30 GHz, while on-body measurements showed 2.189 GHz due to body loading. Mounted on an elastic abdominal belt, the antenna was compared to a BIOPAC reference system using a brief calibration method. Results showed excellent agreement with the reference, achieving waveform correlation r = 0.98, respiratory volume bias of +0.02 L, and respiration rate error of -0.2 ± 0.6 BPM. The specific absorption rate (SAR) values were well below safety limits. This lightweight, low-cost, textile-compatible system provides accurate, continuous respiratory monitoring without requiring separate stretch sensors.

16:10 Design and Characterization of Broadband Antenna of on-Body Antenna for in- and off-Body Communication Systems

Muhammad Qamar (Queen Mary University of London, United Kingdom (Great Britain)); Kamil Yavuz Kapusuz (Ghent University & IMEC, Belgium); Mohamed Thaha and Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))

This paper presents a compact, low-profile, and broadband coplanar waveguide (CPW)-fed antenna designed for both on-body and off-body wireless communication within the lower and upper Industrial, Scientific, and Medical (ISM) and WLAN frequency bands. The antenna, fabricated on a Rogers RO4003 substrate with dimensions of 50 × 60 × 0.8 mm^3, achieves a wide impedance bandwidth ranging from 0.4 GHz to 1.6 GHz, enabling reliable operation across multiple medical and wireless communication bands. The broadband performance is achieved through a combination of ground plane modification and shorting between the patch and the ground. Furthermore, robustness analysis was carried out for different human tissues to evaluate the antenna's stability and performance in realistic body-loading conditions. The results validate the antenna's suitability for continuous health monitoring, biomedical telemetry, and wireless body area network (WBAN) applications requiring broadband, low-profile, and biocompatible on-body antennas.

16:30 Wireless Tracking of Cranial Bone Regeneration via Biodegradable Implant Degradation Monitoring

Mahdi Salimitorkamani, Burak Ferhat Ozcan and Sema Dumanli (Bogazici University, Turkey)

Advances in additive manufacturing and biomaterials are ushering in a new era of cranial implants, where patient-specific, 3D-printed biodegradable devices are becoming standard practice. This study proposes a partially conformal slot antenna for monitoring cranial bone regeneration using a biodegradable implant. The on-body antenna operates at 2.4 GHz and is fabricated on a Rogers 3010 substrate with a flexible graphite-doped silicone superstrate. A lattice-shaped biodegradable implant with a 12 mm radius is embedded in the cranial region and covered with a liquid layer to mimic post-surgical conditions. Bone regeneration and implant degradation are simulated by varying the implant radius from 12 mm to 0 mm. The antenna's resonant frequency shifts as the defect heals due to changes in the effective permittivity of the implanted region. Results show that a 2 mm reduction in implant radius produces at least a 53 MHz frequency shift, confirming the antenna's sensitivity to bone regeneration.

16:50 A Three-Antenna Integrated System for Wireless Multichannel Breath Monitoring

Alessio Mostaccio, Sergio Biondi, Nicoletta Panunzio and Gaetano Marrocco (University of Rome Tor Vergata, Italy)

Accurate and unobtrusive monitoring of human respiration is of growing interest for both clinical diagnosis and physiological assessment. Previous studies have demonstrated that temperature-based passive RFID sensors can reliably reconstruct the respiratory waveform in terms of frequency, duration, and amplitude, providing a minimally invasive alternative to conventional flow meters. This work presents the design and preliminary characterization of a three-channel wireless sensor capable of simultaneously detecting temperature variations at the nostrils and mouth to perform multivariate breath analysis. The device consists of three antennas, embedding temperature-sensing integrated circuits, and operating in the UHF RAIN RFID band (900 MHz). Specifically, two miniature loop elements are positioned within the nostrils, while a third external U-shaped dipole monitors the oral airflow. The experimental electromagnetic characterization of the device compares well with simulations, returning reading distances of 80 cm and 25 cm for the nasal and oral channels, respectively.

17:10 Inductive Coupling Wireless Power Transfer for Implantable Devices: Impact of Eddy Current

Maoyuan Li (Institute of Science Tokyo, Japan); Yumiao He (Peking Union Medical College Hospital, China); Kun Li (The University of Electro-Communications, Japan); Takahiro Aoyagi (Institute of Science Tokyo, Japan); Ilangko Balasingham (NTNU, Norway)

Wireless power transfer (WPT) is a key technology for enabling the long-term operation of active implantable medical devices. However, when the receiver is placed within biological tissue, WPT systems face significant challenges due to losses and dispersion. In this study, we investigate the critical role of eddy current loss in inductive coupling-based WPT. Our results show that eddy current effects alter the optimal value of the compensation capacitance, which must be adjusted to account for electric field absorption in tissue, i.e., the specific absorption rate (SAR). By adjusting the compensation capacitance appropriately, the power transfer efficiency (PTE) can be maintained at nearly the same level as when the system operates in free space. Furthermore, the analysis demonstrates that SAR is strongly influenced by the placement of the compensation capacitor.

Wednesday, April 22 15:50 - 17:30

CS9 Advances in OTA chambers, from reverberation chambers to hybrids

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Laurens A. Bronckers (Eindhoven University of Technology, The Netherlands), Nazanin Farid (Eindhoven University of Technology, The Netherlands)

Room: London

15:50 Gain Reconstruction in Plane Wave Generator Under Different Synthesized Test Zone Quality Conditions

Pavlo Krasov and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Jonas Fridén (Ericsson AB, Sweden); Aidin Razavi (Ericsson Research, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)

In this paper, we examine the accuracy of gain reconstruction in a plane wave generator-based antenna measurement system through simulations conducted under varying test zone conditions. We use both a single element of an antenna array and a full antenna array as our devices under test, allowing us to illustrate cases with different sizes and aperture efficiencies. We demonstrate that using the root mean square metric for the test zone characterization enables easier error propagation analysis compared to the peak-to-peak variation of amplitude in the test zone, a method widely recognized by the IEEE and 3GPP. The peak-to-peak variation metric may overconstrain requirements on the quality of the test zone when testing high-gain array-like base-station antennas.

16:10 A Single-Chamber Solution Unifying Anechoic and Reverberation Chamber-like OTA Testing via Electronic Test Zone Synthesis and Mode Stirring

Marianna Ivashina, Oleg Iupikov and Pavlo Krasov (Chalmers University of Technology, Sweden); Aidin Razavi (Ericsson Research, Sweden); Rob Maaskant (CHALMERS, Sweden); Jonas Fridén (Ericsson AB, Sweden)

Over-the-air (OTA) characterization of wireless de- vices typically requires anechoic chambers (ACs) for directional metrics (e.g., patterns) and reverberation chambers (RCs) for integrated-power metrics (e.g., total radiated power TRP). This increases test footprint and cycle time while raising handling risk for high-power devices, such as 5G/6G base stations. We present a hybrid approach based on an overmoded waveguide that supports discrete set of propagating plane waves (PWs) synthesized by a beamforming chamber array. A unified model integrates embedded-element-field calibration, PW synthesis, electronic stirring, and TRP evaluation, enabling measurements without moving the device under test. In AC-like mode, this yields an uncertainty in the reconstructed patterns below 1.5 dB within 60 degrees range for a 5-by-5 array-antenna under test. In RC-like mode, electronic stirring and planar averaging produce RIMP-like statistics with Rician-K-factor below -25 dB and Rayleigh-like CDFs; agreement with a commercial RC is within 1 dB across frequency.

16:30 Positioning Uncertainties of Traceable Synthetic Aperture Measurements in a Hybrid Chamber

Robert Horansky (NIST, USA); Mohamed Kashef (National Institute of Standards and Technology (NIST), USA); Alireza Kazamipour (Communication Technology Lab, NIST, USA); Kate A. Remley and Dylan Williams (NIST, USA)

Our group has created a traceable, over-the-air, reconfigurable testbed utilizing multipath reflections in a hybrid chamber at millimeter-wave frequencies for characterizing active antenna elements. As part of this effort, we utilize an articulated robotic arm to provide the antenna motion for a synthetic aperture system that provides magnitude and phase of modulated signals as a function of angle-of-arrival. The distance between sampling points of the measurement grid of the synthetic aperture and the uncertainties in that distance are measured with an infrared camera system and can be a limiting aspect of the measurement. Furthermore, the nature of the correlations in the uncertainties can have profound effects on the resuls either providing an incorrect angle-of-arrival, increased sidelobes, or both. We investigate the use of the infrared cameras and commercial motion capture software to quantify antenna locations in space. We evaluate the uncertainty introduced by the camera system in a manner traceable to primary standards. We also find evidence of correlated spatial errors in the camera system along with stable repeatability that could allow even better resolution for future applications.

16:50 Characterizing a Large Reverberation Chamber for OTA Measurements at MmWave Frequencies

Haifa Nabila, Ulf Johannsen and Laurens A. Bronckers (Eindhoven University of Technology, The Netherlands)

The use of a reverberation chamber typically requires the use of a large chamber for low frequencies and a small chamber for high frequencies. However, in some cases, small chambers are unsuitable due to physical size constraints and excessive power levels. In this case, a chamber that is large enough for the setup and capable of supporting high-frequency measurements is required. To address this issue, this paper characterized a large reverberation chamber at a frequency of 32-40 GHz. The results indicate that the loss and the unstirred-to-stirred energy ratio in the large chamber are higher than those in a smaller chamber, while the field uniformity and time constant are better. Interestingly, the larger loss here makes it a natural fit for high-power measurements. These findings demonstrate that mmWave measurements can still be performed in large reverberation chambers, and large and small chambers have different suitability for different types of device.

17:10 Loss Optimization in mm-Wave Reverberation Chamber with Integrated Positioning System

Nazanin Farid (Eindhoven University of Technology, The Netherlands); Jonas Fridén (Ericsson AB, Sweden); A. B. (Bart) Smolders and Laurens A. Bronckers (Eindhoven University of Technology, The Netherlands)

To facilitate the integration of a positioning system for automated measurements, a systematic empirical approach is proposed to identify and mitigate losses in a mmWave reverberation chamber, ensuring preserved performance. Chamber decay time is used to quantify losses at each modification step, allowing the effects of individual changes to be isolated. Results indicate that the positioning system's control cables are the dominant loss contributors compared to feedthrough leakage. Copper shielding of the internal cable sections significantly improved decay time. The optimized setup is validated using standard metrics, including coherence bandwidth, K-factor, and power transfer function. The estimated coherence bandwidth of 3 MHz indicates high modal density, while the K-factor confirms the dominance of stirred energy. The standard deviation of power transfer function remains below 0.2 dB, demonstrating preserved uniformity. The presented approach provides a practical workflow for detecting and mitigating loss mechanisms when integrating additional components into a reverberation chamber.

Wednesday, April 22 15:50 - 17:30

EO4 Computational and Numerical Techniques: Physical Optics Approaches

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Riccardo Ozzola (Delft University of Technology, The Netherlands), Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

Room: Firenze

15:50 An Empirical Diffuse Reflection Model Based on Equivalent Surface Currents

Muhammet Fatih Bayramoglu (University of Oulu, Finland & Verkotan Oy, Finland); Veikko Hovinen and Markku Juntti (University of Oulu, Finland)

We propose an empirical model for diffuse reflection to be utilized in ray-tracing based radio channel simulators. The model is inspired by equivalent surface currents. The proposed model works on a discretized environment. Scattered fields are evaluated as a linear combination of fields induced by the equivalent surface currents on each discretized component. The coefficients of the linear combination determines the scattering pattern. These coefficients are adjusted by a measurement campaign carried out in an anechoic chamber at frequencies from 7GHz to 15GHz. Simulations done with the proposed model indicate that layered dielectric materials, for instance drywall, might exhibit a diffuse reflection features at certain frequencies even if they are smooth.

16:10 Efficient 3D Simulations of Array Antennas with Dielectric Lenses Using a Physical Optics Model

Núria Flores-Espinosa (KTH Royal Institute of Technology, Sweden); Pilar Castillo-Tapia (Eindhoven University of Technology, The Netherlands); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In recent years, considerable attention has been paid to the integration of array antennas with dielectric lenses, as these lenses not only protect the array but also enhance its performance. However, the design of these structures using full-wave simulations is time-consuming and computationally expensive. This paper introduces a 3D ray-tracing physical-optics (RT-PO) method aimed at decreasing both simulation time and the computational demands for structures combining phased array antennas and dielectric lenses. The RT-PO model is capable of simulating multilayer 3D lenses following three main steps: geometrical optics, ray tube theory, and far-field evaluation. Some preliminary simulation results are presented, showing the effectiveness of the model.

16:30 Multi-Scale Analysis of Integrated Lens Antennas with a PPW-Based Decoupling Technique

Erik Speksnijder (TU Delft, The Netherlands); Riccardo Ozzola and Andrea Neto (Delft University of Technology, The Netherlands)

A volume-surface integral equation is formulated used to study dielectric lens antennas with an arbitrary feed. By applying the equivalence theorem in the extinction formulation, the feed can be studied in a parallel plate waveguide (PPW). Therefore, different mesh sizes can be used for the feed and the lens, the total number of unknowns can be reduced, and the multi-scale issues arising from the feed modeling can be avoided.

16:50 Analysis of Integrated Lens Antennas with Distributed Sources and Stratified-Media Spectral Green's Functions

Marti Xargay (Delft University of Technology (TU Delft), The Netherlands); Dunja Lončarević and Nuria LLombart (Delft University of Technology, The Netherlands)

Integrated lenses are widely employed in high-frequency antenna design owing to their simplicity and versatility. While high-frequency asymptotic methods such as Physical Optics (PO) offer efficiency and reasonable accuracy, their validity degrades for regions with incidence above the critical angle (shadow regions), or in the presence of layered coatings like matching layers (MLs). Modeling the feed as a distributed source of magnetic currents, the approach followed in this work enables accurate equivalent current evaluation by representing the lens surface as individual half-space problems described via Stratified-Media Spectral Green's functions (sGF). The method is validated through simulations of two critical configurations: a lens with strongly illuminated shadow region, and a highpermittivity lens with a quarter-wavelength ML. In both cases, the followed method shows reasonably good agreement with full-wave results and consistently outperforms conventional PO.

17:10 Spaceplates Based on Metasurface Cavities

Daniela Gardey De Carvalho and Francisco J. Díaz-Fernández (Universitat Politècnica de València, Spain); Viktar Asadchy (Aalto University, Finland); Ana Díaz-Rubio (Universitat Politècnica de València, Spain)

Spaceplates are nonlocal devices that replicate the angular response of free space over an equivalent, but much larger, thickness. They have emerged as promising candidates for reducing the volume of optical and quasi-optical systems, including lens systems and lens antennas. In this work, we analyze advanced cavity configurations based on nonlocal metasurfaces with purely electric responses. We investigate cavities composed of two and three layers, demonstrating that ideal spaceplate performance can only be achieved with a three-layer cavity, where each metasurface is carefully engineered to provide the required nonlocal behavior.

Wednesday, April 22 15:50 - 17:30

E15 Metasurfaces in Antenna Design

TO8 Fundamental research and emerging technologies/processes / / Electromagnetics
Chairs: Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain)), Marcello Zucchi (Fondazione LINKS, Italy)

Room: Barcelona

15:50 A Double-Path Wave Arrangement for Evaluating the Feed Efficiency of Metasurface-Antennas

Ravikanth Thanikonda, Vydehi Nitta and Stefano Maci (University of Siena, Italy)

This paper presents the design and analysis of a high-efficiency metasurface (MTS) aperture antenna optimized for millimeter-wave operation. A circular aperture with a radius of 10 wavelengths is designed at 29 GHz on a grounded dielectric substrate having an average transparent reactance of minus 300 ohms. The metasurface is excited by a vertically oriented dipole of height 2.5 mm connected to a balanced circular patch of radius 0.8 mm through a triaxial feeding structure. The coupling between the feed and surface-wave mode, analyzed using the average transparent reactance concept, provides a feed efficiency of about 88 percent. A tapered alpha profile controls the leakage rate across the aperture, ensuring smooth amplitude decay. The combined feed optimization and leakage taper achieve a total radiation efficiency of 70 percent and a simulated gain of 35 dBi, demonstrating high gain, polarization purity, and compactness suitable for 6G and satellite communication systems.

16:10 Current-Based Concurrent Synthesis of Dual-Polarization Metasurface Antennas

Lucia Teodorani (Politecnico di Torino, Italy); Marcello Zucchi (Fondazione LINKS, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

In this paper, a current-based numerical method for the synthesis of tensor metasurfaces is extended to accommodate the design of dual-polarized multi-feed antennas. This is achieved by introducing a new functional, regulating the interactions between the multiple sets of fields, to the objective function to be minimized. The latter also encompasses all tensor impedance realizability constraints and radiation requirements, which are expressed in terms of the current only; the surface impedance distribution is retrieved at the end from the optimized current. Results are shown for the case of a circular metasurface that, when excited from one of two feeds placed at different locations on the surface, radiates either a x- or y-linearly polarized broadside beam.

16:30 Current-Based Synthesis of Beam Switching Metasurface Antennas

Shaghayegh Samadzadehghezelghayeh and Lucia Teodorani (Politecnico di Torino, Italy); Marcello Zucchi (Fondazione LINKS, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

We extend the current-based metasurface synthesis of tensorial surface impedance to demonstrate beam switching with multiple feeds and one-beam-per-feed. The process optimizes the surface current (as opposed to impedance), and impedance determination is carried out as a post-processing. The cost functional encodes tensor-impedance passivity and realizability, and far-field masks. To achieve beam switching, we add a functional enforcing pairwise cross-testing constraints among all excitations to ensure co-existence of multiple currents on the same aperture due to different feeds. The resulting current-only problem is solved with a nonlinear conjugate-gradient method featuring a closed-form line search, and the optimized tensor impedance is realized using unit cells ad-hoc selected from a database of precomputed geometries.

16:50 Overcoming Fabry-Pérot Cavity Antenna Limitations Using Two-Dimensional Huygens' Metasurfaces

Pablo Mateos-Ruiz (University of Malaga, Spain); Elena Abdo-Sánchez (University of Málaga & E. T. S. I. Telecomunicación, Spain); Carlos Camacho-Peñalosa (University of Málaga, Spain); George V. Eleftheriades (University of Toronto, Canada)
This paper presents a two-dimensional Fabry-Pérot cavity antenna (FPCA) based on a bianisotropic Huygens' metasurface (BHMS) acting as an enhanced version of the usual partially reflective surface. The BHMS wavefront transformation capabilities enable achieving broadside pencil-beam radiation without relying on the conventional resonance condition that constraints classic FPCA designs regarding excitation and maximum directivity. By rigorously stipulating the guided and radiated field, the BHMS is able to implement the required transmission phase shift across the radiating aperture while guaranteeing proper wave propagation inside the cavity without impedance mismatches. Hence, the proposed approach allows achieving higher directivity without the guided modes getting closer to cutoff nor the beam becoming conical. This concept is validated through a design example showcasing a directive broadside beam with a preliminarily stable frequency behavior in simulation.

17:10 Frequency-Diverse Bunching Metasurface Antenna for Microwave Coincidence Imaging

Mengran Zhao (Queen's University Belfast, United Kingdom (Great Britain) & Xi'an Jiaotong University, China); Shitao Zhu (Xi'an Jiaotong University, China); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))
A frequency-diverse bunching metasurface antenna (FDBMA) that can be used for microwave coincidence imaging (MCI) is proposed in this paper. The proposed FDBMA consists of two distinct types of apertures: the bunching aperture and the random aperture. A triple-layer-metal-baffle (TLMB) is designed to partition different apertures and improve the bunching characteristic. The bunching aperture is formed by a seven-element patch antenna array, which generates the bunching beam. Additionally, the random aperture comprises a random modulated metasurface along with twelve evenly distributed patch antennas serving as excitation sources. The random apertures superpose the frequency-diverse random beams on the bunching beam, thereby achieving the low-correlated frequency-diverse bunching radiation patterns. Low-correlated radiation patterns can be used as different measurement modes, which ensures the feasibility of MCI. The proposed FDBMA is verified through full-wave simulations.

Wednesday, April 22 15:50 - 17:30

E20 Reflection and scattering from Metasurfaces

T07 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Ilir Gashi (University of Siena, Italy), Enrica Martini (University of Siena, Italy)

Room: Rome

15:50 A Rigorous Model for Anomalous Reflection Using Piecewise-Uniform Boundary Conditions

Federico Giusti, Enrica Martini, Stefano Maci and Matteo Albani (University of Siena, Italy)
Metasurfaces provide powerful means for controlling electromagnetic waves, with reflection steering being one of the most widely studied applications, particularly in the context of smart radio environments. Recent advances in anomalous reflector design have led to a variety of synthesis techniques, ranging from analytical formulations to optimization-driven methods. In this work, we uncover a fundamental indeterminacy in the phase of the zero-th and negatively indexed propagating and evanescent Floquet modes in the canonical anomalous reflection problem, when modeled using an impenetrable continuous boundary condition with a tangent-type profile. To address this issue, we propose an alternative formulation, closer to actual implementation, based on a piecewise-uniform version of the required continuous boundary condition, ensuring a well-posed and physically consistent solution. The validity of the proposed model is confirmed through full-wave simulations, demonstrating perfect agreement in both amplitude and phase across all scattered Floquet harmonics.

16:10 Canonical Problem of Out-of-Plane Anomalous Reflection from Modulated Opaque Impedance Surfaces

Federico Giusti (University of Siena, Italy); Serena Assefa Asfaw (Università degli Studi di Siena, Italy); Matteo Albani and Enrica Martini (University of Siena, Italy)
Metasurfaces (MTSs) enable anomalous reflection and refraction beyond conventional Snell's law. While previous analytical studies have focused on in-plane incidence, practical scenarios such as smart-radio environments often involve oblique, out-of-plane illumination. In this work, we present an analytical solution for the complex scattering coefficients of all propagating and evanescent Floquet modes for out-of-plane anomalous reflection from a homogenized impenetrable impedance surface. This formulation extends previous in-plane models, providing a rigorous framework for the accurate characterization of noncoplanar reflections. Comparisons with the in-plane solution highlight similarities, differences, and advantages, offering insights for the design of high-efficiency anomalous reflectors under realistic illumination conditions.

16:30 Physical Bounds on Anomalous Scattering

Mats Gustafsson (Lund University, Sweden)
Anomalous scattering structures are instrumental to reflector arrays, reconfigurable intelligent surfaces, and metasurface antennas, yet the fundamental limits of redirecting scattering remain unclear. This work establishes new bounds on anomalous scattering in antenna arrays, incorporating non-local (beyond-diagonal) matching networks and providing their explicit synthesis. Arbitrary antenna designs within a finite region are analyzed, revealing limits governed by maximal extincted power and a mixed term, significant only in forward and specular directions.

16:50 Current-Only Inverse Design of Anomalous Reflection Metasurfaces

Francesco Lattanzio and Lucia Teodorani (Politecnico di Torino, Italy); Marcello Zucchi (Fondazione LINKS, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)
We discuss the automated design (inverse design) of metasurfaces to achieve anomalous reflection and minimize radiation into the specular direction -- a condition often referred to as "perfect anomalous reflection". We effect the design with a current-only method, in which the object of the optimization is the current (density), as opposed to the surface impedance; the latter is obtained from the current in a post-processing step. The method obtains a significant reduction of radiation in unwanted directions, confirmed by simulation with an external (CST) tool of the entire structure. This communication also adds to the ongoing discussion on locality vs. non-locality to achieve the desired pattern.

17:10 Enhancing the Scattering Characteristics of Checkerboard Metasurfaces Using Vortex Waves

Cicheng Wang and Helin Yang (Central China Normal University, China); Yufei Zhao, Qihao LV and Yong Liang Guan (Nanyang Technological University, Singapore)

Checkerboard metasurfaces (CBM) with low-scattering characteristics are commonly used to reduce a target's radar cross section (RCS). This paper proposes an anti-stealth method exploiting the helical phase distribution of orbital angular momentum (OAM) to enhance CBM scattering. A CBM designed based on the principle of destructive interference demonstrates outstanding RCS reduction, achieving more than 10 dB suppression across the 10-13 GHz frequency range, with a maximum reduction of 28.31 dB at 11.6 GHz. Systematic investigation of OAM modes (l=0,1,2,3) and beam waist radii reveals optimal anti-stealth performance at mode l=(\pm)2 when the beam waist matches the metasurface dimensions. A designed OAM antenna was used for the simulation of CBM scattering characteristics and was compared with the plane wave. Electric field analysis confirms that the helical phase wavefront of optimized OAM waves completely nullifies the low-scattering properties, causing the checkerboard structure to lose its stealth capability and achieving significant anti-stealth effect.

Wednesday, April 22 15:50 - 17:30

M04 Radar and RCS measurement

T05 Positioning, localization, identification & tracking / / Measurements
Chairs: Thomas Dallmann (Technische Universität Ilmenau, Germany), Sergiy Pivnenko (Antenna Systems Solutions, Denmark)

Room: Dusseldorf

15:50 Near-Field Turntable 3-D in-ISAR of a Large Vehicle in Semi-Anechoic Chamber

Lorenzo Ciorba (University of Bern & Institute of Applied Physics, Switzerland); Christoph Rudolf Von Rohr (Armasuisse, Switzerland); Tobias Plüss, Gunter Stober and Axel Murk (University of Bern, Switzerland)

A three-dimensional (3-D) interferometric inverse synthetic aperture radar (In-ISAR) image of a large vehicle is formed from near-field data measured in a semi-anechoic chamber. In particular, the 7-m size vehicle is rotated on a turntable by 360° resulting in a circular scan. The target is illuminated by a X-band radar during the rotation and the backscattered signal is recorded for each angular step. A backprojection ISAR algorithm taking into account path loss and spherical phase front of the incident wave is applied to these measured radar data and a two-dimensional (2-D) ISAR picture is obtained. Acquiring an additional measurement by displacing the receiving antenna along the altitude axis, the In-ISAR technique is applied to produce a 3-D point cloud representing the target.

16:10 Experimental Testing of the Multiple Radar Bayesian Localisation and Tracking Algorithm

Rasmus Himmelstrup Andersen, Aske Barnaby Rasborg Best, Malthe Raschke Nielsen, Troels Pedersen and Anders Malthe Westerkam (Aalborg University, Denmark)

This paper presents experimental testing and evaluation of a distributed radar tracking system using frequency-modulated continuous-wave (FMCW) MIMO radars. Target localisation and tracking is performed using the multiple radar Bayesian localisation and tracking (MRBLaT) algorithm, a track-before-detect (TBD) method that operates directly on raw radar data, allowing robust performance in low SNR environments. The experimental setup comprises three off-the-shelf radars, where frequency division multiplexing (FDM) is applied to avoid mutual interference. Synchronisation is achieved through simple timestamp alignment managed by a control centre. Two experimental scenarios, the linear drone track and the curved reflector track, demonstrate the algorithm's ability to track targets under real-world conditions, despite environmental clutter and hardware limitations. Results demonstrate accurate tracking with position errors below 0.7 m and confirm real-world capabilities of tracking using MRBLaT.

16:30 Background Subtraction with Drift Correction for Bistatic Radar Reflectivity Measurements

Alexander Ihlow, Marius Schmidt, Carsten Andrich and Reiner S. Thomä (Technische Universität Ilmenau, Germany)

Fundamental research on bistatic radar reflectivity is highly relevant, e.g., to the upcoming mobile communication standard 6G, which includes integrated sensing and communication (ISAC). We introduce a model for correcting instrumentation drift during bistatic radar measurements in anechoic chambers. Usually, background subtraction is applied with the goal to yield the target reflection signal as best as possible while coherently subtracting all signals which were present in both the foreground and background measurement. However, even slight incoherences between the foreground and background measurement process deteriorate the result. We analyze these effects in real measurements in the frequency range 2-18 GHz, taken with the Bistatic Radar (BIRA) measurement facility at TU Ilmenau. Applying our proposed drift correction model, we demonstrate up to 40 dB improvement for direct signal interference (DSI) subtraction over the state of the art.

16:50 Radar Cross Section Measurements of Foreign Object Debris Detection Radar Targets at W-Band

Ilhami Unal (University College Dublin, Ireland); Süleyman Baykut (TÜBİTAK BİLGEM-BTE, Turkey); Sergiy Panin (Millimeter Wave and Terahertz Research Laboratories (MİLTAL), Turkey)

In this study, W-band radar cross section (RCS) characteristics of target samples for foreign object debris (foD) detection radar system (FODRAD), which is developed at TUBITAK BILGEM, are presented. While the RCS measurements are taken inside the anechoic chamber at TUBITAK MAM, outdoor back scattering features of some of the samples are also investigated when they're located on the asphalt, at 1.5o elevation angle of incidence. The measured foD radar targets are a metallic cylinder, golf ball, concrete ball, crushed tin can and M16 screw, as well. Simulation and verification studies for measurements inside the anechoic chamber are also carried out for the samples that could be modeled. Finally, detection capability of the foD radar system is demonstrated on an airport runway using measured results obtained for the radar targets located at 246 m distance.

17:10 Enhanced Polarimetric Phase Calibration for Automotive Radar Using near-Field Dihedral Scattering with Misalignment Angle Correction

Changxu Zhao and Yanki Aslan (Delft University of Technology, The Netherlands); Alejandro Garcia-Tejero (Universidad Politecnica de Madrid, Spain & HUBER SUHNER, Switzerland); Alexander Yarovoy (TU Delft, The Netherlands)

Calibration of mm-Wave fully-polarimetric MIMO radar is considered. An enhanced polarimetric phase calibration method is proposed, which operates in the far-field region of the radar but utilizes calibration targets within their near-field scattering region. The method exploits near-field dihedral scattering with yaw angle correction to improve calibration repeatability across different measurement sessions. Simulations and measurements show that using a larger dihedral compared to the smaller one employed for far-field calibration in the near-field region increases received power by up to 15.7 dB, thereby enhancing the signal-to-noise ratio. Although near field sensitivity to alignment introduces phase variations, the proposed yaw angle correction effectively compensates them, achieving phase consistency comparable to far-field calibration under high-SNR conditions, and outperforming it under low-SNR conditions. The method provides a robust approach for stable polarimetric calibration in compact automotive radar setups.

Wednesday, April 22 15:50 - 17:30

PO6 Propagation Measurements and Channel Sounding

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Propagation
Chairs: Pekka Kyösti (Keysight Technologies & University of Oulu, Finland), Sana Salous (Durham University, United Kingdom (Great Britain))

Room: Copenhagen

15:50 Modeling of 917.5 MHz Highway Tunnel Pathloss Measurements

Jesper Ødum Nielsen and Gert Frølund Pedersen (Aalborg University, Denmark)
The current work investigates the narrowband 917.5 MHz radio channel between sensor locations distributed along the side wall of a highway tunnel and a gateway at the tunnel entrance. Since the channel gain may vary considerably with the exact sensor location, statistics of the measured channel are derived and models are tested for fitness. This allows for link budget calculations required for planning of the communications network for the sensors.

16:10 Double-Directional Channel Measurements at 234 GHz and 318 GHz in a Symmetric Large Hall

Lafir Naveeth Mohamed (University of Oulu, Finland); Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Veikko Hovinen (University of Oulu, Finland); Nuutti Tervo (University of Oulu, 6G Flagship, Finland); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland)
Propagation measurements at sub-terahertz (sub- THz) radio frequencies are essential for accurate radio channel characterization and for supporting future communication and sensing applications. This paper presents sub-THz dual-band channel characterization results based on double-directional measurement campaigns conducted in a symmetric large hall. The channel frequency responses (CFR) were recorded at multiple transmitter-receiver location combinations. The frequency- dependent channel characteristics are analyzed in terms of path loss, delay spread, angular spread, and Rician K-factor. The number of multipath components (MPCs) observed in this environment is very small at both frequencies, with mean values below three. Except for the path loss exponent and K- factor, the fitting results show that the mean delay spread and angular spread both decrease with increasing frequency, but the reduction is not significant. In addition, we also investigate the impact of symmetrically placed transmitters on sub-THz channel characteristics.

16:30 Performance Comparison of Joint Delay-Doppler Estimation Algorithms

Lorenz Mohr (Technische Universität Ilmenau, Germany); Michael Döbereiner (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany); Steffen Schieler (Technische Universität Ilmenau, Germany); Joerg Robert (TU Ilmenau, Germany); Christian Schneider, Sebastian Semper and Reiner S. Thomä (Technische Universität Ilmenau, Germany)
Integrated sensing and communications (ISAC), radar, and beamforming require real-time, high-resolution estimation algorithms to determine delay-Doppler values of specular paths within the wireless propagation channel. Our contribution is the measurement-based performance comparison of the delay-Doppler estimation between three different algorithms-comprising maximum likelihood (ML), convolutional neural network (CNN), and constant false alarm rate (CFAR) approaches. We apply these algorithms to publicly available channel data which includes two spherical targets with analytically describable delay-Doppler parameters. The comparison of the three algorithms features the target detection rate, root mean squared errors (RMSEs) of the delay-Doppler estimates, and a runtime analysis. Notably, all three algorithms demonstrate similar parameter estimation capabilities in bi-static scenarios, achieving target detection probabilities of up to 80 %. Conversely, forward and backward scattering conditions pose a problem to the estimation due to strong line-of-sight (LoS) contribution, reducing the corresponding detection probability down to 0 %.

16:50 Comparison of Radio Propagation Channels in the W-Band and D-Band for Indoor Environments

Fabián C Quinchia (Universidad Politécnica de Cartagena, Spain); Maria-Teresa Martinez-Ingles (University Centre of Defence at the Spanish Air Force Academy, MDE-UPCT, Spain); Jose-Maria Molina-Garcia-Pardo and Juan Pascual-García (Universidad Politécnica de Cartagena, Spain)
In this paper, we compare the large-scale fading characteristics at W and D bands, in an indoor line-of-sight scenario, using measurements obtained with a wideband channel sounding. Particularly, the floating-intercept (FI) and close-in (CI) path loss models have been estimated from the measurements. To further examine the frequency dependence, the multi-frequency close-in model with a frequency-weighted path loss exponent (CIF) is also considered.

17:10 Rain Attenuation Measurements over a 1 km Free-Space Optical Link in Madrid

Elizabeth Verdugo (PUC-Rio, Brazil); Lorenzo Luini (Politecnico di Milano, Italy); Jose M Riera (Universidad Politécnica de Madrid, Spain); Laura Resteghini (Huawei Technologies, European Research Center, Italy); Roberto Nebuloni (Ieiit - Cnr, Italy)
We present preliminary results from a propagation experiment in Madrid, Spain, aimed at quantifying the impact of rain on a 1 km free-space optical (FSO) link at 1.55 μm. The measurement set-up also included two disdrometers and two visibility sensors deployed at each side of the link. Rain attenuation did not exceed 10 dB along the path even under heavy rainfall intensities (70 mm/h). Furthermore, predictions based on rain intensity may underestimate attenuation during light rainfall due to the effect of small droplets, which are accounted for by a visibility-based model. The latter approach works rather well also in moderate-to-heavy rain.

Wednesday, April 22 17:40 - 20:00

BYA Building your Academic Career

Visibility, Choices, and Professional Journeys (A WiAP & ECAP WGs Event)

Room: Edinburgh

The EurAAP Early Careers and Women in Antennas and Propagation working groups organise a workshop in which invited speakers will talk about their career in the field of Antennas and Propagation. After the workshop, there will be a happy hour for the participants to mingle. More information is provided in the ebook.

Thursday, April 23

Thursday, April 23 8:00 - 9:40

AO2a Active RIS Design and Synthesis 1

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Manuel Arrebola (Universidad Politécnica de Madrid, Spain), Wilhelm Keusgen (Technische Universität Berlin, Germany)

Room: London

8:00 Monolayer Reconfigurable Intelligent Surface with Integrated Biasing for Millimeter-Wave Beam Scanning

Akhilesh Kumar (Indian Institute of Technology, Patna, India); Amit Kumar Singh (IIT Patna, India)
This paper presents 1-bit Reconfigurable Intelligent Surface (RIS) with a compact monolayer biasing network capable of beamforming. The RIS consists of a 24 x 24 array of unit cells with 0.42λ periodicity at 28 GHz. The unit cell features E- and T-shaped top patches connected by a PIN diode and a U-shaped bottom patch linked to the top layer by using via. The T- and U-shaped patches also serve as integrated biasing lines. The proposed unit cell of RIS achieves more than 90% reflection and a 180deg phase shift in both diode states, enabling beam steering up to 60deg with maximum scan loss of 2.5 dB. It provides gain of 25 dBi at broadside and 22.5 dBi at 60deg, with 6 GHz bandwidth (25-31 GHz) and consistently low scan loss, making it suitable for improving coverage, link reliability, and blockage mitigation in advanced 5G and 6G networks

8:20 Design of a Centimeter-Wave Reconfigurable Intelligent Surface for Communication System Application

Felix-Christopher Lutz (Technische Universität Berlin, Germany); Dennis Osterland and Andreas Benzin (Technische Universitaet Berlin, Germany); Wilhelm Keusgen and Giuseppe Caire (Technische Universität Berlin, Germany)
In this work, a Reflective Intelligent Surface (RIS) is designed and evaluated. The design is based on aperture- coupled stacked patches, enabling compact array realization with dual-polarization capability and broadband behavior. Initially, a single antenna element was designed, based on which, two arrays were designed, one 2×2, to be used as the signal source for the far-field RIS measurements and one 8×8, the RIS. To keep the design efficient, 2-bit switched delay line phase shifters are used for beam steering. All hardware elements were individually manufactured and tested. Additionally, the whole system was assembled and tested in a bi-static configuration. To ensure satisfactory performance, the phase distribution of the incident wave was determined directly. This was achieved by radio frequency connectors at each unit cell, bypassing the phase shifters. This modular design allows for easy identification of deviation sources from the ideal design and to perform better root cause analysis.

8:40 Towards the Optimization of Liquid Crystal Reconfigurable Intelligent Surfaces

Bilal Hammu Mohamed (Technical University of Berlin, Germany); Markus Widmaier, Hanghang Li and Marco Dettling (University of Stuttgart, Germany); Fabian Tobias Bette (Rohde & Schwarz GmbH & Co. KG, Germany); Holger Baur (University Stuttgart, Germany); Wilhelm Keusgen (Technische Universität Berlin, Germany); Norbert Fruehauf (University of Stuttgart, Germany); Matthias Jost (Merck Electronics KGaA, Germany)
In this paper, two reconfigurable intelligent surfaces based on liquid crystal in the mmWave frequency range are presented and a characterisation of their amplitude and phase vs frequency is performed for different applied voltages. The two charaterised RIS are a single-polarization RIS based on multiple resonators while the other one is a novel dual-polarized phaseshift-based RIS with a high shrinking factor in order to compensate for the low tunability of the LC. Besides, the effect of the orientation of the LC-molecules in the performance is compared, as well as two different LC-mixtures: the GT7-29001 from Merck KGaA and the GT8, also from Merck KGaA.

9:00 Design and Implementation of a Dual-Polarized Reconfigurable Intelligent Surface Using an Ultra-Thin 10 Um Liquid Crystal Layer

Zhuoao Xu (University of Surrey, United Kingdom (Great Britain)); Shadi Danesh (5GIC & 6GIC, Institute for Communication Systems (ICS), University of Surrey, United Kingdom (Great Britain)); Ali Ali and Demos Serghiou (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain))
This paper presents an ultra-thin Liquid Crystal Reconfigurable Intelligent Surface (LC-RIS) fabricated using a process compatible with conventional Liquid Crystal Display (LCD) technology, enabling large-scale manufacturing. The LC layer has a thickness of only 10 um, providing improved response speed and reduced insertion loss. Simulation results show that, under normal incidence, the symmetric structure of the unit cell yields nearly identical responses for both x- and y-polarizations, with reflection magnitudes exceeding -10 dB and phase range over 180° across a 500 MHz bandwidth centered at 28 GHz. Moreover, consistent reflection characteristics are maintained for oblique incidences up to 30°. Furthermore, the proposed design has been implemented and experimentally validated in hardware. Two phase profiles corresponding to azimuthal beam deflections of 45° and -30° were designed and verified, with results matching the expectations. The proposed LC-RIS design paves the way for low-cost, large-scale commercialization aimed at enhancing indoor 5G coverage.

9:20 Semi-Analytic Modeling and Design of a RIS Based on an Infinite 2D Array of Planar Antennas with Tunable Reactance

Ilir Gashi and Matteo Albani (University of Siena, Italy)
This work develops a formulation for the scattering analysis of infinite Reconfigurable Intelligent Surfaces (RIS) modeled as periodic arrays of reactive-loaded antennas. By leveraging Floquet modal decomposition and discrete Fourier transforms, the approach enables the calculation of reflection coefficients under both uniform and periodic loading. The framework facilitates the extraction of scattering parameters from single-cell simulations and supports the design of RIS-based reflectors with controllable phase profiles.

Thursday, April 23 8:00 - 9:40

AO6a Antenna Array Theory and Synthesis 1

TO7 Electromagnetic modelling and simulation tools / / Antennas
Chairs: Do-Hoon Kwon (University of Massachusetts Amherst, USA), Paolo Rocca (University of Trento & ELEDIA Research Center, Italy)

Room: Paris

8:00 Vector Effective Heights for Isolated Antennas, Finite Arrays, and Infinite Arrays

Do-Hoon Kwon (University of Massachusetts Amherst, USA)

The traditional definition of the vector effective height for isolated antennas is extended to finite and infinite arrays that radiate spherical, cylindrical, and plane waves. For arrays, each element effective height represents the vector radiation pattern in the presence of mutual coupling by all other elements having open-circuit terminations. Extended to 1- D and 2-D infinite periodic configurations, the effective heights retain the same definition in terms of the induced currents. They help characterize the transmitting, receiving, and scattering characteristics of antennas as well as arrays of finite and infinite dimensions.

8:20 Full-Matrix Hybrid-Z Polarimetric Modeling of Finite Arrays with Edge Effects

Jeffrey P. Massman (Analog Devices, USA)

This paper introduces a full-matrix Hybrid-Z network that generalizes the dyadic discrete kernel with a lattice-based polarimetric mutual-coupling model and addresses limitations of column-only constructions by assembling the complete 2N × 2N polarimetric impedance matrix from closed-form dyadic kernels including per-element self-terms. The formulation enforces reciprocity by design and embeds finite-aperture phenomena without full-wave simulation, yielding the full polarimetric scattering parameters needed to compute scan-dependent quantities. An example 8x8 finite array is developed. The model reproduces established signatures with axis-aligned co-pol coupling and diagonal-dominant cross-pol, including redistribution near edges. Absolute scaling is anchored to measurable metrics via nearest-neighbor levels and per-element reflections, while a small parameter set modulates radiative, near-field, and image contributions. Quantitative validation is included against published Vivaldi-array simulation data at 9 GHz. The resulting analytic, lightweight network is well suited as a computationally efficient scheme for calibration and coupling-aware processing in dual-polarized and high-performance finite antenna arrays.

8:40 A Novel Approach to Wideband Phased Array Antennas

Younes Radi, Pardha Sourya Nayani and Javaria Aslam (Syracuse University, USA)

Across diverse scientific domains, including modern communications and defense, there is growing demand for phased arrays offering high gain and efficiency over broad bandwidths. Conventional phased array architectures, however, are fundamentally constrained by trade-offs among bandwidth, efficiency, and complexity. To overcome these limitations, we propose new design concept based on direct antenna modulation (DAM), enabling bandwidth enhancement without compromising key performance metrics. We introduce a fundamentally new DAM topology that eliminates the need for precise, high-speed switching inherent to conventional approaches, while maintaining high efficiency. This represents the first demonstration of DAM applied to phased array antennas, introducing a new paradigm for wideband array design. As a proof-of-concept, we designed a patch array and performed full-wave time-domain simulations capturing the complete spatiotemporal dynamics of the system. The results demonstrate a several-fold increase in bandwidth over an identical array using conventional excitation, going beyond what is achievable with traditional phased-array architectures.

9:00 Beyond Hannan's Limit on Embedded Element Efficiency Using Tightly Coupled Array Elements

Yanwen Chen and Stefano Maci (University of Siena, Italy)

Dense array antennas are becoming increasingly popular in modern wireless and radar systems due to their large bandwidth and beamforming capabilities. It is well known that closely spaced elements experience significant mutual coupling. This paper revisits the concept of embedded element efficiency (EEE) and challenges the conventional Hannan's limit on EEE imposed by the assumption of a cosine-shaped embedded element gain pattern (EEGP) for dense arrays. We demonstrate that higher EEE can be achieved using Tightly Coupled Array (TCA) elements, resulting in broader EEGPs and improved scanning performance. Evidence from numerical simulations further confirms this theory. These findings propose a refined understanding of the embedded directivity-efficiency trade-off in dense arrays, offering valuable insights for next-generation antenna array system design.

9:20 Extending Aperiodic (Random) Array Theory to Non-Independent, Non-Identically Distributed Elements

Thomas E. Christian, Jr. (Sandia National Laboratories & University of New Mexico, USA); Christos Christodoulou (The University of New Mexico, USA); Jacques Loui and Jeffery T Williams (Sandia National Laboratories, USA)

Classical array theory models aperiodic arrays using a probabilistic framework that assumes independently and identically distributed (i.i.d.) element locations. In practice, minimum-spacing constraints introduce spatial correlations that alter the sidelobe region of the array radiation pattern. This paper presents a generalized probabilistic formulation for correlated, non-i.i.d. arrays. A closed-form second-moment expression is derived that extends classical aperiodic array theory by incorporating spatial correlation through the pair-correlation function and structure factor. The formulation enables direct analytical prediction of the blue-noise ring's onset and peak and shows that correlation reshapes sidelobe statistics, accurately modeled by weighted mixtures of Nakagami and Gamma distributions, for amplitude and power respectively. Monte Carlo simulations validate the analytical results, showing excellent agreement with the ensemble-averaged spectral and statistical behavior of correlated arrays.

Thursday, April 23 8:00 - 9:40

A09a Antennas and Probes for Measurements 1

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas

Chairs: Adrian Bekasiewicz (Gdansk University of Technology, Poland), Marianna Ivashina (Chalmers University of Technology, Sweden)

Room: Barcelona

8:00 Design Challenges and Solutions for Characterizing Mutual Coupling Coefficients in PCB-Based Ka-Band Dual-Polarized Wide-Scan Phased Arrays

Theodoros Pavlidis (Chalmers University of Technology, Sweden & Satcube AB, Sweden); Thomas Schäfer (Satcube, Sweden); Ahmed A Kishk (Concordia University, Canada); Marianna Ivashina (Chalmers University of Technology, Sweden)

A scalable measurement setup for PCB-based, wide-scanning phased arrays operating in the SATCOM Ka-band (27.5-31 GHz) is designed. This setup addresses the critical challenges of dense element spacing in dual-polarization configurations as well as the nonideal performance of commercial surface-mount device (SMD) resistors at millimeter-wave frequencies. The measurement setup uses SMD connectors and resistors, eliminating the need for additional fixtures and/or PCB conductor layers. The footprint required for the connector transition is minimized by shaping the connector pad, reducing the number of pad-grounding vias needed, and increasing the flexibility in connector pad placement. Miniaturized terminations using SMD resistors are designed by co-simulating transmission lines, grounding vias and resistor equivalent models. The designed terminations and transition are used in the fabrication of phased array prototypes. Test boards for the transition and terminations are fabricated and their S-parameters measured. The measurement results validate the repeatable performance of the designed components.

8:20 Electromagnetic Compatibility Evaluation of a Dynamic Wireless Power Transfer System for Electric Vehicle Charging

Ozuem Chukwuka (University Gustave Eiffel & MC2 Technologies, France); Mohammed Kalaagi (Université Gustave Eiffel, Villeneuve D'ascq, France); Romain Alcesilas (Université Gustave Eiffel, France); Narimane awada Mislmani (University of Gustave Eiffel
& IFSTTAR-LEOST, France); Divitha Seetharamdoo (Univ Gustave Eiffel COSYS LEOST Univ Lille Nord de France & Univ Lille Nord de France, France)
Wireless Power Transfer (WPT) technology enables contactless charging of Electric Vehicles (EVs), supporting both static and dynamic operation through magnetic coupling between roadway transmitters and vehicle receivers. Inductive Power Transfer (IPT), typically operating around 85 kHz, offers high efficiency and robustness but also generates strong electromagnetic fields that raise Electromagnetic Compatibility (EMC) and Electromagnetic Field (EMF) exposure concerns. This paper presents an experimental characterization of a full-scale dynamic WPT system deployed along the A10 highway near Paris. Using high-resolution spectrum analyzer measurements, the electromagnetic emissions of the system are analyzed under realistic operating conditions. The results indicate that the dynamic WPT system operates within acceptable EMC levels under real-world conditions, with no significant interference detected across the evaluated spectrum. These results provide experimental validation supporting the safe and compliant deployment of largescale Electric Road Systems (ERS) based on inductive charging technology.

8:40 A 5.8-GHz High-Input-Impedance Miniaturized Balun for Open-Circuit Voltage Measurements of Balanced Antennas

Gabriele Atzeni, Matteo Bruno Lodi and Giacomo Muntoni (University of Cagliari, Italy); Antonio Sorrentino (Università di Cagliari, Italy); Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)
Accurate characterization of the open-circuit voltage of antennas is fundamental to the optimization of wireless systems. However, conventional measurement techniques that rely on direct connections to a network analyzer introduce loading effects, significantly affecting the measured signal, especially for balanced and small antennas. This paper presents a high-impedance balun for open-circuit voltage measurements of balanced antenna structures. The proposed device features a balanced high-impedance input that minimizes antenna loading, while the unbalanced output is compatible with standard 50-Ohm equipment. Its small geometry, lower than 7 mm at 5.8 GHz, ensures minimal disturbance of the near-field distribution. The proposed balun maintains a high impedance transformation ratio larger than 68 in a 200-MHz bandwidth, with a common-mode rejection ratio of 50 dB, and an amplitude imbalance lower than 1.5 dB from 100 MHz to 7 GHz. Simulation results confirm that the proposed balun provides a compact solution for precise open-circuit voltage measurements.

9:00 Characterisation of the Multi-Moded Response of a Lens Absorber Coupled Kinetic Inductance Detector via Energy Absorption Interferometry at 1.5 THz

Daan Roos (SRON & University of Technology Delft, The Netherlands); Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands); Stephen J.C. Yates (SRON, The Netherlands); Stafford Withington (Cavendish Laboratory, United Kingdom (Great Britain)); Willem Jellema (SRON, The Netherlands)
Multi-mode distributed absorbers are widely used in thermal imagers and astronomical instruments, yet their multi-moded nature and impact on sensitivity are often overlooked. We characterize a 1.5 THz lens-absorber coupled KID using the EAI framework, with simulations based on a spectral technique, propagated through the optical system using TICRA GRASP. Excellent agreement with measurements validates both the measurement procedure and the numerically efficient EAI simulation, and quantifies the optical system's effect on the modal content of multi-mode detectors.

9:20 Characterization of Variable Phase Resolution and Cross-Channel Amplitude Imbalance Effects in 100GHz Active Beam-Steering Phased Array

Viktor Chernikov (Chalmers University of Technology, Sweden); Goran Granstrom (GOTMIC, Sweden); Marcus Gavell (Gotmic AB, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)
This paper characterizes how different-resolution phase control and amplitude imbalance affect scanning performance in W-band active phased array antennas. The case study is a ridge- gap-waveguide array antenna with 0.56 wavelengths spacing at 94 GHz and a multi-channel active module with integrated phase shifters (5-bit) and power amplifiers operating at 92-96 GHz. The analysis approach incorporates measured front-end performance and the simulated array antenna S-parameters and embedded-element patterns. Using these results, we evaluate 1- to 5-bit phase control and the amplitude imbalance across active channels. The active array antenna achieves grating-lobe-free beamsteering within plus-minus 50 degrees; main beam scan loss does not exceed 1.3 dB. A rise in the average side-lobe level and quantization lobes due to the phase quantization and amplitude imbalance is demonstrated for the practical front-end. From these results, we formulate strategies for performance improvement. The framework is generalized to other millimeter-wave arrays with electronic beam-steering.

Thursday, April 23 8:00 - 9:40

A26a On body and implantable antennas 1

T06 Biomedical and health / / Antennas
Chairs: Pai-Yen Chen (University of Illinois at Chicago, USA), Mahmoud Wagih (University of Glasgow, United Kingdom (Great Britain))

Room: Krakow

8:00 Design and Simulation of a near-Field Probe for Body Radiometric Thermometry Under Dynamic Coupling Conditions

Chen Dong and Ruochen Gu (Beihang University, China); Hu Anyong (Beijing University of Aeronautics and Astronautics, China); Jungang Miao (Being University, China)
The antenna-body matching is highly dependent on several factors, such as the gap distance and the body's dielectric properties. Dynamic changes in these parameters can lead to impedance mismatch. For optimal matching, cascaded matching layers were sequentially constructed from the innermost section to the outer surface of a horn antenna, ordered by increasing dielectric constants. Dynamic coupling conditions was also considered in the design process to minimize mismatches. As a simulation result, the reflection coefficient of the proposed probe is less than -20 dB in the range of 32 to 36 GHz when it is directly in contact with the skin. Based on the -15 dB reflection coefficient criterion, the maximum thickness of clothing between the probe and the human body can reach 0.6 mm. The antenna achieves a reflection coefficient better than -18 dB, regardless of variations in the dielectric constant of the underlying human body.

8:20 Enhancing Deep-Tissue Power Transfer Through Expandable Nitinol Antenna for Vascular Implants

Ilaria Facchi and Nabhan Yameen (Trinity College Dublin, Ireland); Ana Flavia De Almeida Barreto and Thomas D. O'Sullivan (University of Notre Dame, USA); Friedrich Wetterling (Trinity College Dublin, Ireland)

The development of implantable medical devices (IMDs) for deep-tissue applications, such as endovascular monitoring, is limited by wireless power transfer (WPT) challenges and signal attenuation in heterogeneous biological tissues, alongside strict miniaturization constraints. Here, we present a novel nitinol-supported expandable antenna designed for intravascular deployment. Leveraging nitinol's shape-memory effect, the antenna, operating at 8 MHz, transitions from a collapsed 1.5 cm diameter to a fully expanded 3 cm diameter, conforming to major vessels such as the inferior vena cava. Finite-element simulations in Sim4Life and benchtop measurements using an external single-loop coil demonstrated quasi-quadratic scaling of induced voltage with antenna radius and quartic scaling with transmitted power, with the expanded state yielding markedly improved WPT. The antenna design supports integration with independent sensors for physiological monitoring. This expandable antenna platform offers a scalable solution for powering and communicating with deep IMDs, enabling precision vascular medicine applications.

8:40 A Wearable 3D-Printed Embroidered Antenna for Wireless Powering of Deep Medical Implants

Dinesh R. Gawade (Tyndall National Institute, Ireland); Brendan Callaghan (TYNDALL NATIONAL INSTITUTE, Ireland); Weifu Liao, Abubaker Elobied and Gholamhosein Moloudian (Tyndall National Institute, Ireland); Sanjeev Kumar (Tyndall National Institute, Ireland & University College Cork, Ireland); Brendan O'Flynn (Tyndall National Institude, Ireland); Daniel O'Hare (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland)

This paper presents an embroidered wearable transmit antenna for wireless powering to deeply implanted medical devices. In conventional embroidered antennas, the textile is used as the substrate. However, in a wearable scenario, bending of the textile due to body motion can leads to resonance detuning and reducing radiation efficiency, thereby decreasing WPT efficiency. To address this, a 3D-printed, biocompatible-dielectric is proposed as the substrate. The radiating patch and ground plane are embroidered onto cotton fabric using conductive yarn and bonded to the substrate. Furthermore, to enhance radiation efficiency, a fractal-based defected-ground-structure is investigated. The Antenna EM simulation and measurement results is in close agreement and the antenna exhibits a -10 dB impedance bandwidth of 340 MHz (30.9% fractional). Furthermore, EM simulations using the Ansys Human-Body-Model show 17.6% radiation efficiency at 1.1 GHz. Finally, compared with a classical patch, the proposed antenna shows~ 5× improvement in E-Field radiation into to deep-body.

9:00 Optimal Frequency of Shallow-Implanted Antennas for Brain-Machine Interfaces

Mingxiang Gao (ETH Zurich, Switzerland & IT'IS Foundation, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia); Cong Ding (EPFL, Switzerland); Myles Capstick (IT'IS Foundation, Switzerland); Mahsa Shoaran (EPFL); Niels Kuster (Foundation for Research on Information Technologies in Society, IT'IS Foundation, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

The optimal operating frequency of shallow-implanted antennas is critical for achieving efficient wireless communication in brain-machine interface (BMI) applications. This paper presents an analytical study of shallow-implanted antennas using planar body models, with closed-form expressions that characterize the dependence of maximum radiation gain on implantation depth, surrounding tissue properties, operating frequency, and implant dimensions. The analysis reveals that shallow implants benefit from reduced propagation losses at higher frequencies while mitigating excessive near-field losses at lower frequencies, thereby favoring operation in several gigahertz range. Numerical simulations using an anatomical head model validate the analytical predictions, confirming that higher-frequency bands, such as those employed in implantable impulse-radio ultra-wideband (IR-UWB) devices for intracranial neural sensing, improve the implant's radiation performance while simultaneously enabling high-data-rate communication. These findings provide practical design guidance for shallow brain implants and support the advancement of next-generation, high-performance wireless BMI systems.

9:20 An AI-Driven Wearable Antenna System for American Sign Language Transcription

Zaynab Attoun, Jana Salameh, Pia Saade, Rami Mezher, Georgio Abou Jaoude, Joseph Costantine and Youssef Tawk (American University of Beirut, Lebanon)

This paper introduces a flexible, wearable slotted patch antenna integrated into a glove for real-time American Sign Language (ASL) transcription. The antenna, fabricated on a Polyethylene Terephthalate (PET) substrate and operating from 500 MHz to 3 GHz, incorporates circular copper traces on the fingertips. Hand gestures dynamically modify the antenna's surface current distribution and reflection coefficient ($|S_{11}|$), which are captured via a Bluetooth-enabled mini-VNA. A sequential neural network processes the $|S_{11}|$ signatures, achieving an ASL-to-English translation accuracy of 88.2%. The translated words are displayed through a mobile application with text, image, and audio outputs. Experimental results confirm the feasibility of this low-cost, flexible system for accurate, real-time gesture recognition and communication.

Thursday, April 23 8:00 - 9:40

CS32a Electromagnetic Information Theory 1

T08 Fundamental research and emerging technologies/processes / Convened Session / Propagation
Chairs: Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)), Mats Gustafsson (Lund University, Sweden)

Room: The Hague

8:00 Information Theory for Photonic Inference: Objectives, Constraints, and Image Formation

Owen D. Miller and Lukas Kienesberger (Yale University, USA); Zeyu Kuang (TU Wien, USA)

As photonic scatterers are increasingly designed as inputs to information-extraction (or inference) systems, ``end-to-end'' optimization has become a powerful tool for joint design of the front-end photonics and back-end algorithms. Yet this process can be opaque, leaving unclear why designs emerge as optimal or what the fundamental limits might be. Here we describe two information-theoretic objectives for modeling the photonic front-end. "Generalized focusing," in which incoherent sources should be scattered to localized receivers, emerges as a key optimal-design principle. Moreover, these objectives can replace the end-to-end approach that requires large amounts of unbiased data, while exhibiting equivalently strong performance.

8:20 Characterization of the Maximum Number of Independent Links from a Phased Array Prototype

Riccardo Ozzola (Delft University of Technology, The Netherlands); Cesare Tadolini (TU Delft, The Netherlands); Roderick Giosevan Tapia Barroso (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Ulrik Imberg (Huawei Technologies, Sweden AB, Sweden); Daniele Cavallo and Andrea Neto (Delft University of Technology, The Netherlands)

In this work, we review the concept of the observable field and describe how it can be used to set an upper bound on the performance of multi-beam antenna arrays. The concept of the observable field is linked with the maximum gain achievable by an antenna, given space constraints, and provides a benchmark to determine the maximum number of independent space channels in a massive multiple-input multiple-output (MIMO) scenario. This theory is then applied to assess the maximum number of independent links generated by a wideband and wide-angle scanning phased array designed for mobile communications.

8:40 Near-Field Communication Degrees of Freedom in Canonical Geometries

Mats Gustafsson (Lund University, Sweden)
The number of degrees of freedom (NDoF) serves as a key measure of the capacity and spatial richness of wireless communication systems. While NDoF can be numerically evaluated for arbitrary regions and propagation environments, analytical formulations offer deeper physical insight. In this work, we extend recent asymptotic NDoF expressions, originally derived for free-space conditions, to more complex environments, including ground planes, corners, and waveguides.

9:00 Analysis of Field Information Distribution in Space: A Framework for Electromagnetic Signal and Information Theory

Marco Donald Migliore (University of Cassino, Italy); Marco Di Renzo (Paris-Saclay University, France)
This paper builds on fundamental relationships between deterministic and stochastic approaches to propose a novel strategy for analyzing how spatial information is distributed around transmitting antennas, based on the analysis of mutual information of the field in different points of the space.

9:20 On the Diminishing Return of Spatial Decorrelation for MIMO System in the Presence of User Pairing

Simin Song (Xi'an Jiaotong University, China); Jianchuan Wei (Xian Jiaotong University, China); Xiaoming Chen (Xi'an Jiaotong University, China)
This paper investigates the interaction between the electromagnetic domain and the digital domain for enhancing multiple-input multiple-output (MIMO) performance. In our previous work, we proposed a phase-correcting-element (PCE)-based decorrelation technique implemented in the electromagnetic domain to improve channel capacity. Here, we integrate two user pairing algorithms (cosine similarity-based and sumrate maximization greedy scheduling) into the MIMO system to select low-correlated user equipment (UE) sets in the digital domain for MIMO capacity improvement. Although both methods independently enhance channel capacity, their combined gains are sub-additive. After optimal user pairing reduces interuser correlation, the marginal capacity gain attributable to PCEs decreases from 36% to just 3%. These results highlight a practical trade-off in balancing electromagnetic and digital optimization strategies in MIMO system design.

Thursday, April 23 8:00 - 9:40

CS34a From Complex Simulations to Functional Antennas: Solving Challenges for Space Applications 1

TO3 Aerospace, space and non-terrestrial networks / Convened Session / Propagation
Chairs: Cecilia Cappellin (TICRA, Denmark), Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

Room: Rome

8:00 Preliminary Antenna Design of the VISAR Instrument for VERITAS

Paolo Focardi (Jet Propulsion Laboratory, USA & California Institute of Technology, USA); Gaurangi Gupta (NASA Jet Propulsion Laboratory, Caltech, USA); Sara Manafi (JPL, USA); Jacqueline C. Chen (NASA Jet Propulsion Laboratory, USA)
The preliminary design of the VISAR instrument antenna for VERITAS and some of its early trades are presented in this paper. The overall architecture of the instrument is presented with its major components. The preliminary design of the antenna elements is also presented along with the major trades currently under consideration. Very challenging stability requirements are imposed on this instrument and the plans in place to meet these requirements are also discussed.

8:20 Reflectarray Antenna Product for CubeSat Missions in Low Earth Orbit

Nelson Fonseca and Gautier Mazingue (Anywaves, France); Louis Mangenot (ANYWAVES, France); Maxime Romier (Anywaves, France); Nicolas Capet (ANYWAVES FRANCE, France)
This paper discusses the outcome of recent activities at Anywaves aiming at the development of a reflectarray antenna product for space missions using NanoSats. These missions are particularly well suited for this product, when high antenna gain is required and limited volume is available for stowage. In an effort to industrialize the concept, a generic product definition is retained, which is suitable for operating frequencies ranging from X-band up to Ka-band, and possibly above. A patent pending panel design has been developed, providing stable RF and mechanical properties over typical low Earth orbit environmental conditions. It anticipated unit cell design evolutions, aiming at improving the overall antenna response, and specifically the synthesized co- and cross-polarized radiation patterns. Numerical results at Ka-band are reported here, indicating promising tuning capability at unit cell level. These design evolutions remain compatible with the generic product definition, following a design for manufacturing and assembly approach.

8:40 Design and Optimization of Phased Arrays for Beam Scanning Using Full-Wave Analysis and Active S-Parameters

Pasquale Giuseppe Nicolaci, Mark Whale, Edoardo Baldazzi, Erik Jørgensen and Min Zhou (TICRA, Denmark)
Accurate modeling and optimization of phased arrays are important for achieving desired beam scanning and impedance matching in modern antenna systems. This paper presents a full-wave analysis and optimization framework implemented in TICRA's ARRAY software, combining a Fast Direct Solver (FDS) with domain decomposition for efficient simulations of large finite arrays. Two representative cases are analyzed: an open-ended ridged waveguide array and a multilayer dielectric patch array. Comparisons between approximate and full-wave models demonstrate the limitations of conventional analytical approaches and the benefits of directly incorporating active scattering parameters into the full-wave optimization. The results highlight how simultaneous optimization of beamforming and active reflection coefficients enables improved far-field pattern control and reduced mismatch losses, providing an effective workflow for end-to-end phased array design.

9:00 Array Fed Reflector Active Antennas for Hummingsat

Antoine R. Calleau (SWISSto12 SA, Switzerland); Francesco Leone, Ivan Herrero, Miguel Bustamante, Stefano Sirci and Eduardo Fernandez (Swissto12 SA, Switzerland); Tomislav Debogovic (SWISSto12 SA, Switzerland); James Beluot (Thales AVS-MIS, Switzerland); Renan LeGall (Thales AVS-MIS, France); Esteban Menargues (SWISSto12, Switzerland)
SWISSto12 is developing active antennas for future HummingSat programs. These developments include both AFR and DRA antennas in X-, Ku- and Ka-band, all of them optimized to fit in HummingSat power and mass limits. This paper focuses on the developments carried out in the project ARAMIS, which focuses on TX critical technologies, and where SWISSto12 is prime contractor and Thales AVS-MIS is subcontractor.

9:20 All-Metal Connected-Element Arrays for LEO Orbits in Ka-Band

Carlos Vazquez-Sogorb (Thales Alenia Space, Italy); Roger Montoya-Roca (Thales Alenia Space, Consiglio Nazionale Delle Ricerche and Politecnico di Torino, Italy); Fabio Paonessa (Consiglio Nazionale Delle Ricerche (CNR-IEIIT), Italy); Giuseppe Addamo (Cnr-Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni, Italy); Oscar Peverini (IEIIT-CNR, Italy); Davide Maiarelli (Thales Alenia Space, Italy); Giovanni Gasparro (THALES ALENIA SPACE ITALIA, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

This paper presents a compact six-ridged hexagonal waveguide aperture with integrated grooves, developed for Ka-band transmit array applications within the framework of next-generation non-terrestrial networks. The proposed design combines sixfold geometric symmetry with a continuous groove structure to enhance polarization stability, reduce inter-element coupling, and maintain broadband impedance matching over wide scanning angles. The aperture operates efficiently across the 17.7-20.2 GHz band, achieving reflection and coupling levels below -10 dB, scan loss under 3 dB up to 50°, and cross-polarization discrimination above 15 dB up to 60°. A seven-element cluster implementation validates the element's robustness and wide-angle performance. Results confirm the suitability of the proposed aperture for compact, high-efficiency Ka-band phased arrays in satellite communication payloads

Thursday, April 23 8:00 - 9:40

CS39a Fundamental challenges and novel methodologies in the next-generation computational electromagnetics 1

TO7 Electromagnetic modelling and simulation tools / Convened Session / Electromagnetics
Chairs: Zhen Peng (University of Illinois at Urbana-Champaign, USA), Francesca Vipiana (Politecnico di Torino, Italy)

Room: Madrid

8:00 Electromagnetic Modeling with Hybrid Multilevel Fast Multipole Inhomogeneous Plane Wave Algorithms for Planar Multilayered Media

Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Propagating plane-wave representations are the basis of the high-frequency multilevel fast multipole method (MLFMM) for homogeneous space problems, while mixed (propagating) inhomogeneous plane-wave representations are more suitable for electromagnetic modeling with presence of multilayered planar media. Thus, hybrid approaches are discussed which combine the MLFMM appropriately with mixed inhomogeneous plane-wave representations. The inhomogeneous plane waves are extrapolated from the propagating plane wave expansions in terms of spherical harmonics of the sources and observers. They are only used to take care of the multilayered medium contributions. The inhomogeneous plane waves are translated on a fixed level of the octtree, since they do not need any buffer boxes. The hybrid algorithm is demonstrated for inverse source solutions related to antenna measurements and for field computations from given sources.

8:20 The Impact of Line Integrals in Full-Wave Modeling of Coax-Fed Antennas

Jean Cavillot (Université Catholique de Louvain (UCL), Belgium); Christophe Craeye (Université Catholique de Louvain, Belgium)

Special attention is required when applying the MoM to coaxial-fed printed antennas. First, the junction between vertical and horizontal conductors must be carefully considered. In this paper, we realize this transition thanks to broken rooftops which have the merit of being elementary basis functions, thus allowing a fine representation of the feeder structure. In this case, an additional line of charge distributions appear due to the difference between scalar potentials associated to vertical and horizontal conductors. The impact of these lines of charges is studied in this paper. Second, the feeding technique needs to be carefully selected. Here, we compare the accuracy of the deltagap excitation to the one based on an impressed magnetic frill of current. The importance of both the line of charges and the technique of excitation is highlighted by confronting our results against the ones obtained from the CST software.

8:40 A Fast Direct Solver for Electrodynamic Problems with Wideband Nested Equivalence Source Approximation

Yuhan Zuo (Nanjing University of Science and Technology, China); Mengmeng Li (Nanjing University of Science and Technology & Communication Engineering, China); Dazhi Ding (Nanjing University of Science and Technology, China)

We propose a fast direct solver with wideband nested equivalence source approximation (WNESA) for analyzing electrodynamic problems. Compared with previous works of NESA, equivalences for each group are distributed into different directions to ensure the accuracy of compressions at higher levels for low rank matrices. To factorize the far couplings in the system matrix, elimination matrices considering all cluster basis in all directions are introduced to each group. Then, an LU factorization is performed to factorize the near couplings. This process is recursively performed from the lowest leaf level to the highest root level. The inverse of the system matrix can be obtained by the intermediate matrices arising from the factorization process. Numerical results verify the accuracy of our proposed method.

9:00 Efficient BIE-Based Shape Optimization for the Design of mm-Wave Lenses

Jacob Linden (University of Chicago, USA); Felipe Vico (Universidad Politécnica de Valencia, Spain); Jeremy Hoskins (University of Chicago, USA); Manas Rachh (Indian Institute of Technology Bombay, India)

In this work, we present a 2D boundary integral equation (BIE) approach for designing homogeneous lenses in the mm-wave regime via shape optimization. The cost function for the lens design problem is minimized using a gradient- based optimization approach, and analytically available shape derivatives are computed efficiently using the precomputed solver for evaluating the cost function. These lenses tend to have sharp corners, which require particular care due to the singular nature of solutions in their vicinity. We use the recursively compressed inverse preconditioning (RCIP) algorithm, which is further ac- celerated by interpolating the entries of the preconditioner in the opening angle of the corner. Using this approach, we find two novel lens designs, and compare their performance to the plano-convex lens and the Fresnel lens.

9:20 Integral Equations with Metasurface Boundary Conditions

Elizabeth Bleszynski (Monopole Resesarch, USA); Marek Bleszynski (Monopole Resaearch, USA); Thomas Jaroszewicz (Monopole Research, USA)

We construct a coupled set of integral equations for thin metamaterial sheets based on non-local, derivative boundary conditions. Such integral equations are applicable to metasurfaces of infinite size, consisting of uniformly distributed elements, as well as finite size metasurface sheets with boundary, having a discontinuity in the material properties. We present complete expressions for matrix elements the obtained integral equations by using the Galerking method with conventional Rao Wilton Glisson basis functions. We discuss representative applications of our approach for thin planar sheet problems.

Thursday, April 23 8:00 - 9:40

CS40a Approaches for Electromagnetic Dosimetry and Human Body Interaction in Life Sciences 1

T06 Biomedical and health / Convened Session / Propagation
Chairs: Marta Cavagnaro (Sapienza University of Rome, Italy), Kemal Sumser (Eindhoven University of Technology, The Netherlands)

Room: Prague

8:00 Experimental Performance Assessment of Substrate-Free Epidermal RFID UHF Antenna

Adina B. Barba (University of Rome Tor Vergata, Italy & Radio6ense Srl, Italy); Alessio Mostaccio and Gaetano Marrocco (University of Rome Tor Vergata, Italy); Rasha Bayomi, Sunghoon Lee and Takao Someya (RIKEN, Japan); Cecilia Occhiuzzi (University of Roma Tor Vergata, Italy)
Epidermal electronics are attracting increasing interest as body-integrated platforms for wireless monitoring and physiological sensing. A key challenge lies in developing antennas that are thin, breathable, and efficient when directly in contact with the skin. Recent advances in substrate-free ultra-high-frequency (UHF) radio frequency identification (RFID) epidermal antennas based on gold nanomesh conductors has opened promising avenues for ultra-thin, breathable, and biocompatible wireless devices. This work presents the first experimental validation of a tattoo-like UHF RFID antenna realized with gold nanomesh technology. After the experimental validation of the material's sheet resistance, a loop epidermal antenna, fabricated from gold nanomesh and inductively coupled to an exciter hosting an RFID IC, was realized and applied to a stratified human phantom. Measured results closely matched simulations, with deviations under 2.5dB. Compared to a bulk-gold reference, the G-nm antenna showed only 3dB lower realized gain, confirming its suitability for efficient epidermal wireless communication.

8:20 Robotized SAR-Based Quality Assurance Procedures for Characterizing Hyperthermia Applicators for Clinical and Preclinical Use

Remko Zweije, Petra Kok and Johannes Crezee (Academic Medical Center / University of Amsterdam, The Netherlands)
A robotized quality assurance (QA) procedure is presented for characterizing radiative radio-frequent (RF) and microwave (MW) applicators for therapeutic hyperthermia. The method uses E-field measurements for achieving relative specific absorption rate (SAR) applicator characterization and can be used for a wide variety of hyperthermia devices including MW systems for small animal models, superficial MW antennas, loco-regional phased arrays of RF and MW antennas. The methodology yields 2D and 3D SAR distributions with high spatial resolution and permits a rapid workflow suitable for routine clinical use as well as for academic research. The workflow is comparable to the dosimetry characterization procedures of linear accelerators used in radiotherapy.

8:40 Reflectivity-Based Skin Phantom for Far- and near-Field Testing at 60 GHz

Rossella Rizzo (University of Rennes, France & University of Naples, Italy); Giuseppe Ruello (Università di Napoli Federico II, Italy); Maxim Zhadobov (University of RENNES 1, France); Giulia Sacco (IETR CNRS, France)
This paper presents the validation of a flexible solid phantom specifically designed for millimeter-wave (mmW) body-centric applications. The phantom consists of a silicone-carbon composite backed by an electrotextile layer and emulates the reflection properties of human skin around 60 GHz. Its performance is demonstrated through two complementary tests: far-field measurements, and near-field simulations with a leaky-wave antenna (LWA) operating in direct contact with the phantom. The results confirm its accuracy and reproducibility for both electromagnetic (EM) and mechanical interactions in realistic mmW scenarios.

9:00 A Numerical Analysis of the Relation Between Electromagnetic and Thermal Dose Parameters in Quality Assurance Procedures for Superficial Hyperthermia

Marco Di Cristofano and Marta Cavagnaro (Sapienza University of Rome, Italy)
Oncological radiative hyperthermia (HT) is a therapy aimed at heating the tumour using electromagnetic (EM) fields. The synergic application of HT and radio/chemotherapy improves the outcome of these cancer therapies. Superficial HT is applied to tumours up to 3 - 4 cm depth. Typical working frequencies are 434 MHz and 915 MHz. Quality assurance (QA) protocols from the European Society for Hyperthermic Oncology (ESHO) recommend using multilayer tissue-equivalent phantoms to validate HT devices. The current guidelines propose the evaluation of thermal dose parameters for QA procedures. This work presents a numerical study simulating the application of a commercial superficial HT antenna on the multilayer phantom, investigating the relation between electromagnetic and thermal dose parameters. The results aim to support and refine QA procedures for superficial hyperthermia treatments, in order to consider the feasibility of both EM and thermal measurements for the validation of HT devices.

9:20 Preliminary Characterisation of a Distorted Transmission Line for Forearm Phantom Permittivity Measurement

Xiaoru Liu (Trinity College Dublin, Ireland); Adam Narbudowicz (Technical University of Denmark, Denmark); Declan O'Loughlin (Trinity College Dublin, Ireland)
Good hydration can be important both for general health and for patients in clinical setting to avoid disease and speed recovery. Microwave-based hydration measurement techniques have many advantages as a measurement modality as microwave propagation is sensitive to the water content of biological tissue. In this work, a distorted transmission line sensor is investigated as a possible measurement tool for the average electrical properties of the forearm. The sensor was characterised and validated using homogeneous phantoms with a range of electrical properties similar to biological tissues. The measured and simulated S-parameters exhibited consistent trends, with distinguishable responses among different phantom compositions. The transmission coefficient magnitude decreased by about 3 dB as the relative permittivity decreased from 50 to 16 near 1.18 GHz. The findings in this paper are an initial validation of the proposed distorted transmission line sensor for measuring the average properties of arm phantoms non-invasively.

Thursday, April 23 8:00 - 9:40

CS52a AMTA Convened Session - Emerging Measurement Techniques for 5G and Beyond - 10th Anniversary Sessi...

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O'Neil (ETS-Lindgren, USA)

Room: Copenhagen

8:00 Numerical Analysis of Antenna Measurements Using Industrial Robots

Vince Rodriguez (NSI-MI Technologies, USA & University of Mississippi, USA); Mark Ingerson (NSI-MI AMETEK, USA); Gwenael Dun (NSI-MI Technologies, France); Esra Celenk (NSI-MI Technologies, USA)

Recent work by the authors [1,2] has concentrated on the effects of robotic arms on the probe illumination as well as on the proper absorber treatment and where that treatment may be necessary. In this paper the authors look at the potential effect of the robot arm on the antenna under test (AUT). Numerical models are used to estimate a potential effect for a low directivity antenna, such as a dipole and for a medium directivity antenna. The medium directivity antenna used in the simulations is a standard gain horn. Simulations are done using an open-ended waveguide as the probe and then the simulation is repeated with the robotic arm supporting the probe. The goal of the simulations is to see any potential effects from the presence of the arm in proximity to the AUT on the measured near field.

8:20 A Novel Quantitative Methodology for Assessing Radio Base Station PIM Performance with over-the-Air Environment

Queenie Zhang, Xiang Yue and Lei Deng (Ericsson AB, Sweden); Xiaoying Jiang (Ericsson (China) Communications Co. Ltd, China); Noor Choudhury and Ingolf Meier (Ericsson AB, Sweden); Nezahat Gunenc (Ericsson Antenna Technology Germany GmbH, Germany); Kabir Kathuria, Lennart Blixt, Anders Karlsson and Bo Xu (Ericsson AB, Sweden)

Passive intermodulation (PIM) is known to impair network performance. This paper specifically considers testing of dynamic over-the-air (OTA) conditions. Generally, external PIM sources tend to be weak and lack repeatability, rendering quantitative OTA testing unreliable. A novel high-level PIM source combining conductive alloy wire (FeCrAl) using a Yagi antenna configuration is shown to exhibit sufficiently strong nonlinear characteristics to generate consistent and reliably repeatable intermodulation distortion. Tests are carried out in a low-PIM anechoic chamber, calibrated for far-field operation. Emulation of both static and dynamic PIM behaviors are supported, enabling directionally controlled and repeatable interference for realistic evaluation of radio base station (RBS) performance. This methodology fills a critical testing gap and provides a reliable foundation for OTA-based PIM diagnostics and mitigation strategy development.

8:40 Drone-Based Shipborne Antenna Radiation Pattern Measurement System

Simon Henault and Kathia Levis (Defence Research and Development Canada, Canada)

A new low-cost and lightweight drone payload that can measure radiation patterns of antennas operating on navy ships is demonstrated. To mitigate issues related to the possible movement of the ship during measurements, a low-cost shipborne system that monitors and records the ship position and attitude was developed. This system automatically adapts the drone flight path in real time based on the movement of the ship, thereby optimizing the flight time and ensuring that the main beam of the shipborne antenna is measured. Onshore experiments of this system are presented with and without simulated ship movement, and drone-based radiation pattern measurements are compared with indoor measurements performed in a spherical near-field facility.

9:00 Robotic Measurement System for Next Generation Communications

Jae-Yong Kwon and Sangsu Lee (Korea Research Institute of Standards and Science, Korea (South))

This paper presents a robotic antenna measurement system developed by the Korea Research Institute of Standards and Science (KRISS) for next-generation communication applications in the millimeter-wave and sub-terahertz frequency ranges. The system, named KR-MANMS (KRISS Robotic Millimeter-wave Antenna Measurement System), achieves spatial measurement precision on the order of several tens of micrometers and supports a wide range of metrology-grade measurements. Using a W-band standard gain horn antenna with a traceable gain, the system's measurement capability was validated through comparison, demonstrating agreement with NIST results. The flexibility of the multi-robot configuration enables diverse applications, including phased-array calibration, metalens characterization, and human-body channel blockage studies up to 750 GHz. These results confirm that the KR-MANMS provides a highly accurate and versatile platform for future antenna and channel metrology in 6G and beyond wireless systems.

9:20 Radiation Pattern Measurement for an Oscillator-Integrated W-Band Millimetre-Wave Antenna Using a Dual Receiving Configuration with an Antenna-Coupled Electrode Electro-Optic Modulator

Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan); Michitaka Ameya (AIST, Japan); Masahiro Sato and Masatoshi Onizawa (SEIKOH GIKEN, Japan); Hiroshi Murata (Mie University, Japan); Masanobu Hirose (7G aa Co., Ltd., Japan)

We have newly developed a millimeter-wave vector measurement system for an oscillator-integrated antenna, consisting of a two-mixer receiving system and an EO sensor for the 80 GHz band. This system consists of two mixers: one for measuring the antenna pattern using a horn antenna, and one for measuring the phase reference using the EO sensor. In this paper, we show the developed W-band millimeter-wave measurement system configuration. In addition, we show the measurement results for a FMCW radar for the 80 GHz band.

Thursday, April 23 8:00 - 9:40

CS54a Recent Progress in Channel Modeling and Its Applications for mmWave and THz Bands 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Pekka Kyösti (Keysight Technologies & University of Oulu, Finland), Yejian Lyu (Shanghai Jiao Tong University, China)

Room: Gothenburg

8:00 Channel Measurements and Characterization for Terahertz Communications in Industrial Environments

Siyuan Shao and Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain)); Pekka Kyösti (Keysight

Technologies & University of Oulu, Finland) The Industrial Internet of Things (IIoT) enables seamless connectivity between machines, sensors, and control systems, supporting automation, efficiency, and intelligence in modern factories. Terahertz (THz) communications provide ultra-high bandwidth and fine spatial resolution required to meet these demanding needs. However, THz radio propagation in metal-rich industrial environments remains largely unknown. This paper presents comprehensive bidirectional channel measurements at 318 GHz conducted in representative industrial environments, i.e., a factory hall and a warehouse. The collected data are used for modeling and analysis to extract key channel characteristics, including the number of multipath components (MPCs), path loss, delay spread, and angular spread. The findings offer valuable insights for the practical deployment of THz communications in IoT scenarios.

8:20 Concept and Evaluation of a Multi-User RIS Model for Indoor Scenarios at 300 GHz

Georg Jensen (TU Braunschweig, Germany); Christoph Herold (Technische Universität Braunschweig, Germany); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Thomas Kürner (Technische Universität Braunschweig, Germany); Ashwin Sathish Kumar (BITS Pilani, India)

This paper proposes a model for multi-user reconfigurable intelligent surfaces (RISs) in Terahertz (THz) communication systems. THz frequencies enable extremely high data rates but rely heavily on line-of-sight (LOS) connections and are highly susceptible to shadowing. This is common in industrial environments due to the presence of large machinery. A gradient-based optimization algorithm was used to optimize the radar cross section (RCS) of RIS for all users. Simulations in a 3D indoor environment using a conventional 3D ray-tracer demonstrate significantly improved coverage compared to classic single-user RIS configurations.

8:40 Fast Fading Measurements and Analysis on Sub-THz Frequencies

Joonas Kokkoniemi and Veikko Hovinen (University of Oulu, Finland)

Recent research papers have shown that different types of environments support large numbers of simultaneous communication paths on the sub-THz frequencies (100-300 GHz). These enable both non-line of sight communications and multiple-input multiple-output communications. However, very few papers consider how these paths evolve due to motion. That is, how does the signal fade at very high frequencies. In this paper we show some initial results on fast fading measurements and analysis in laboratory environment. Our results show that fast fading can be ultra-fast at sub-THz depending on the system setup. The channel states can change significantly even within a few wavelengths. This causes a lot of challenges for mobile sub-THz applications and will require frequent channel state updates or smart equalization strategies to maintain high quality of service.

9:00 Angle-Resolved Industrial Channel Characterization at 3.9 and 28 GHz

Mathis Schmieder (Fraunhofer Heinrich Hertz Institute, Germany); Alper Schultze (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Germany); Ramez Askar (Fraunhofer HHI, Germany); Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany); Wilhelm Keusgen (Technische Universität Berlin, Germany); Taro Eichler (Rohde & Schwarz, Germany)

This paper reports on angle-resolved radio channel measurements at 3.9 GHz and 28 GHz in a densely packed industrial production hall. The channel was captured at 87 positions with 3D distances between 13 m and 87 m and the power, delay, and angular characteristics were evaluated. The measurements compared with the 3GPP TR 38.901 Indoor Factory model and frequency-dependent models for path loss, K-factor, RMS delay spread, and azimuth spread of arrival were extracted. Parameter cross-correlations were calculated and evaluated. The results show that the K-factor and delay spread are almost frequency independent and that the angle spread increases with frequency.

9:20 Comparative Analysis of Channel Spatial Non-Stationarity Between FR3 and THz Bands

Mengdi Ma, Pan Tang, Huixin Xu and Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Kun Yang (Zhejiang Ocean University, China); Tao Jiang (China Mobile Research Institute, China)

The sixth-generation (6G) communication systems is driving into higher frequency bands, such as FR3 and terahertz (THz), leveraging massive MIMO and extremely large-scale MIMO (XL-MIMO) technologies to achieve ultra-high capacity communications. However, higher frequencies and larger array scales complicate spatial non-stationarity (SnS), challenging channel modeling. Existing studies are mostly limited to single bands or dissimilar measurement conditions, complicating fair SnS comparison across bands. To address this, we conducted channel measurements for FR3 and THz Band under a unified measurement framework, using uniform linear arrays (ULA) of identical length, and analyzed SnS characteristics along the array dimension in terms of pathloss (PL) and delay spread (DS). Results show that the fluctuation amplitudes of PL and DS across the array follow normal distributions in both bands, but the parameters in THz are more random, indicating stronger SnS. This study provides an empirical basis for channel modeling and optimization in XL-MIMO systems.

Thursday, April 23 8:00 - 9:40

EO3a Computational and Numerical Techniques: Integral Equations 1

T07 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Vydehi Nitta (University of Siena, Italy), Balasubramaniam Shanker (The Ohio State University, USA)

Room: Firenze

8:00 Generalized Entire Domain Basis Functions for Modulated Metasurface Analysis

Federico Giusti, Stefano Maci and Enrica Martini (University of Siena, Italy)

This paper presents a general approach for defining two entire-domain basis functions to be used in the Method of Moments (MoM) for modulated metasurfaces (MTSs) analysis consisting of arbitrarily shaped metallic elements. Basis functions are derived from the eigenmode analysis of a single unit cell under a quasi-static assumption and expressed as linear combinations of Rao-Wilton-Glisson functions. These two functions accurately capture current behavior across all propagation directions in the first Brillouin zone, reducing the MoM formulation to only two unknowns per element. Functions derived for a reference element can be scaled and rotated to adapt to all elements of a modulated MTS. To demonstrate their effectiveness, they are used to develop a periodic spectral MoM for characterizing the dispersion of 2D periodic MTSs with minimal unknowns. The method is applied to double-anchor patch MTSs on a grounded dielectric slab, with results validated against CST Eigenmode Solver, showing excellent agreement.

8:20 Inverse Approach for the Design of 1-D Sparse-Array Metasurface Antennas

Jonathan Dessy (UCLouvain, Belgium); Modeste Bodehou (Université d'Abomey-Calavi, Benin); Christophe Craeye (Université Catholique de Louvain, Belgium)

This paper addresses the design of 1-D sparse-array metasurface (MTS) antennas based on the solution of the electric field integral equation (EFIE). Sparse-array MTSs are regular antenna arrays in which each array cell corresponds to a modulated MTS, with a cell size larger than half wavelength. The overall structure can be described as a periodic modulated surface impedance with periodicity corresponding to the array cell size. In this paper, the planar MTS is modulated along one direction and is invariant along the other direction. The structure infinitely extends along both directions. Given the imposed periodicity, and assuming linear phase shift excitation along the array, the analysis and the design can be restricted to that of a single cell. Harmonic basis functions are proposed for the current and impedance expansion. An inverse solution of the EFIE is formulated to derive the surface impedance from a desired flat-top embedded element pattern (EEP).

8:40 Analytical Analysis of Novel Calderon Preconditioners for Scattering from Perfect Electrically Conducting Objects

Chad Moorman (The Ohio State University, USA); Daniel Dault (Air Force Research Laboratory, USA); Balasubramaniam Shanker (The Ohio State University, USA)

Preconditioning the electric field integral equation (EFIE) is an age-old problem which has seen great progress in recent years. Analytic preconditioning operators for the EFIE have been developed and evaluated for their efficacy, and numerical prescriptions exist. Here, we discuss a different and novel analytic prescription of a preconditioner for the EFIE that is simpler to implement and yet provides an operator that is of the form of an identity plus a compact operator. As a result, this is well conditioned and immune to low-frequency or dense mesh breakdown. In this paper, we demonstrate these properties analytically for a sphere.

9:00 Efficient Evaluation of 4-D Reaction Integrals in the Spatial-Domain MoM Analysis of Multilayered Periodic Structures with RWG Basis Functions Defined in a Uniform Triangular Mesh

Francisco J. Hidalgo (Universidad de Sevilla, Spain); Rafael R. Boix (University of Seville, Spain); Miguel Camacho (Universidad de Sevilla, Spain); Juan Córcoles (Universidad Politécnica de Madrid, Spain)

This paper proposes a method to reduce the number of numerical integrals from four to two in the computation of the reaction integrals for the spatial-domain Method of Moments (MoM) analysis of multilayered periodic structures with Rao-Wilton-Glisson (RWG) basis functions defined in a uniform triangular mesh. The results obtained indicate important CPU time savings can be attained when the novel approach is used. These results have been validated by comparison with both previously published results and commercial software results for the unit cell of periodic frequency selective surfaces.

Thursday, April 23 8:00 - 9:40

P11a Sensing, Localisation and ISAC - Part II 1

T05 Positioning, localization, identification & tracking / / Propagation
Chairs: Marina Barbiroli (University of Bologna, Italy & DEI, Italy), Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

Room: Dusseldorf

8:00 Modeling and Simulation of Macroplastic Detection Using Microwave Scattering over Dynamic Sea Surfaces

Mario Vala (University of Lisbon, Portugal & Instituto de Telecomunicações, Portugal); Tomás Soares da Costa (ULisboa - Instituto Superior Técnico & Instituto Telecomunicações, Portugal); Joao M Felicio (Instituto Superior Técnico, Portugal & Instituto Telecomunicacoes, Portugal); Nuno R. Leonor (Polytechnic Institute of Leiria (IPL) & Instituto de Telecomunicações (IT), Leiria, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Paulo Marques (ISEL-IT Lisboa, Portugal); Antonio A Moreira (IST - University of Lisbon & Instituto de Telecomunicações/ Lisbon, Portugal); Sergio Matos (Iscte-IUL / Instituto de Telecommunicações, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca (Anywaves, France); Peter de Maagt (European Space Agency, The Netherlands)

This work presents a simulation framework for studying the detectability of floating macroplastics over water surfaces using electromagnetic modeling. The simulation tool combines sea surface generation, object tracking, and post-processing to replicate realistic conditions in a controlled environment. Implemented in CST Microwave Studio with the Asymptotic Solver, it reproduces scattering behavior for varying wave heights and target configurations. Simulated results show good agreement with measurements performed at Deltares and demonstrate consistent detection trends. The framework enables the exploration of complex and dynamic scenarios beyond experimental limitations, providing a foundation for future remote sensing system optimization.

8:20 A New Inversion Framework for Soil Moisture Estimation Using GNSS Reflectometry

Luigi Di Michele (Università Degli Studi di Cagliari, Italy); Marco Murgia (University of Cagliari, Italy); Nazzareno Pierdicca (Uni Roma1, Italy); Ferdinando Nunziata (Sapienza Università di Roma, Italy); Hamed Izadgoshasb (Università Degli Studi di Roma La Sapienza, Italy); Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)

Soil moisture (SM) is a key aspect of the water cycle, agriculture, and climate modeling, yet conventional sensors face trade-offs in coverage, revisit, and all-weather capability. GNSS Reflectometry (GNSS-R) overcomes these limitations by passively exploiting navigation-signal reflections. This study presents a semi-empirical inversion framework using collocated CYGNSS and SMAP data, where the objective function matches measured and modeled effective reflectivities to estimate SM. Preliminary results show consistent retrieval of surface-scattering and vegetation parameters, providing a foundation for future HydroGNSS applications with enhanced vegetation and roughness corrections for global, all-weather SM monitoring.

8:40 Bio-Inspired Parallel Information Processing in Electronic Skins Using OFDM Principles

Oleksandr Malyuskin (Queen's University Belfast, United Kingdom (Great Britain))

Large-area electronic skins (e-skins) capable of high spatial resolution require simultaneous data acquisition from hundreds or thousands of sensing pixels, posing severe challenges in wiring complexity, data bandwidth, and digital signal processing (DSP) capacity. In biological systems, such massive parallelisation is achieved efficiently through the hierarchical structure of the central and peripheral nervous systems. However, direct implementation of this mechanism in conventional DSP hardware is constrained by limited interconnect scalability and processing power. This work introduces a novel approach that combines bio-inspired e-skin wiring architectures with orthogonal frequency-division multiplexing (OFDM)-based information access, a technique widely used in wireless communications. The proposed framework enables simultaneous, low-latency access to large arrays of tactile sensing pixels through spectral-domain multiplexing, significantly reducing interconnect overhead while maintaining high data throughput. This hybrid bio- and communication-inspired concept paves the way toward scalable, high-performance large-area e-skin systems.

9:00 Impact of RIS Size on Machine Learning-Enabled Beam Sweeping for User Localization

Md Tarek Hassan (Centre for Wireless Innovation, Queen's University Belfast, United Kingdom (Great Britain)); Dmitry E Zelenchuk (Queen's University of Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)); Irina Munina (Trinity College Dublin, Ireland)

This paper investigates machine learning (ML)-assisted user localization in reconfigurable intelligent surface (RIS)-aided millimeter-wave (mmWave) systems using minimal-beam probing. A system model with three RIS apertures ((10\times10), (20\times20), and (30\times30)) is considered, where the surface sequentially applies a limited set of probing beams and the user equipment (UE) records the corresponding received power. Using ML regression, we train the regressor models to predict the UE positions from these measurements and update the RIS phase distribution for efficient beam forming towards the intended UE. Simulations show that small RIS arrays achieve accurate predictions with limited probing, whereas larger apertures need deeper sweeps to curb outliers. The best approach attains mean errors below (1.5,\text{dB}) for a (10\times10) aperture and improves further on larger apertures with six probing beams. This underscores a trade-off among RIS size, probing overhead, and ML method choice for efficient RIS-aided localization in future sixth-generation (6G) wireless networks.

9:20 UAV-Mounted Multichannel Subsurface Imaging System: Impact of Flight Path Deviations and Positioning Errors

María García Fernández, Guillermo Alvarez Narciandi, Yuri Alvarez-Lopez and Fernando Las-Heras (University of Oviedo, Spain)
Array-based ground penetrating radar (GPR) imaging systems mounted on board unmanned aerial vehicles (UAV) are a promising solution to increase the scanning throughput in conventional GPR imaging systems. To retrieve high-resolution images from the subsurface, these systems can employ synthetic aperture radar (SAR) techniques. However, to coherently combine the radar measurements acquired with such systems, a high positioning accuracy is crucial. This work analyzes the impact of flight path deviations and positioning errors on the performance of an array-based UAV-mounted GPR system operating from 1 to 3 GHz. For this purpose, both phenomena have been modelled stochastically as a random walk and as independent Gaussian distributions for each dimension of movement, respectively. Results show that even moderate flight path deviations do not affect significantly the quality of the imaging results. Furthermore, the imaging quality is also maintained for positioning errors with standard deviations up to 2 cm per dimension.

Thursday, April 23 10:10 - 11:50

A02b Active RIS Design and Synthesis 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Manuel Arrebola (Universidad Politécnica de Madrid, Spain), Wilhelm Keusgen (Technische Universität Berlin, Germany)

Room: London

10:10 A 400-Element 28 GHz 2 Bit RIS with Scalable Control Architecture

Francisco G. Vilarinho and Sofia Inacio (INESC TEC, Portugal); Nuno Paulino (INESC TEC, Portugal & University of Porto, Portugal); Luis M. Pessoa (INESC TEC & Faculty of Engineering, University of Porto, Portugal)
The increasing adoption of millimeter-wave (mmWave) frequencies in 5G and 6G networks introduces significant challenges in propagation, including severe path loss and blockage sensitivity. Reconfigurable Intelligent Surfaces (RISs) appeared as a promising technology to mitigate these effects by manipulating incident electromagnetic waves to extend coverage and enhance signal quality.
This paper presents the design and characterization of a 28 GHz 2-bit RIS tile, comprising a 20 × 20 array of reflective unit cells. Both PIN diode and varactor diode designs were evaluated through simulations. Consequently, a modular control architecture was developed, enabling scalable biasing through a daisy-chained SPI network of DACs and multiplexers. The proposed RIS design achieves four discrete phase states covering 270° with reflection losses below 2 dB. Beamsteering simulations demonstrate the RIS behaviour in steering angles up to 60°. The proposed RIS provides a foundation for a scalable, low-power option suitable for FR2 band.

10:30 Preliminary Analysis of Multiple Collaborative RIS for near-Field mmWave Communications: Performance and Challenges

Álvaro F. Vaquero (Universidad de Oviedo, Spain); Álvaro Pendás-Recondo and Sergio Menéndez Feito (University of Oviedo, Spain); Manuel Arrebola (Universidad Politécnica de Madrid, Spain)
This work analyzes the deployment of multiple spatially distributed Reconfigurable Intelligent Surfaces (RIS) to enhance near-field mmWave coverage while reducing individual RIS size. A physics-based near-field model is derived that represents each RIS as an equivalent radiating source within a common coordinate system, enabling direct superposition of their contributions at arbitrary observation points. Using this framework, we compare the radiated coverage produced by a single electrically large RIS with that produced by several smaller, cooperative RISs. Numerical results indicate that collaborative RIS configurations can achieve coverage areas comparable to those obtained with a single large RIS. Additionally, link-level performance is evaluated, showing comparable communication performance in both scenarios. These results demonstrate the potential of cooperative deployments to reduce the size of individual surfaces, thereby lowering power consumption, circuitry complexity, and cost, without sacrificing near-field mmWave communication performance.

10:50 Evaluation of a near-Field Fed RIS-Based Centimeter-Wave Beamforming System

Dennis Osterland (Technische Universitaet Berlin, Germany); Felix-Christopher Lutz (Technische Universität Berlin, Germany); Andreas Benzin (Technische Universitaet Berlin, Germany); Wilhelm Keusgen and Giuseppe Caire (Technische Universität Berlin, Germany)
In this research, a Near-field Fed Reflective Intelligent Surface (NFED-RIS) System is evaluated in far-field as an alternative beamforming system for centimeter-wave operation. A dual-polarized 8x8 RIS within the centimeter-wave band was designed for this study. The NFED-RIS system, which is based on these two patch arrays, will be experimentally evaluated in a far-field anechoic chamber. The RIS is considered a passive reflect array antenna that can be utilized as an analog beamformer. This is achieved by dynamically reflecting incident waves from the Feeder, resulting in steerable beams in the far-field. The parabolic phase distribution of the impinging wave from the Feeder at the RIS needs to be compensated in such a way that the reflected wave has a uniform phase distribution which forms the basis to shape beams in the far-field. The NFED-RIS system demonstrates remarkable performance as an alternative cost-efficient beamforming system in comparison to conventional phased arrays.

11:10 How Many Bits are Required for RIS Designs Without Far-Field Quantization Lobe?

Ruiqi Wang, Yiming Yang and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)
Reconfigurable Intelligent Surface (RIS) designs with 1-bit phase resolution often suffer from strong quantization lobes in the far field, which significantly degrade wireless communication performance. This work investigates the minimum phase resolution required for RIS to eliminate far-field quantization lobe. The analysis demonstrates that 2-bit phase discretization offers an optimal balance between performance and hardware complexity. A practical 2-bit RIS unit cell is designed, and a 20 by 20 array configuration is implemented to evaluate its performance. The quantization-lobe suppression capability is validated through full-wave radar cross-section (RCS) simulations under plane-wave illumination for the entire RIS array. The fabricated prototype is further characterized experimentally, achieving a -13.1 dB quantization-lobe level compared to -0.8 dB for its 1-bit counterpart, confirming both the analytical and full-wave simulation results.

11:30 Reflective Intelligent Surface Unit Cell Based on Memristor for Mid-Band 5G Communications

Mohamed Elsaid Ghatas (INESC TEC, Campus Da FEUP, Portugal & University of Porto, Portugal); Carina C. Silva (Institute for Systems and Computer Engineering Technology and Science-INESC TEC, Portugal); Tomas Mingates, Jonas Deuermeier and Asal Kiazadeh (NOVA University Lisbon, Portugal); Vitor Grade Tavares (INESC TEC/Faculty of Engineering, University of Porto, Portugal); Luis M. Pessoa (INESC TEC & Faculty of Engineering, University of Porto, Portugal)

As communication systems have advanced, increasing energy efficiency and reducing power consumption have become key trends in 5G and beyond. This has driven improvements in Reconfigurable Intelligent Surfaces (RISs). This paper explores how memristors can improve the performance of reconfigurable intelligent surfaces (RIS). It focuses on designing and simulating RIS unit cells that are structurally compatible with memristors to support their integration. Additionally, it addresses the reducing power consumption and developing low-voltage (1-2 V) electrical circuits that can reliably control memristors. The proposed RIS unit cell operates based on the mutual coupling approach. The simulation study of the proposed unit cell uses the actual memristor performance measurements of a memristor to model the reconfigurability within the RIS-UC. The simulated RIS-UC achieves a reflection loss of less than 1.3 dB across a 0.67 GHz bandwidth at a central frequency of 6 GHz.

Thursday, April 23 10:10 - 11:50

A06b Antenna Array Theory and Synthesis 2

TO7 Electromagnetic modelling and simulation tools / / Antennas
Chairs: Do-Hoon Kwon (University of Massachusetts Amherst, USA), Paolo Rocca (University of Trento & ELEDIA Research Center, Italy)

Room: Paris

10:10 Planar Array Beampattern Synthesis with Sidelobe Level Reduction Under Dynamic Range Constraints via Convex Optimization

Roger Montoya-Roca (Thales Alenia Space, Consiglio Nazionale Delle Ricerche and Politecnico di Torino, Italy); Carlos Vazquez-Sogorb, Alessandro Calcaterra and Davide Maiarelli (Thales Alenia Space, Italy); Giovanni Gasparro (THALES ALENIA SPACE ITALIA, Italy)

In this paper, a convex optimization algorithm with a dynamic range constraint is proposed for the very first time to synthesize the excitation coefficients of periodic planar arrays, aiming to achieve very low sidelobe levels across the entire visible region. The study considers square lattices with both square and concentric ring apertures, as well as triangular lattices with hexagonal apertures. The results demonstrate that the triangular lattice provides better performance in terms of sidelobe level, squint error, tapering efficiency, and half-power beamwidth compared to the square lattice configuration.

10:30 Constrained Antenna Design Using a Null-Space Inverse Source Formulation

Lorenzo Poli (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento & ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

A general synthesis framework for radiating systems is presented, enabling the generation of prescribed power patterns while simultaneously satisfying additional geometrical and/or electrical constraints on the sources. The proposed method relies on an inverse-source (IS) formulation that exploits the null-space of the radiation operator, turning the intrinsic non-uniqueness of the IS problem into a design advantage. As a case study, the proposed approach is customized and validated on a phased array configuration, where the non-radiating components are optimized under electrical constraints, such as limits on the excitation dynamic range ratio, demonstrating its effectiveness and versatility.

10:50 Properties of Circularly Polarised Spherical Retrodirective Array

George A Travers (Queen's University Belfast, United Kingdom (Great Britain)); Mengran Zhao (Queen's University Belfast, United Kingdom (Great Britain) & Xi'an Jiaotong University, China); Vincent Fusco and Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain))

In this paper we provide the first ever discussion of the characteristics of a spherical retrodirective array. The array is populated with planar circularly polarised (CP) microstrip patch antennas. The proposed retrodirective array offers significant potential to realise orientation-agnostic, continuous, self-steering coverage in both hemispheres. In this work we use numerical full-wave simulations to determine for the first time the main radiation characteristics, far-field and axial ratio, of a spherical CP retrodirective array operating at 2.45 GHz and describe their dependence on both orientation and aperture cross section. Beam patterns with main lobe directivity of 16-16.6 dBi, comparable in directivity to a planar array of the same aperture, that preserve the handedness of the pilot signal, are presented in all cardinal directions.

11:10 Modeling of Cylindrical Connected Arrays

Roderick Giosevan Tapia Barroso and Daniele Cavallo (Delft University of Technology, The Netherlands)

We present an analysis of cylindrical connected array unit cells. Closed-form expressions of the active input impedance are derived for both connected slots and dipoles in the presence of a backing reflector. The dipoles and slots can be oriented along the circumferential or longitudinal directions in cylindrical coordinates. A study on the variation of impedance as a function of the radius of curvature is presented. To solve issues related to numerical instabilities of Bessel-type functions, a method is proposed to approximate the higher-order mode component of the cylindrical array impedance with the one of the equivalent planar geometry. This approach is justified by the observation that the reactive energy associated with the unit cell is weakly dependent on the curvature.

11:30 Self-Focusing Receive Beamforming Through Multi-Carrier Information Embedding

Celin Mary Veluthedath Jacob (Heriot-Watt University, Edinburgh, United Kingdom (Great Britain)); Jayakrishnan Methapettyparambu Purushothama, Yishan Wang, Jiayu Hou and Yuan Ding (Heriot-Watt University, United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain))

A self-focusing receive beamforming scheme is proposed in this paper. It is achieved by embedding information in the intermedium frequency (IF) components produced by non-linearly mixing the incoming multi-tone radio frequency (RF) signals. This receiver structure enjoys low-cost, low-power consumption, and, more importantly, the receive beamforming gain irrespective of the angles of arrival (AoAs) of the incoming RF signals. The theoretical derivations are presented, and are further validated through circuits and system simulations. The results highlight the self-focusing capability of the proposed receive architecture, offering a promising solution for the resource-constrained Internet of Things (IoT) applications.

Thursday, April 23 10:10 - 11:50

A09b Antennas and Probes for Measurements 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Adrian Bekasiewicz (Gdansk University of Technology, Poland), Marianna Ivashina (Chalmers University of Technology, Sweden)

Room: Barcelona

10:10 Subarray Design and Measurement Techniques for THz Antenna-in-Package (AiP)

Dongjin Jung (Samsung Electronics, Korea (South) & Skyworks Solutions, USA); Taek Sun Kwon (Samsung Electronics, 34 Seongchon-gil, Seoul Korea, Korea (South)); Kyeongho Yeom, Kyungpil Jung, Jaekwang Kwon, Seunghun Kim, Sungjae Oh, Jungsik Kim and Seongkyun Kim (Samsung Electronics, Korea (South))
This paper presents 4×1 subarray design and measurement for terahertz (THz) antenna-in-package (AiP) operating from 136 to 148 GHz. Four dual-fed and dual-polarized proximity-coupled stacked patch antennas with 0.45λ0 element spacing are tied together through two independent 4-way power dividers. The 4-way power dividers for corporate feeding of each antenna elements are vertically implemented in an 8-layer PCB laminate for their size reduction. Therefore, the 4-way power dividers can be integrated within the 4×1 subarray size of 1.8λ0×0.45λ0. The designed 4×1 subarray, serving as a unit cell array of THz AiP, is measured on our custom-built probe station. To obtain accurate antenna and feeding network performance, RF probe measurement is performed on bump pads placed on the bottom metal layer of the subarray. The measured radiation patterns showed good agreement to the simulation results. The designed 4×1 subarray achieved a maximum realized gain of 8.15 dBi at 144 GHz.

10:30 Didactic Methodology for the Characterization of Lego-Based Antennas Using USRPs

Hassaan Ahmad Sadiq (University of Luxembourg, Luxembourg & Signal Communication and Processing (SIGCOM), Luxembourg); Juan Andres Vásquez Peralvo and Symeon Chatzinotas (University of Luxembourg, Luxembourg)
This paper presents a didactic methodology for demonstrating antenna principles using modular LEGO-based prototypes and software-defined radio platforms. Three representative scenarios at 2.46 GHz were investigated: directional-to-directional, directional-to-non-directional, and non-directional-to-non-directional antenna pairings. Link performance was evaluated in terms of received power and signal-to-noise ratio (SNR), highlighting the distinct behaviors of each case. Directional pairs showed strong alignment sensitivity, mixed configurations revealed reduced efficiency, and non-directional pairs exhibited wider coverage with lower gain. Beyond technical findings, the modular approach emphasizes accessibility and engagement, enabling students to visualize radiation concepts and experiment with antenna behavior in real time. By combining antenna design and assembly with the communication and programming features of SDR platforms, students develop a deeper understanding of antenna physics and communication theory. The results confirm that LEGO-based antenna kits offer a low-cost, effective educational tool fostering hands-on learning of wireless communication fundamentals.

10:50 Low-Cost and Rapid Manufacturing of High-Precision Reflectors for Compact Antenna Test Ranges Based on Flexible Molds

Mingming Wang, Yahui Qi, Yexuan Gao and Dongsheng Li (Beihang University, China)
To address the inability of existing reflector manufacturing processes to meet the "high precision and stability" requirements of large-scale compact antenna test ranges (CATR), this paper proposes high-precision reflector panel forming process based on "flexible mold, vacuum negative pressure, honeycomb sandwich structure". This process is suitable for low-cost and rapid manufacturing of high-precision reflectors. It uses height-adjustable reusable nail dies to form an envelope surface, replacing fixed molds to reduce manufacturing costs and shorten production cycle. The reflector with honeycomb sandwich has a stiffness of 11698N/mm, and its maximum thermal deformation is only 4.7um within the temperature range of 11℃~31℃. This process has been successfully applied in CATR with a 15m focal length, achieving a single-panel precision of 24.7um and final reflector surface precision of 29um after assembling.

11:10 A Wirelessly Tunable Load for 2.45 GHz Antenna Array Characterization via Embedded Element Pattern Measurements

Oliver Bennett M.R. Bennett, Maria Kovaleva, Oscar Longworth-Baker and Avalon Shaw (Curtin University, Australia); Philipp del Hougne (Univ Rennes, France)
Backscatter modulation is at the heart of a diverse range of techniques for antenna array characterization. Realizations of the required tunable load(s) are typically tethered to external controllers, creating cabling clutter, motion constraints, and electromagnetic perturbations. Here, we prototype an untethered, wirelessly controlled, four-state tunable load module designed for operation at 2.45 GHz. The module (W-PCB) integrates an RF switch that is commanded via a lightweight publish-subscribe wireless link, enabling rapid, repeatable re-configuration without harnesses. We built eight W-PCB modules and characterized their input impedances; then, we used them to characterize a 9-element patch array using a backscatter modulation technique based on embedded element patterns. We envision future generations of our wirelessly tunable load to play an important role in improving the scalability and practicality of backscatter-based antenna array characterization.

11:30 Compact Sub-Ku-Band Vivaldi Radiator for Antenna Test Measurements in Non-Anechoic Conditions

Adrian Bekasiewicz and Rafal Lech (Gdansk University of Technology, Poland); Yingsong Li (Anhui University, China)
Experimental validation of prototype radiators in non-anechoic environments is often performed using rudimentary positioning equipment that is unsuitable for heavy, conventional reference antennas (RAs). In this work, a compact (80 × 79 mm2) spline-parameterized antipodal Vivaldi antenna dedicated to work as RA for far-field tests in uncontrolled conditions is considered. The structure geometry is obtained as a result of a bi-stage design process. It is characterized by a wideband operation with average gain and front-to-back ratio of 6.1 dB and 8.1 dB within the frequency range of 2 GHz to 18 GHz, as well as high polarization purity (axial ratio above 20 dB for most of the frequencies), which make it suitable for sub-Ku-band experiments. Benchmark of the antenna against structures from the literature and measurements of manufactured prototype are also provided.

Thursday, April 23 10:10 - 11:50

A26b On body and implantable antennas 2

T06 Biomedical and health / / Antennas
Chairs: Pai-Yen Chen (University of Illinois at Chicago, USA), Mahmoud Wagih (University of Glasgow, United Kingdom (Great Britain))

Room: Krakow

10:10 Improved Phase-Based Tissue Differentiation with Ingestible Antennas in Gastrointestinal Tract

Erdem Cil (University of Rennes 1, France); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France)

Due to the varying electromagnetic properties of the gastrointestinal tissues-stomach, small intestine, and large intestine-ingestible antennas encounter variations in their operational parameters as they advance through the gastrointestinal tract. Previous studies have shown that tracking variations in the phase of the reflection coefficient enables differentiation between the gastrointestinal tissues. This paper proposes an antenna optimization strategy to increase the phase differences obtained across different tissues to improve the differentiation capability. First, analytical equations are derived to relate the rate of phase change to the real and imaginary parts of the antenna input impedance, and these equations are interpreted in the context of the proposed methodology. Next, the improvement achieved with the strategy is verified through numerical simulations using a microstrip patch antenna. The results indicate that the phase differences can be significantly increased with the proposed strategy, thereby improving the phase-based differentiation capability for gastrointestinal tissues.

10:30 Design of a Flexible Antenna at 868 MHz for Relaying in-to-Out Body Communication

Yizhen Yang (Ghent University, Belgium & IMEC, Belgium); Gunter Vermeeren (Ghent University, Belgium); Wout Joseph (Ghent University/IMEC, Belgium)

A compact and flexible monopole antenna operating in the 868~MHz band is proposed for relaying signals from implanted devices through the human body. The antenna, fabricated on a thin polymer substrate, exhibits a measured fractional bandwidth of about 40% and stable resonance when placed on the abdominal surface. Simulations and measurements confirm good impedance matching and reliable radiation characteristics. Using an anatomically realistic human model, the relay reduces transmission loss by up to 34 dB compared to a direct internal-to-external link, while the specific absorption rate (SAR) at 14~dBm input power remains well below international safety limits. The proposed design provides a practical and safe solution for improving in-to-out body communication links.

10:50 Compact Flexible Meta-Antenna on PDMS Substrate for Wearable Applications

Yingrui Lu and Zijian Dong (Xi'an Jiaotong Liverpool University, China); Mark Leach (Xi'an Jiaotong-Liverpool University, China); Pengfei Song (Xi'an Jiaotong Liverpool University, China); Yi Huang (University of Liverpool, United Kingdom (Great Britain)); Zhenzhen Jiang (Xi'an Jiaotong-Liverpool University, China & University of Liverpool, United Kingdom (Great Britain))

A compact dual-band meta-antenna operating in the 2.45- and 5.8-GHz Industrial, Scientific, and Medical bands is proposed for wearable applications. Polydimethylsiloxane (PDMS) is employed as a flexible substrate, while conductive fabric is used for both radiating and ground layers to enhance practicality and comfort in wearable integration. The performance of the design was experimentally validated, including assessments of bending effects on reflection coefficient and radiation patterns. Measured bandwidths of 2.9% and 22.2% were achieved in the 2.45- and 5.8-GHz bands, respectively, with corresponding measured gains of 3.8 dBi and 6.7 dBi. The maximum specific absorption rate (SAR) of 0.464 W/kg and 0.217 W/kg at 2.45- and 5.8-GHz respectively, are well below the international safety limits. The proposed design demonstrates stable performance, high flexibility, and strong potential for wearable applications.

11:10 Screen-Printed and Embroidered Cotton Textile-Based Antennas for Energy Harvesting and Wearable IoT Applications

Abubaker Elobied and Gholamhosein Moloudian (Tyndall National Institute, Ireland); Sanjeev Kumar (Tyndall National Institute, Ireland & University College Cork, Ireland); R Murray (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland); Brendan O'Flynn (Tyndall National Institude, Ireland)

This paper presents the methodology, design considerations, and low-impact fabrication processes for developing cotton textile-based antennas for sustainable energy harvesting applications. The proposed antennas were fabricated using screen-printing and embroidery techniques. Silver nanoparticle ink and conductive thread were used as conductive materials for screen-printing and embroidery respectively, while a cotton textile served as the dielectric substrate. Measurement results reveal that the screen-printed antenna achieved a resonant frequency of 2.43 GHz, a bandwidth of 90 MHz, and a gain of 2.8 dBi, while the embroidered counterpart demonstrated a slightly higher center frequency of 2.44 GHz, a bandwidth of 100 MHz, and a lower gain of 1.3 dBi. These results show close agreement with the simulations, confirming that the proposed antennas are suitable for use in RF energy-harvesting systems and wearable IoT systems designed for the 2.45 GHz ISM band.

11:30 Wearable Radar Array for Electronic Travel Aid Applications at 24 GHz

Lara Prendes and María Elena de Cos Gómez (Universidad de Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)

A compact lightweight wearable dielectric resonator antenna (DRA) array, suitable for electronic travel aid (ETA) applications in the 24.05 - 24.25 GHz frequency band, for short to medium range detection, is presented. The combination of the wearable DRA array with an artificial magnetic conductor (AMC) electromagnetically isolates the antenna from the human body, while preserving the radiation properties. The resulting device size is 36.5 × 32.78 × 4.732 mm3 and provides a wide bandwidth (14.30%), a gain of 8.7 dBi, a radiation efficiency of 98% and a front-to-back ratio (FTBR) greater than 20 dB in the entire operational band.

Thursday, April 23 10:10 - 11:50

CS32b Electromagnetic Information Theory 2

T08 Fundamental research and emerging technologies/processes / Convened Session / Propagation
Chairs: Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)), Mats Gustafsson (Lund University, Sweden)

Room: The Hague

10:10 DoF-Bounded Average Maximum Directivity for MIMO Arrays

Federico Puggelli (Huawei Technologies Italia Srl); Yanwen Chen (University of Siena, Italy); Bruno Biscontini (Huawei Technologies Italia Srl); Stefano Maci (University of Siena, Italy)

Radio Access Networks moving toward sixth generation (6G) systems rely on Base Transceiver Station (BTS) antennas implementing Multiple Input Multiple Output (MIMO). Such arrays require models and bounds that explicitly account for mutual coupling, mismatch, polarization, and spatial selectivity at the cell level. Building on a recent framework that linked the average maximum gain (AMG) to a correlation matrix of embedded element patterns (EEPs), the present study introduce the spillover Correlation Matrix (SCM), which captures the angular leakage of radiated power outside the communication cell. The trace of this matrix yields the average maximum Directivity (AMD) within the cell, which establishes a bound of AMG. Moreover, an upper bound to AMD is derived in terms of the electromagnetic degrees of freedom (DoF), thus providing geometry-dependent physical limits for any antenna inside the same box. These findings supply actionable guidance for array design and evaluation in future BTS deployments.

10:30 Electromagnetic Information Theory in Phase Space: From Emission to Communication

Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Stephen Creagh (University of Nottingham, United Kingdom (Great Britain))

We discuss the Wigner-Weyl phase-space formulation of electromagnetic wave propagation as a framework for analysing eigenvalue spectra and degrees of freedom (DoF), in wireless communication between continuous surfaces. The approach, exploiting methods from quantum mechanics, enables counting of communication eigenmodes through semiclassical phase-space volumes and provides a physical link between geometry, signal correlation, and channel capacity. We discuss recent theoretical developments, highlighting connections between Slepian eigenvalue theory, Weyl laws, and electromagnetic information theory. We outline key mathematical results, numerical methodologies based on ray-dynamical propagation, and their applications to holographic and reconfigurable intelligent surfaces.

10:50 Efficient and Accurate EM-Based Design of Large Dynamic Scattering Arrays

Francesca Benassi, Simone Trovarello and Diego Masotti (University of Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Davide Dardari (University of Bologna & CNIT, Italy)

This work presents an efficient approach that combines full-wave electromagnetic (EM) simulation with radiation and circuit theory to accurately and rapidly predict the reconfiguration capabilities of large Dynamic Scattering Arrays (DSAs). By optimizing the port terminations of the array elements, the method enables fast evaluation of various beaming configurations. Once the array architecture is defined, in terms of elements topology, materials, and spacing, a single full-wave EM simulation, using normalized sources for each element port, is performed. This simulation captures both the near-field coupling among elements and their embedded far-field behavior, which are then used to efficiently optimize the port terminations of the array elements for any desired configuration, including single or multi-port excitations for simultaneous multi-beam operation. Preliminary numerical results are presented for a 127-element dipole array, with 126 arranged concentrically around the central one. DSA radiation performance, for both single- and multi-port excitations, is analyzed.

11:10 A Unified Degrees of Freedom Model Connecting Signal Propagation and Spatial Division Multiplexing

Guohao Liu (Tsinghua University, China); Jun Luo, Lin Peng and Min Fang (ZTE Corporation, China); Zhi Sun (Tsinghua University, China)

Electromagnetic (EM) wave propagation can be represented by vector spherical harmonics, the number of which corresponds to the orthogonal information streams the field can support. However, effective spatial division multiplexing (SDM) requires a mapping between the high-dimensional space spanned by these propagation bases, the antenna-array excitation space, and the receiver's physical domain. In this paper, we present a unified spherical-harmonic framework to define reactive, radiating near-field, and far-field regions and quantify each region's EM degrees of freedom (DoF). We design the array manifold to elucidate the mapping from Radio Frequency ports to propagation-channel bases. Then, we propose an energy-allocation strategy over these bases to achieve an optimal mapping from the EM information space to the receiver's physical space. Simulations demonstrate that the SDM DoF realized in the receiver's physical domain closely matches the EM-space DoF, validating the proposed scheme's effectiveness in exploiting the SDM resources inherent in EM wave propagation.

11:30 Electromagnetic Information Theory: Deterministic and Stochastic Signal Space Formulations

Massimo Franceschetti (University of California at San Diego, USA)

We outline a signal-space approach to characterize the number of uncorrelated channels available for communication via electromagnetic fields, paralleling the classical degrees of freedom theory originally developed in a deterministic setting. This framework bridges the stochastic models commonly used in communication theory with a deterministic perspective grounded in Maxwell's equations.

Thursday, April 23 10:10 - 11:50

CS34b From Complex Simulations to Functional Antennas: Solving Challenges for Space Applications 2

T03 Aerospace, space and non-terrestrial networks / Convened Session / Propagation
Chairs: Cecilia Cappellin (TICRA, Denmark), Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

Room: Rome

10:10 Reconfigurable Luneburg Lens Reflector Based on Quasi-Conformal Transformation Optics

Do-Kyun Kim and Cheongmin Lee (Yonsei University, Korea (South)); Ic-Pyo Hong (Kongju National University, Korea (South)); Jong-Gwan Yook (Yonsei University, Korea (South))

This paper proposes a novel reconfigurable retroreflector that combines a quasi-conformal transformation optics (QCTO)-flattened Luneburg lens with a reconfigurable circuit analog (CA) absorber. Using the QCTO approach, the conventional spherical Luneburg lens is transformed into a planar compatible configuration that preserves wide-angle focusing and allows integration on planar surfaces. At the focal region, a matching layer is constructed to reduce impedance discontinuity, and the continuous permittivity profile is discretized into ten layers using k-means clustering for practical fabrication. A reconfigurable CA absorber placed at the focal plane allows selective switching between reflective and absorptive states. The performance of the proposed structure is validated through full-wave electromagnetic (EM) simulations. Radar cross section (RCS) characteristics are analyzed under both reflective and absorptive operation modes.

10:30 Theoretical Design of a Simultaneous S/X/Ka Feed System with Monopulse Tracking in All Receive Bands

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia); Robert Hoferer (Spacetime Machine Co, unknown)

The landscape of the SATCOM industry is changing due to the proliferation of satellites launched in LEO or MEO orbits, while the launch of GEO satellites has been vastly reduced in favor of multi-band, multi-orbit feed and antenna solutions. The design of a simultaneous S/X/Ka feed system with monopulse tracking in all receive bands is presented.

10:50 Optimal Frequency Reuse for Regular Multibeam Satellite Antennas

Francesco Lisi (Heriot-Watt University, United Kingdom (Great Britain)); Piero Angeletti (European Space Agency, The Netherlands); Joao Mota (Heriot-Watt University, United Kingdom (Great Britain)); Julien Maurin (Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

This paper addresses optimal frequency reuse in multibeam satellite systems featuring regular beam lattices, such as those employed in GEO, MEO, and LEO constellations. To maximize spectral efficiency while mitigating co-channel interference, the study formulates the resource assignment problem as an optimization over lattice substructures. We apply the maximum same-colour nearest-neighbour sublattice (MASCONDS) algorithm, a globally optimal method that identifies the sublattice partition maximizing the minimum co-channel distance for any lattice and reuse factor. Numerical analyses with a hexagonal lattice for a non-canonical reuse factor validate the approach using a GEO communication payload with a direct radiating array model operating in Ka-band. The MASCONDS solution consistently yields the highest carrier-to-interference ratio across all configurations. These results demonstrate the method's effectiveness for advanced satellite payloads constrained by digital processor port counts.

11:10 Design and Modelling of Polarizing FSS for SatCom

Ashifa Mohammed Musthafa (Eindhoven University of Technology & Antenna Company, The Netherlands); Elmine Meyer and Ulf Johannsen (Eindhoven University of Technology, The Netherlands); Diego Caratelli (The Antenna Company, The Netherlands)
The paper presents a single-layer transmit/reflect polarizing frequency-selective surface (FSS) polarizer radome for satellite communication (SatCom) applications. The proposed FSS comprises a novel cross-loop split-ring resonator (CL-SRR) unit cell structure. This design utilizes numerical techniques and a semi-analytical procedure based on equivalent circuit theory. Unlike the previously proposed polarizer FSS limited to linear-to-circular polarizing capability, this FSS also exhibits filtering capability by transmitting/reflecting in-band signals with low losses, both in reflect and transmit modes. The FSS effectively polarized the incoming linearly polarized waves to circular polarization in Ku-band frequencies (with axial ratio bandwidth higher than 0.5 GHz), a requirement for SatCom applications. Full-wave simulations of filtering and radiation properties are presented.

11:30 Thinned Arrays with Sectors for Next-Generation SatCom Systems

Margaux Pellet (European Space Agency - ESA-ESTEC, The Netherlands); Piero Angeletti (European Space Agency, The Netherlands); Carolina Tienda (ESA, ESTEC, Noordwijk, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)
Mitigating side lobe levels in the radiation pattern of a phased-array is critical for on-board telecommunication as unwanted lobes give rise to interference. Thinned arrays present a favourable solution, with a lower mass and manufacturing cost than their fully populated array counterpart, while reducing significantly the first side lobe level. An additional degree of freedom is introduced to reduce the thinning cost further: the p-fold strategy. Thinning is therefore applied at sector levels, lowering the number of radiating elements to process during the thinning stage.

Thursday, April 23 10:10 - 11:50

CS39b Fundamental challenges and novel methodologies in the next-generation computational electromagnetics 2

TO7 Electromagnetic modelling and simulation tools / Convened Session / Electromagnetics
Chairs: Zhen Peng (University of Illinois at Urbana-Champaign, USA), Francesca Vipiana (Politecnico di Torino, Italy)

Room: Madrid

10:10 Coupled Solution of Time-Domain Volume Integral and Hydrodynamic Equations for Analysis of Scattering from Nanostructures

Meruyert Khamitova, Hakan Bagci and Sebastian Celis Sierra (King Abdullah University of Science and Technology (KAUST), Saudi Arabia); Ran Zhao (University of Electronic Science and Technology of China (UESTC), Saudi Arabia)
The transient electromagnetic response of metallic nanostructures is analyzed using a time-domain volume electric field integral equation (VIE) solver coupled with the hydrodynamic equation (HDE). The HDE models the polarization current induced by free electrons in the metal in response to the driving electric field. The electric field and polarization current are expanded in space using Schaubert-Wilton-Glisson (SWG) basis functions and in time using shifted Lagrange polynomials. Galerkin testing in space and point matching in time yield a matrix system solved with a marching-on-in-time (MOT) scheme, providing the temporal evolution of the unknown expansion coefficients. The accuracy of the proposed MOT-based time-domain VIE--HDE solver is verified through numerical results.

10:30 ACA-Based Optimal Direction Selection for Sub-Nyquist Monostatic RCS Reconstruction

Víctor Martín (Universidad Rey Juan Carlos, Spain); Antonio Gomez-Rodriguez (EM3WORKS, Spain & Universidad de Extremadura, Spain); Fernando Obelleiro (University of Vigo, Spain); Jose M. Taboada (University of Extremadura, Spain); Luis Landesa (Universidad de Extremadura, Spain)
The efficient computation of monostatic radar cross section (MRCS) for electrically large targets requires minimizing the number of incident directions to be simulated while preserving accuracy. Building upon a previously developed interpolation reconstruction technique, this work introduces an Adaptive Cross Approximation (ACA)-based strategy to guide the optimal selection of excitation directions. In the proposed approach, ACA is employed to estimate the interpolation error associated with each subset of sampled directions. This local error estimation enables the adaptive identification of the next most informative incident direction, the one expected to yield the largest interpolation error, without the need to compute the error over the entire range of possible directions. Consequently, the method accelerates the reconstruction process while maintaining high accuracy. Numerical results demonstrate that this ACA-driven adaptive sampling scheme achieves near-optimal MRCS reconstruction with a substantially reduced number of method of moments solutions.

10:50 Studies on the MoM Matrix and Solution Accuracy with a Novel Test Integral Scheme

Víctor Martín (Universidad Rey Juan Carlos, Spain); Javier Rivero (Politecnico di Torino, Italy); Donald Wilton (University of Houston, USA); William Johnson (Private Consultant, USA); Francesca Vipiana (Politecnico di Torino, Italy)
Accurate and efficient evaluation of the double-surface reaction integrals remains a key challenge in the method of moments (MoM). This work focuses on the analysis and validation of a new quadrature scheme for the test integral, specifically designed to improve accuracy in near-singular configurations. The proposed method, based on the behavior of the vertex-function, achieves significantly higher precision than conventional Gaussian quadrature, while maintaining full compatibility with standard MoM implementations.

11:10 A Method-of-Moments MIMO Channel Model for Non-Line-of-Sight Scenarios

Yuyu Lu (King Abdullah University of Science and Technology (KAUST), Saudi Arabia); Ran Zhao (University of Electronic Science and Technology of China (UESTC), Saudi Arabia); Hakan Bagci (King Abdullah University of Science and Technology (KAUST), Saudi Arabia)
A multiple-input multiple-output (MIMO) channel model based on the method of moments (MoM) is proposed for analyzing non-line-of-sight (NLoS) scenarios involving perfect electrically conducting (PEC) scatterers. The model employs the dyadic Green's function and the electric field integral equation (EFIE) to accurately characterize electromagnetic wave propagation between transmit and receive antennas. The channel matrix is formulated through a system of linear equations using MoM and subsequently used to determine the effective degrees of freedom (EDOF). Numerical results confirm the accuracy of the proposed approach in computing the received electric field and demonstrate the influence of antenna count and aperture dimensions on the EDOF.

11:30 Fast Angular Sweep Monostatic Radar Cross Section Computation via Model Order Reduction

Noelia Naranjo and Valentin de la Rubia (Universidad Politecnica de Madrid, Spain)
The radar cross section (RCS) is a fundamental parameter in radar engineering, as it determines the detectability of a given target by a radar system. Increasing interest in very low observability (VLO) targets has arisen recently. As a result, especial effort is put in developing numerical tools to accurately predict the electromagnetic scattering from PEC objects. Integral equation methods are commonly used in this task. However, full-wave computation of the monostatic RCS at a single angle can be rather time-consuming, nevermind computing the RCS in a specific angular interval with a fine sampling. In fact, this is what is needed in industrial applications. A reduced order model for fast full-wave monostatic RCS evaluation is used to easily achieve fine details in the desired angular domain. An integral equation solver is used to get the electromagnetic scattering in non-penetrable objects. Several radar targets will show the possibilities of these approaches.

Thursday, April 23 10:10 - 11:50

CS40b Approaches for Electromagnetic Dosimetry and Human Body Interaction in Life Sciences 2

T06 Biomedical and health / Convened Session / Propagation
Chairs: Marta Cavagnaro (Sapienza University of Rome, Italy), Kemal Sumser (Eindhoven University of Technology, The Netherlands)

Room: Prague

10:10 Sensitivity Optimisation of Capacitive Pressure Sensors Through Geometrical Parameter Tuning

Muhammad Farooq (University of Galway, Ireland & Translational Medical Devices (TMD) Lab, Ireland); Icaro V Soares, Marcin J. Kraśny, Manavi Tejaswini, Mahtab. Vafaeefar, Ted Vaughan, Derek T. O Keeffe, Martin O Halloran and Adnan Elahi (University of Galway, Ireland)
Physiological pressure monitoring requires highly sensitive, conformable sensors for effective clinical diagnostics. Capacitive pressure sensors are selected for their stability and low power consumption; however, low sensitivity can limit the applications. In this work, we present a COMSOL simulation-based optimisation of a flexible capacitive sensor structure, specifically investigating the influence of the vacuum cavity thickness on overall performance. By varying the cavity from 200 um down to 40 um, we achieved a 5-fold increase in sensitivity for the 40 um cavity device compared to the thickest sensor iteration. This optimal configuration demonstrated a capacitance change exceeding 80% (from 1.53 pF to 2.76 pF) across a physiological range of 0 to 200 mmHg. Moreover, the optimised sensor maintains an ultrathin profile of only 100 um, making it suitable for biomedical and wearable applications.

10:30 3D Reconstruction of the Electric Field from Sparse Measurements for Faster Routine Clinical Hyperthermia Quality Assurance

Deovrat Phal (TU Eindhoven, The Netherlands); Kemal Sumser (Eindhoven University of Technology, The Netherlands); Michael Zeinoun (Sensius BV, The Netherlands); Sergio Curto (Erasmus University Medical Center, The Netherlands); Margarethus M. Paulides (Eindhoven University of Technology & Erasmus MC Rotterdam (Hon.), The Netherlands)
Routine quality assurance (QA) of hyperthermia (HT) applicators is time-consuming when full-volume electric-field (E-field) validation is required. Building on prior 2D compressed sensing (CS), we extend this approach to 3D volumetric reconstruction using a robotic scanning system and an isotropic EM probe. We compare 3D-CS, 2D-CS, and interpolation under 1%-40% of total measurements. Across the low-sampling regime (≤10%), 3D-CS yields the largest fidelity gains against 2D CS; Peak signal-to-noise (PSNR) increases by 4 to 6 dB and Structural Similarity index (SSIM) increases by 0.02 to 0.04, SSIM approaches unity by ≈15-20% sampling. Using only 3% of full measurements, the acquisition time is reduced from >8 hrs to ≈30 minutes while maintaining clinically relevant structure, confirmed by 50% isovolume contour agreement. Acceptable volumetric accuracy (ΔEFV ≤2.5%) was achieved using 3%-5% of total samples for 3D-CS. Our results support the integration of 3D CS into routine HT QA workflows.

10:50 Effect of MR Coil Integration on Heating Performance in Hyperthermia Breast Treatments

Niels J. Bijl (Einhoven University of Technology, The Netherlands); Alexandra D. de Boer, Ioannis Androulakis and Massimiliano Zanoli (Erasmus MC Cancer Institute, The Netherlands); Kemal Sumser (Eindhoven University of Technology, The Netherlands); Margarethus M. Paulides (Eindhoven University of Technology & Erasmus MC Rotterdam (Hon.), The Netherlands); Sergio Curto (Erasmus University Medical Center, The Netherlands)
Hyperthermia treatment (HT) involves heating target tissues to 39-44°C for 60 to 90 minutes, with the therapeutic efficacy being highly dependent on precise thermal control. This study explores the integration of magnetic resonance (MR) receive coils on a HT breast applicator to investigate the effect of the MR coils on the heating performance of the applicator. Through a combination of electromagnetic simulations and experimental validation, the feasibility and impact of this design were assessed. Using a Gamma analysis with 5mm distance-to-agreement and 5% dose-difference an acceptance of more than 95% was achieved, demonstrating that the coils had a minor effect on the heating performance of the HT applicator. The findings in this research underscore the feasibility of coil integration within a HT applicator as a means to improve imaging quality and thermal monitoring, contributing to the advancement of MR-guided hyperthermia techniques.

11:10 Is Pregnancy-Tissue Dielectric Accuracy Important for Fetal SAR at RF Band?

Kayvan Qolami (Politecnico di Milano, Italy & CNR - Istituto di Elettronica, Ingegneria dell'Informazione e Delle Telecomunicazioni (CNR-IEIIT), Italy); Silvia Gallucci (CNR Consiglio Nazionale Delle RIcerche, Italy); Marta Parazzini (CNR Consiglio Nazionale Delle Ricerche, Italy)
This study aims to assess radiofrequency (RF) exposure dosimetry in the human fetus. It analyzes the effect of variations in dielectric properties such as tissue conductivity and relative permittivity on electromagnetic energy absorption. A high-resolution anatomical model of a pregnant woman, including a detailed fetus, was exposed to a 700 MHz RF wave. The key pregnancy-related tissues examined for dielectric variability were the amniotic fluid and fetal skin, both of which significantly influence whole-body SAR (WBSAR) and peak localized SAR (pSAR1g). Results show that changes in the conductivity of both tissues have a substantial effect on SAR metrics, with the amniotic fluid having a dominant influence while variations in relative permittivity have minimal impact. Despite the significant fetal SAR variations due to the dielectric changes, all SAR values remain below ICNIRP safety limits.

11:30 Closing Gaps in Quality Assurance Procedures for Deep Hyperthermia Applicators

Mattia De Lazzari (Chalmers University of Technology, Sweden); Dario Rodrigues (University of Maryland School of Medicine, USA); Hana Dobšíček Trefná (Chalmers University of Technology, Sweden)
Quality assurance (QA) in hyperthermia (HT) is essential to ensure consistent and effective heating performance of clinical HT systems. To evaluate the heating capability of deep HT applicators, the new ESHO QA guidelines define quantitative metrics derived from temperature measurements in homogeneous phantoms. However, their implementation has revealed limitations related to thermal mapping accuracy and challenges in evaluating quality metrics from the available data.
This work introduces an improved QA framework addressing these gaps. A dedicated thermometry protocol was developed, including systematic calibration of the thermal mapping (TM) system and validation through standardized heating experiments benchmarked against electromagnetic-thermal simulations. Calibration reduced the mean deviation between experiments and simulations from 0.5°C to 0.2°C. A revised TEFV definition based on temperature profiles inflection points enables reliable estimation of this parameter, demonstrating robustness and easy integration into QA workflows.

Thursday, April 23 10:10 - 11:50

CS52b AMTA Convened Session - Emerging Measurement Techniques for 5G and Beyond - 10th Anniversary Session 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Measurements
Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O'Neil (ETS-Lindgren, USA)

Room: Copenhagen

10:10 A Demonstration of Azimuth-Swept Measurements of Cellular Resource Grid Spectrograms

Daniel Kuester, M. Keith Forsyth and Jordan Bernhardt (National Institute of Standards and Technology, USA); Joseph Mruk (MITRE, USA); Duncan A McGillivray (National Institute of Standards and Technology & National Advanced Spectrum and Communications Test Network, USA); Aric Sanders (NIST, USA); Adam Wunderlich (National Institute of Standards and Technology, USA); William F Young (The MITRE Corporation, USA)

A method for characterizing direction-dependent waveforms from deployed 5G-NR cellular networks is presented to support radio spectrum sharing analysis. The approach leverages a high-directivity fan beam antenna on a rotating mount to achieve azimuthal selectivity in spectrogram measurements of the cellular resource grid. We investigate two measurement scopes: 100-MHz channel bandwidth, and the narrower signal synchronization block (SSB). While spectrograms of the full channel exhibit significant temporal variability that complicate the analysis of fast measurements, power measured within the SSB is shown to be a comparatively stable. Comparisons between fan beams as well as a commercially available parabolic dish show that this SSB-based approach can rapidly identify the angular dependence of received power from base stations. The results are validated through a model incorporating calibrated gain patterns, confirming that an elevation-insensitive fan beam scan of SSB power levels is practical survey tool for field characterization of cellular networks.

10:30 Total Radiated Power Measurements for 3GPP 5G New Radio Conformance Testing Using Reverberation Chamber

Jerdvisanop Chakarothai (National Institute of Information and Communications Technology, Japan); Yunsong Gui (National Physical Laboratory (UK), United Kingdom (Great Britain)); Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain))

Over-the-air (OTA) conformance testing for multiple-input-multiple-output (MIMO) RF parametrics has been studied in 3GPP (Third Generation Partnership Project). However, conventional methods are costly, time-consuming and cumbersome due to the beam-steering capabilities of fifth-generation (5G) new radio (NR) systems. This paper presents a new cost-effective and time-efficient method for measuring the total radiated power (TRP) of 5G NR base stations (BS) using a reverberation chamber (RC). A testbed employing real 5G NR signals is designed to accurately characterize transmission between transmitting and receiving antennas inside the RC. Its validity is confirmed by comparing results with those from a conventional vector network analyzer (VNA). The testbed is then used to evaluate antenna efficiency via three-antenna method. Finally, TRP is derived for conformance testing, and the time-efficiency of the proposed method is demonstrated by comparing the total measurement time with the VNA-based approach.

10:50 Channel Validation for 3GPP Standardized FR1 Dynamic Channel Models with the Multi-Probe Anechoic Chamber

Xiaohang Yang (CAICT, China); Hao Sun (China Academy of Information and Telecommunications Technology, China); Xiaoyi Chen (CMCC, China); Xiang Zhang (China Academy of Information and Communications Technology, China); Wei Fan (SouthEast University, China)

Over-the-air (OTA) testing has been adopted as the feasible method for the performance evaluation of multi-input and multi-output (MIMO) devices in the standardization. To evaluate the device performance in a more realistic manner, the 3rd generation partnership project (3GPP) has started the study item on FR1 dynamic MIMO OTA testing. The dynamic channel models has been proposed with the consideration of time-varying channel parameters, i.e., angular, power, and delay profiles. This paper discusses the channel validation of 3GPP FR1 dynamic channel model, where a realistic validation campaign has been conducted within the multi-probe anechoic chamber. The validation results of dynamic channel models, including power delay profile (PDP), temporal correlation function (TCF), spatial correlation function (SCF), and path loss (PL), has been provided for the first time.

11:10 Over-the-Air Cold-Source Technique to Determine the Noise Figure of Integrated Antenna Systems

Naila Rubab and Roel X.F. Budé (Eindhoven University of Technology, The Netherlands); Antonius Johannes van den Biggelaar (ANTENNEX, The Netherlands)

Characterizing the noise-figure (NF) of systems having antennas integrated can only be achieved using an over- the-air (OTA) approach. This work applies the cold-source technique in an OTA configuration to estimate the NF of a device under test (DUT) consisting of a receiving antenna and a low- noise amplifier (LNA). The measurements are carried out in a reverberation chamber, providing a controlled and repeatable measurement environment. To validate this OTA technique, a reference is established by separately characterizing the LNA and the antenna using standard conducted measurement techniques, and subsequently combining the results. The RMS deviation between the reference and OTA method is 0.25 and 0.20 dB for the measured NF and gain, respectively. This agreement confirms the applicability of the cold-source technique for OTA noise-figure characterization of integrated antennas

11:30 A Reference Antenna for RF Spectrum Coexistence Analysis of Directional Systems

Joseph Mruk (MITRE, USA); M. Keith Forsyth and Benjamin L Moser (National Institute of Standards and Technology, USA); Joshua Gordon (US National Institute of Standards and Technology, USA)

RF spectrum resource allocations have increased due to commercial demand for wireless communications. Due to this increased demand, dynamic and AI native spectrum aware systems need data to tailor decision making to account for aggregate emissions. Efficient use of the spectrum is achieved by allowing both commercial and non-commercial operators to operate in collocated band allocations. In this paper, we introduce the concept of a reference antenna topology that emulates a receiver with a varying directional antenna pattern to measure aggregate emissions from commercial cellular deployments.

Thursday, April 23 10:10 - 11:50

CS54b Recent Progress in Channel Modeling and Its Applications for mmWave and THz Bands 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Pekka Kyösti (Keysight Technologies & University of Oulu, Finland), Yejian Lyu (Shanghai Jiao Tong University, China)

Room: Gothenburg

10:10 CM3FR: Enabling NLoS THz Links and Localization Through Material Classification

John Pertell, Arjun Singh and Pin Chi Liang (SUNY Polytechnic Institute, USA); Josep M Jornet (Northeastern University & Institute for the Wireless Internet of Things, USA); Priyangshu Sen (SUNY Polytechnic Institute, USA)

Terahertz-band (0.1-10THz) communication is expected to play a crucial role in the next-generations of wireless technology by enabling high data-rates, ultra-secure transmission, and high-resolution sensing. However, THz-waves are susceptible to blockage, necessitating use of NLoS-links alongside LoS-links. Due to sparse THz-channel and the difficulties in establishing reliable NLoS-links, it is essential to form channel-aware connections to ensure reliability. Here, we characterize the reflection properties of ultra-broadband NLoS-links through various building materials. Based on these characteristics, we develop a physics-aware material classification and receiver localization model using 1D-CNN-ResNet architecture that handles multitask heads in a unified pipeline. Unlike existing methods that rely on dedicated radar systems, our architecture fully depends on reflection multipath profiles and their characteristics. The proposed solution achieves 65% accuracy in material classification and 86% in distinguishing good and poor reflectors with absolute error of 0.78m in localization over 8m, considering different transmission powers and angles-of-incidence.

10:30 Investigation and Experimental Evaluation of Ray-Tracing Capabilities for Channel Modeling at High Frequencies: MmWave and THz

Guangcheng Yu and Zhiqiang Yuan (Southeast University, China); Binhui Liu (China Electronic Product Reliability and Environmental Testing Institute, China); Wei Fan (SouthEast University, China)

Accurate channel models are crucial for the high-frequency systems, including those in the millimeter-wave (mmWave) and terahertz (THz) bands. High-frequency channels exhibit high propagation loss, sparsity, and near-field effects in massive MIMO systems, making deterministic ray-tracing (RT) well-suited for modeling. While RT for high-frequency modeling is widely discussed, its real-world performance requires further investigation. In this article, two measurements at 28 and 100 GHz are used to evaluate the implementation performance of RT in massive MIMO mmwave and THz scenarios. At both frequencies, dominant propagation paths and near-field characteristics are accurately modeled, although several paths in the mmWave band are not reproduced, indicating higher reliability of RT in THz modeling. Furthermore, extensive 300 GHz measurements across 12 locations enable in-depth THz channel characterization. This analysis is based on extensive channel data from 30 locations (12 measured and 18 RT-simulated). These results provides insights for future high-frequency channel modeling and standardization.

10:50 Two-Way Decomposition Model for RIS-Assisted Channels and Its Validity Conditions

Yuxuan Ding, Minghe Mao and Minseok Kim (Niigata University, Japan)

This paper presents a two-way decomposition model for path gain calculation in reconfigurable intelligent surface (RIS)-assisted wireless channels, in which the cascaded Tx-RIS-Rx channel is decomposed into Tx-RIS and RIS-Rx subchannels. The model is rigorously derived from the one-way coherent cascaded formulation (general model), enabling physically consistent and computationally efficient simulation using ray-tracing tools such as Wireless InSite and the MATLAB Ray Tracer, which currently lack native support for full RIS cascaded modeling. Numerical results show that the proposed model closely matches the general model across both near- and far-field regimes, significantly outperforming the conventional dual-pattern approach, which exhibits non-negligible errors even in the far field and increasingly large discrepancies in the near-field regime. Furthermore, the theoretical conditions for decomposition validity are explicitly derived, clarifying the applicable regimes for both the proposed and conventional models.

11:10 Radio Channel Characterization of a near-Field Focused Transmitarray at Sub-THz Frequency

Antonio Clemente (CEA-Leti, France); Marie Defives (CEA-Leti University Grenoble-Alpes Grenoble, France); Orestis Koutsos (CEA Leti, France); Marina Lotti (Fondazione Ugo Bordoni, Italy); Ronan Sauleau (Universite de Rennes, France); Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France)

Short-range THz links often operate in the radiative near field because antennas are electrically large at these frequencies. This paper characterizes line-of-sight propagation with transmitarray antennas under contrasting beamforming regimes. Using a sub-THz testbed with multi-axis, high-precision positioners, we first evaluate a transmitarray optimized for far-field operation and observe pronounced performance degradation in the near field. We then assess a transmitarray engineered for near-field focusing, which concentrates energy at a finite range and yields a markedly improved short-range link budget.

11:30 Channel Measurement, Modeling, and Analysis for Terahertz Secure V2X Communications

Mingjie Zhu, Yejian Lyu and Chong Han (Shanghai Jiao Tong University, China)

Vehicle-to-everything (V2X) technology has emerged as a key enabler of intelligent transportation systems, and the terahertz (THz) band, with its abundant spectral resources, provides strong potential for supporting ultra-high-speed and low-latency V2X communications. This work investigates the THz V2X channel through measurement, modeling, and security analysis. A V2X measurement campaign reveals notable penetration loss through vehicular materials. A high-resolution point cloud of the vehicle environment is integrated into a ray-tracing (RT) simulator, which is validated by measured power-angle-delay profiles (PADPs). The validated model enables signal-to-interference-plus-noise ratio (SINR), coverage, and secrecy capacity evaluations, showing that in-vehicle SINR is significantly higher than outside, and the overall wiretapping probability from outside to inside is low. These findings provide insights into THz V2X propagation and physical-layer security (PLS) for future V2X communication systems.

Thursday, April 23 10:10 - 11:50

E03b Computational and Numerical Techniques: Integral Equations 2

T07 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy), Balasubramaniam Shanker (The Ohio State University, USA)

Room: Firenze

10:10 Adaptive Mesh Refinement for a Multiscale Electromagnetic Solver Accelerated with MultiAIM

Qinghao Zhang, Yongzhong Li and Piero Triverio (University of Toronto, Canada)

An automated residual-driven h-refinement framework is proposed for the efficient electromagnetic analysis of multiscale layouts excited via lumped ports. The method uses the Augmented Electric Field Integral Equation to enable broadband analysis and facilitate the excitation via lumped ports. To allow for local mesh refinements, the equations are discretized with the multibranch Rao-Wilton-Glisson basis functions. We discuss how the MultiAIM acceleration method can be applied to the resulting non-conformal mesh and set of basis functions. A residual-based error estimator drives mesh refinement, while a convergence criterion ensures automatic termination. Validation on a public microstrip benchmark shows that the proposed approach achieves comparable accuracy to a uniformly refined mesh with 7.4 times faster computation and 2.7 times lower memory usage

10:30 Symmetry Based Characteristic Mode Tracking in Periodic Structures

Lukas Warkentin and Dirk Manteuffel (Leibniz University Hannover, Germany)
The application of symmetry based tracking of characteristic modes (CMs) of periodic structures is investigated. Possible assignment of the CMs to the irreducible representations of the symmetry groups is confirmed by simulation. It is shown, how the symmetry group must be chosen based on the symmetry of the unit cell and the scatterer placed within. Selecting the appropriate symmetry group not only enables symmetry based tracking, but also allows for predictions concerning the orthogonality of characteristic modes.

10:50 Efficient Integral Equation Technique for Rectangular Waveguide Slot Antenna Analysis

Antonio Huéscar (Technical University of Cartagena, Spain); Antonio Oliva Aparicio (Universidad Politécnica de Cartagena, Spain); Fernando D Quesada Pereira and Alejandro Alvarez-Melcon (Technical University of Cartagena, Spain); Vicente Boria (Universidad Politécnica de Valencia, Spain)
In this contribution, an integral equation (IE) formulation is proposed for the analysis of slot antennas. To solve the IE, the problem is divided into two equivalent subproblems: the first related to the rectangular waveguide component and the second related to the free-space medium. Subsequently, an equivalent surface magnetic current density defined at the discontinuity is used to couple the equivalent subproblems. In order to reduce the total number of unknowns before solving the IE using the method of moments (MoM), the Lorenz gauge Green's functions of the rectangular waveguide and and a grounded half space is used respectively for both equivalent subproblems. Furthermore, due to the slow convergence behavior, the Ewald method has been used to accelerate the evaluation of the Green's functions of the rectangular waveguide.

Thursday, April 23 10:10 - 11:50

IW6 Industrial Workshop - IMST (Design, Simulation and Realization of Phased Array Antennas)

/ / Measurements

Room: Stockholm

Simona Bruni and Marta Arias Campo (IMST)
Phased arrays provide scanned beams or multiple beams that are commonly used for radar, communication systems and space applications. This course begins with an introduction to the fundamentals of phased antenna arrays, emphasising key concepts such as array factor, coupling, gain/directivity, and problems such as grating lobes, beam squint and scan blindness. The second part focuses on practical examples of real active array antenna systems and their efficient 3D EM design and integration.

Workshop Outline:
1. Phased array design guidelines. The first part will provide participants with basic guidelines for the analysis and design of phased array antennas. The basic design process will be explained with a focus on key parameters such as technology and array architecture choices, thermal management and array calibration.
2. Satcom and 5G array design, realisation and integration. The second part of the workshop is filled with practical examples of real array antenna systems. Efficient simulation models for different design stages will be explained. Simulated performance will be compared to measurements. Vehicle and aeroplane integrated performance of a Ka-band phased array will be shown as the last step using an antenna digital twin. The hardware for some of the systems presented will also be shown in the course.

Simona Bruni is Director of the Sub-THz Antenna Systems team at IMST GmbH. Her research interests include the design of integrated antennas, high-frequency antenna arrays, and front-end design for communications and automotive applications.

Marta Arias Campo is Director of the Sub-THz Antenna Systems team at IMST GmbH. Her research interests include the analysis and design of lens antennas and quasi-optical structures for high-speed wireless communications and radar applications.

Thursday, April 23 10:10 - 11:50

P11b Sensing, Localisation and ISAC - Part II 2

TO5 Positioning, localization, identification & tracking / / Propagation
Chairs: Marina Barbiroli (University of Bologna, Italy & DEI, Italy), Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

Room: Dusseldorf

10:10 Experimental Analysis of CSI and RSSI for Deep Learning Localization in Underground Mine Tunnels

Hussam Zgheib (UQAT, Canada); Nahi Kandil (Université du Québec en Abitibi-Temiscamingue, Canada); Nadir Hakem (Université du Québec en Abitibi Témiscamingue, Canada); Aurélien Surier (Université du Québec en Abitibi-Témiscamingue, Canada); Clement Nzoleko (UQAT, Canada)
Accurate localization in underground mining tunnels remains a persistent challenge due to multipath propagation, signal attenuation, and the absence of GPS. This work presents an experimental investigation of Wi-Fi signal features-specifically Received Signal Strength Indicator (RSSI) and Channel State Information (CSI) amplitude and phase-for deep learning-based localization. Using a measurement campaign conducted in a real mine, data were collected with ESP32 microcontrollers and processed to train a Fully Connected Neural Network (FCNN) model. The study systematically evaluates the contribution of each signal component to positioning accuracy along the tunnel's longitudinal axis. Results demonstrate that CSI amplitude offers the most reliable spatial information, while combining it with RSSI achieves sub-meter accuracy and strong robustness under both line-of-sight and non-line-of-sight conditions. These findings highlight the potential of low-cost, data-driven localization systems for reliable operation in complex underground environments.

10:30 A Zero-Crossing Path Difference Method for Accurate Angle-of-Arrival Estimation in Outdoor Scenario

Franz M. E. Camilo (Universidade Federal de São João del Rei, Brazil); João Ricardo Reis (IT & IPL, Portugal); Glaucio L. Ramos (Federal University of São João Del-Rei, Brazil); Telmo R. Fernandes (IPLeiria / Institute of Telecommunications & ESTG/IT-DL, Portugal); Nuno R. Leonor (Polytechnic Institute of Leiria (IPL) & Instituto de Telecomunicações (IT), Leiria, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

Accurate Angle of Arrival (AoA) estimation is essential for channel characterization and localization in 5G and 6G systems, where directionality and multipath propagation play a dominant role. This paper presents a Zero-Crossing Path Difference of Arrival (PDoA) method that retrieves AoA directly from measured S-parameters using a minimal two-antenna array. The technique exploits the zero-crossing of the propagation path difference between receiver elements as the array rotates, enabling unambiguous AoA detection with full 360° coverage. Unlike conventional phase-difference or interferometric methods, the proposed approach avoids phase ambiguity and does not require large antenna arrays. The method is implemented and validated through wideband frequency-domain measurements in anechoic chamber and outdoor scenario, showing AoA errors as low as 0.2° indoors and below 4° in outdoor comparisons with ray-tracing simulations. The results demonstrate that the Zero-Crossing PDoA method offers a simple, accurate, and computationally efficient solution for practical AoA measurement and channel characterization for the next-generation wireless systems.

10:50 Automatic Detection of Equatorial Plasma Bubbles Using Rate of TEC Index from SiReNT GNSS Data

Hugo Leray and Michael Dellaiera (National University of Singapore, Singapore); Babu Sree Harsha Pasumarthi (DLR, Germany); Koen Mouthaan (NUS, Singapore)

Equatorial plasma bubbles (EPBs) are regions of reduced plasma density developing within the ionospheric F-layer near the magnetic equator after sunset, rising through surrounding denser plasma. Their evolution modulate trans-ionospheric radio propagation, causing phase and amplitude scintillation, degrading the performance of global navigation satellite system (GNSS). Statistical understanding of such formation can provide signal integrity information for ground-based and space-based augmentation systems. Particularly, detection and classification of EPBs are necessary for distinction between locally generated and drifting bubbles. This challenging task requires characterizing structure of each bubble. Here, automatic detection and enumeration of EPBs through estimation of the rate of total electron content (TEC) index (ROTI) using Singapore satellite positioning reference network (SiReNT) is proposed. Each peak is described by a Gaussian function characterized by a mean value, a scaling factor, and a standard deviation. Using an aggregation strategy, onset and decay of each EPB can be defined.

11:10 Empirical Modeling of Beam-Level RSRP Fading Under Multi-Person Motion for Passive Crowd Counting in Indoor 5G mmWave

Nopphon Keerativoranan (Institute of Science Tokyo, Japan); Hang Song (Hiroshima University, Japan); Hsueh Han Wu and Saurabh Verma (Rakuten Mobile, Inc, Japan); Kelvin Cheng (Rakuten Institute of Technology & Rakuten Mobile, Inc., Japan); Jun-ichi Takada (Institute of Science Tokyo, Japan)

This paper empirically models how multi-person motion perturbs beam-level RSRP in indoor 5G mmWave, targeting passive crowd counting. synchronization-signal (SSB) beam RSRP are collected from a commercial gNodeB in a real office, across five measurement campaigns and up to five simultaneous walking subjects. After removing slow drift on the linear scale, the residual small-scale fluctuations in dB are well captured by a symmetric bell-shaped distribution. Among common small-scale fading distribution, the log-logistic model attains the best fit. Using the logistic scale as a single interpretable "spread" parameter, this study shows a simple, monotonic, approximately linear increase of fast-fading spread with the number of walking person for each SSB beam. The slopes vary by beam, reflecting geometry such as local scattering. The resulting one-parameter link from crowd size to fading spread enables lightweight, explainable features for crowd-aware analytics, link budgeting, and channel emulation in human-populated indoor spaces.

11:30 Fast Full-Wave Simulation of Indoor RSS Maps for Pre-Measurement Validation in Device-Free Localization

Federica Fieramosca and Anastasia Maiolli (Politecnico di Milano, Italy); Alexander H. Paulus (Technical University of Munich, Germany); Stefano Savazzi (Consiglio Nazionale delle Ricerche, Italy); Michele D'Amico (Politecnico di Milano, Italy)

Human localization is increasingly needed in security, healthcare, logistics, and smart environments. Since global navigation systems are unreliable indoors, device-free passive (DfP) methods exploit human-induced perturbations of radio propagation. This paper investigates the use of a compact full-wave electromagnetic (EM) setup as a fast and reliable tool to simulate indoor Wi-Fi propagation and human sensing. The goal is to provide a practical baseline for validating simplified propagation models-such as diffraction-based descriptions-and to reduce the need for costly measurement campaigns. Two-dimensional received signal strength (RSS) attenuation maps are generated and compared with controlled measurements, focusing on attenuation statistics and interference patterns. The simulations reproduce the main spatial features, though discrepancies remain due to simplified material characterization. Diffraction-aware refinements are proposed to mitigate these effects. Overall, the approach provides an efficient pre-measurement reference to support DfP system design and to guide experimental planning.

Thursday, April 23 12:00 - 12:40

INO9 Zhong Chen - Compressed Sensing for Antenna Calibration in Extrapolation Ranges with Refined Physical Models

/ / Measurements

Chair: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain))

Zhong Chen is the Chief Engineer at ETS-Lindgren, located in Cedar Park, Texas. He has 30 years of experience in RF testing, anechoic chamber design, as well as EMC antenna and field probe design and measurements. Mr. Chen is chair of the IEEE Standard 1309 committee responsible for developing calibration standards for field probes, and IEEE Standard 1128 for absorber evaluation. He is a member of the IEEE EMC Society Board of Governors and a former vice president of the Antenna Measurement Techniques Association (AMTA). He is serving as Vice-Chair of ANSI C63 (American National Standards Committee on EMC) and is the immediate past Chair of Subcommittee 1 which is responsible for the antenna calibration (ANSI C63.5) and chamber/test site validation standards. His research interests include antenna design and measurement, measurement uncertainty, data post-processing techniques for site validation and antenna calibration, and development of novel RF absorber materials. He has received recognition for numerous best papers at global conferences. Zhong Chen received his M.S.E.E. degree in Electromagnetics from the Ohio State University at Columbus. He may be reached at zhong.chen@ets-lindgren.com.

Room: Edinburgh

12:00 Compressed Sensing for Antenna Calibration in Extrapolation Ranges with a Refined Physical Model

Zhong Chen (ETS-Lindgren, USA)

Extrapolation calibration enables accurate indoor antenna gain measurements but typically requires dense sampling to suppress multipath-induced oscillations, often taking an entire day. Previous work showed that antenna responses are sparse in spatial-frequency(k-space) and can be reconstructed with compressed sensing (CS) using fewer samples. Here, we enhance this approach by applying a physics-informed preprocessing step: the measured response is fitted in the complex domain to Wacker's generalized transmissionequation, including higher-order antenna-to-antenna coupling, and used to detrend both magnitude and phase. This yields a more compact k-space representation, improved CS reconstruction, and further sampling reduction. We demonstrate the method on an X-band horn and a physically large L-band double-ridged horn, where effective separation is hard to reference. The complex-domain fit reduces extrapolation sensitivity to measurement uncertainties, enabling more reliable far-field gain calibration. This approachextends CS accelerated extrapolation method to both compact and large antennas efficiently.

Thursday, April 23 12:00 - 12:40

IN10 Stefano Maci - Multibeam Antennas Without Beam Forming Networks

/ / Antennas

Chair: Davide Comite

Stefano MACI is a Professor at the University of Siena (UNISI). Since 2000, he has been P.I. of 10 research projects funded by the European Union (EU)
and by the European Space Agency (ESA). He is a Fellow of IEEE since 2004. In 2004 he founded the European School of Antennas (ESoA), a PhD school that presently comprises 35 courses on Antennas, Propagation, and Electromagnetic Theory, and 200 teachers, among them 20 IEEE Fellow. He has been advisor of 40 PhD students. He has been former member of IEEE Antennas and Propagation Society (AP-S) AdCom, the Chair of the Award Committee of the IEEE AP-S, member of the AP Executive Board of IET (UK), Distinguished Lecturer of IEEE and of EurAAP. He was recipient of several prizes and awards, among which the EurAAP Award 2014, the Chen-To Tai Distinguished Educator award 2016, of the Shelkunoff Transaction Prize in 2015, and of the URSI Dellinger Gold Medal in 2020. He is presently Director of ESoA. He has been TPC Chair of the METAMATERIAL 2020 and and General Chair of EuCAP 2023. He was the president of the IEEE Antennas and Propagation Society 2023. In the last ten years he has been invited 60 times as key-note speaker in international conferences. His research activity is documented in 200 papers published in international journals, (among which 100 on IEEE journals), 10 book chapters, and about 450 papers in proceedings of international conferences.

Room: Berlin

12:00 Multibeam Antennas Without Beam Forming Networks

Stefano Maci (University of Siena, Italy)

Recent developments in gradient-index (GRIN) and metasurface-based antennas are enabling low-cost, compact, and highly directive multibeam solutions without the need for traditional beam forming networks (BFNs). By replacing complex RF feeding systems with passive spatial control, these approaches offer substantial reductions in hardware complexity, size, and cost. This talk highlights efficient GRIN lens synthesis techniques designed for multifocal and multibeam operation. A generalized method-beyond classical ray assumptions-enables accurate index profiles that ensure stable performance over wide frequency bands. Supported by a fast geometrical optics solver based on the Fast Sweeping Method, this approach allows direct computation of the spatial index needed to produce a desired field distribution, achieving precise beam shaping and steering passively. We also present metasurface antennas based on both space wave control and surface-wave excitation by multiple point sources. These latter planar structures leverage engineered impedance or phase profiles to convert guided waves into multiple directive beams in free space, entirely without BFNs. Such metasurfaces are inherently thin and low-profile, and are well-suited for low-cost fabrication and integration.

Thursday, April 23 12:40 - 13:30

WG9 EurAAP Working Group on Software and Modelling Tools (Lunchtime Meeting)

Room: Dusseldorf

Thursday, April 23 12:40 - 13:30

WG4 EurAAP Working Group on Women in Antennas and Propagation (lunchtime meeting)

Room: Firenze

Thursday, April 23 12:40 - 13:30

WG7 EurAAP Working Group on EM Technologies for Life Science Applications (lunchtime meeting)

Room: Madrid

Thursday, April 23 12:40 - 13:30

WG3 EurAAP Working Group on Active Array Antennas (lunchtime meeting)

Room: Glasgow

Thursday, April 23 13:30 - 14:40

BPA2 Best Paper Posters: Poster Session 2

Room: Poster Level 3

Best Electromagnetics Paper Award: Recognises outstanding work in the field of electromagnetics, including fundamental research, analytical and numerical methods, and novel developments in electromagnetic theory and applications.

Committee:
Chair: Enrica Martini
Prof. Guy Vandenbosch (KU Leuven, Belgium)
Prof. Okan Yurduseven (Queen's University Belfast, UK)
Prof. Balasubramaniam Shanker (Michigan State University, USA)

Short list:
(1571214827) Martin Petek and Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Guido Valerio (Sorbonne Université, France); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Francesca Vipiana (Politecnico di Torino, Italy) - "The Brillouin Zone of Glide-Symmetric Structures: A New Definition and Its Implications"

(1571210731) Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT)) - "Electromagnetic Modeling with Hybrid Multilevel Fast Multipole Inhomogeneous Plane Wave Algorithms for Planar Multilayered Media"

(1571214521) Samuel J Coogle, Connor B. Jenkins and Asimina Kiourti (The Ohio State University, USA) - "The Mode-Specific Nature of Transducer Design and Impedance Matching for Diatomic Magnetoinductive Waveguides"

(1571215342) Lukas Warkentin and Dirk Manteuffel (Leibniz University Hannover, Germany) - "Symmetry Based Characteristic Mode Tracking in Periodic Structures"

(1571213612) Erik Speksnijder (TU Delft, The Netherlands); Riccardo Ozzola and Andrea Neto (Delft University of Technology, The Netherlands) - "Multi-Scale Analysis of Integrated Lens Antennas with a PPW-Based Decoupling Technique"

Best Antenna Theory and Design Paper Award: Awarded to the paper that presents the most significant contribution in the field of antenna theory, modelling, and innovative design concepts with a strong emphasis on theoretical rigour and originality.

Committee:
Chair: Max Ammann
Prof Miguel Ferrando Bataller (Universitat Politècnica de València, Spain)
Prof Anja Skrivervik (EPFL, Switzerland)
Prof Dirk Manteuffel (Leibniz University of Hannover, Germany)

Short list:
(1571214553) Afsh in Abbaszadeh and Jordan Budhu (Virginia Tech, USA); Kelvin J Nicholson (Defence Science and Technology, Australia) - "A Fully Analytic Approach for the Design and Voronoi Realization of Arbitrarily-Shaped Quasi-Periodic Leaky Wave Antennas"

(1571210954) Ming-Chun Tang (Chongqing University, China); Richard W Ziolkowski (University of Arizona, USA) - "Small Antennas with High Efficiency and Superdirective Performance"

(1571215272) Xuezhi Zheng (Katholieke Universiteit Leuven, Belgium); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium) - "On a Volume Integral Equation Approach Modeling the Electron Beam Spectroscopy of Metallic Nanospheres"

(1571216540) Jeonghyo Lee (POSTECH, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South)) - "Dual-Directional Beam Steering and Fan-Beam Radiation Management Using a Unified Identical Aperture Phased Array"

(1571215079) Sebastian Diaz-Beiza (Universidad Carlos III de Madrid, Spain); Raha Roosefid (Chalmers University of Technology & Satcube AB, Sweden); Jose-Luis Vazquez-Roy (University Carlos III of Madrid, Spain); Ashraf Uz Zaman (Chalmers University of Technology, Sweden); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain) - "Sequential Rotation Feed Network Implemented in Gap Waveguide MLW (GMLW) Coaxial Line Technology for Circularly Polarized Ka-Band Arrays"

Best Applied Antenna Technology Paper Award: Given to the paper that best demonstrates practical advancements in antenna technology, including real-world applications, system integration and performance validation in applied settings.

Committee:
Chair: Suramate Chalermwisutkul
Prof. Qammer Abbasi (University of Glasgow, UK)
Prof. Buon Kiong Lau (Lund University, Sweden)
Marta Martínez-Vázquez (IMST, Germany)

Short list:
(1571215395) Aritra Roy (IMT Atlantique, Brest); Tanguy Lopez and Julien Sarrazin (Sorbonne Université, France) - "2D Direction-of-Arrival Estimation with a Fast-Scanning Single-Port Leaky Wave Antenna"

1571214825) Jiayi Chen (Karlsruhe Institute of Technology, Germany); Reza Aliabadi (Offenburg University, Germany); Xueyun Long, Áron Szabó and Jiyeon Choi (Karlsruhe Institute of Technology, Germany); Benjamin Nuss (Technical University of Munich, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany) - "Dual-Array Large-Scale MIMO Architecture for Automotive TDMA-DDMA Radar"

(1571206025) Vincent Laquerbe (CNES, France) - "Dual Pattern S-Band Antenna for Adaptive Links Within Satellite Swarms"

(1571215433) Jan H. S. Bergman, Mohamed Räsänen and Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland) - "Differential Aperture-Coupled PCB-to-Waveguide Transition for Antenna-IC Integration at 100 GHz"

(1571216026) Mohammad Ameen (National University of Singapore, Singapore); Yiyang Bai (Viterbi School of Engineering, University of Southern California, USA); Peizhuo Yang (National University of Singapore, Singapore); Koen Mouthaan (NUS, Singapore) - "Dual-Polarized Conformal Active Phased Array Antenna with TRM Integration and RFSoC-Based Digital Beamforming for UAV Platforms"

Best Propagation Paper Award: Recognises the paper with the most impactful contribution to the study of radio wave propagation, including modelling, experimental validation, and applications across various environments and frequency bands.

Committee:
Chair: Raffaele D'Errico
Prof. Wout Joseph (Ghent University, Belgium)
Prof. Wei Fan (Southeast University, China)
Dr. Thomas Zemen (AIT Austrian Institute of Technology, Austria)

Short list:
(1571215126) Jérome Eertmans (Université catholique de Louvain, Belgium); Sophie Lequeu and Benoît Legat (UCLouvain, Belgium); Laurent Jacques (University of Louvain, Belgium); Claude Oestges (Université catholique de Louvain, Belgium) - "Fast, Differentiable, GPU-Accelerated Ray Tracing for Multiple Diffraction and Reflection Paths"

(1571215171) Zaher M Kassas, Paul El-Kouba and Sharbel Kozhaya (The Ohio State University, USA) - "Performance Assessment of DOA and Doppler Positioning Under Erroneous Starlink and OneWeb LEO Satellites Ephemerides"

(1571214084) Kentaro Saito and Tatsuki Sakata (Tottori University, Japan) - "Analysis of the 5 GHz Band Air to Ground Propagation Channel Using an Unmanned Aerial Vehicle-Based Virtual Array System"

(1571214258) Altug Kaya, Alper Schultze and Melih Ciftci (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Germany); Aline Friedrich and Indra Ghosh (IMST GmbH, Germany); Mathis Schmieder (Fraunhofer Heinrich Hertz Institute, Germany); Ramez Askar (Fraunhofer HHI, Germany); Sven Wittig (Fraunhofer Heinrich Hertz Institute, Germany); Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany) - "Monostatic mmWave 6G ICAS: Comparing Sensing Capabilities of Cylindrical Phased Arrays and Virtual Uniform Circular Arrays"

(1571215579) Niklas Vaara and Lafir Naveeth Mohamed (University of Oulu, Finland); Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Tuomas Maatta (CubiCasa, Finland); Lam Huynh, Pekka Sangi and Miguel Bordallo Lopez (University of Oulu, Finland); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland); Janne Heikkilä (University of Oulu, Finland) - "Differentiable Ray Tracing for THz Radio Channel Characterization with Point Clouds"

Best Measurements Paper Award: Recognises outstanding work that advances the science and practice of antenna and electromagnetic measurements, with contributions to measurement techniques, instrumentation, near-field and far-field methods, calibration, and experimental validation.

Committee:
Chair: Tian Hong Loh
Dr Christopher Holloway (NIST, USA)
Dr Jae-Yong Kwon (KRISS, Korea)
Emrah Tas (METAS, Switzerland)

Short list:
(1571214962) Carsten Andrich, Isabella B. Varga, Tobias Nowack, Alexander Ihlow, Sebastian Giehl, Michael Schubert, Reiner S. Thomä and Matthias Hein (Technische Universität Ilmenau, Germany) - "Wideband Antenna Deconvolution for Bistatic Millimeter Wave Radar Reflectivity Measurements"

(1571215450) Olav Breinbjerg (ElMaReCo, Denmark); Florindo Bevilacqua, Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy) - "Derivative Sampling with Derivative Probes for Planar near-Field Antenna Measurements"

(1571215485) Rasmus Himmelstrup Andersen, Aske Barnaby Rasborg Best, Malthe Raschke Nielsen, Troels Pedersen and Anders Malthe Westerkam (Aalborg University, Denmark) - "Experimental Testing of the Multiple Radar Bayesian Localisation and Tracking Algorithm"

(1571215780) Marianna Ivashina, Oleg Iupikov and Pavlo Krasov (Chalmers University of Technology, Sweden); Aidin Razavi (Ericsson Research, Sweden); Rob Maaskant (CHALMERS, Sweden); Jonas Fridén (Ericsson AB, Sweden) - "A Single-Chamber Solution Unifying Anechoic and Reverberation Chamber-like OTA Testing via Electronic Test Zone Synthesis and Mode Stirring"

(1571215899) Wataru Kumazawa, Hokuto Isogai and Shintaro Hisatake (Gifu University, Japan) - "Polarization-Resolved Electro-Optic near-Field Measurement and Far-Field Evaluation of a 300 GHz Antenna"

Thursday, April 23 13:30 - 14:40

P3-A01 Antennas for RFID and sensors

TO4 RF sensing for automotive, security, IoT, and other applications / / Antennas
Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 3

3.01 Chipless RF Sensor for Water Detection Using Sustainable Materials

Cong Danh Bui (Trinity College Dublin, Ireland & CONNECT Centre, Ireland); Ping Jack Soh, Sami Myllymaki, Olli Pitkänen, Riikka Haataja, Ossi Laitinen and Henrikki Liimatainen (University of Oulu, Finland); Adam Narbudowicz (Technical University of Denmark, Denmark)

This paper presents a low-profile chipless RF sensor for water detection, implemented using an aerogel substrate and Shieldit textile. The aerogel, derived from birch wood pulp, provides a sustainable, highly porous medium with strong absorptive properties, while Shieldit offers flexibility for easy integration into various applications. The sensing mechanism relies on the meander line resonator's single resonant frequency, which shifts according to the amount of water absorbed in the aerogel and is reflected to a Vivaldi antenna serving as the interrogator. The sensor was fabricated and validated against simulation models, with measurements showing reliable detection of up to 0.4 ml/g of water, as well as the ability to signal excessive liquid accumulation within the substrate.

3.02 Forward Scattering Systems for Low Energy Communications

Abdelwaheb Ourir (Institut Langevin ESPCI Paris CNRS, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France)

In this paper, we propose an original configuration for the backscatter tag that is able to separate the signal reception circuit of the tag from the backscattering system. In this modified architecture of the tag, a first antenna is dedicated to receiving the ambient RF signal from the source, while a second antenna is responsible for forward scattering the modulated signal toward the reader. We present experimental results on power contrast obtained from various configurations of backscatter communication systems. The obtained results demonstrate that performance is significantly improved with the use of forward scattering tags. Furthermore, the fading effects can be substantially mitigated when forward scattering is combined with orthogonally polarized antennas. This configuration leads to a significant design flexibility and facilitates enhanced system performance, particularly in complex or dynamic RF environments.

3.03 Functional Robustness of Self-Healing Passive UHF RFID Tag to Mechanical Damage

Nikta Pournoori, Muhammad Usama Javed and Minna Hakala (Tampere University, Finland); Jarkko Tolvanen (University of Oulu, Finland); Toni Björninen (Tampere University, Finland); Jari Juuti (University of Oulu, Finland); Leena Ukkonen (Tampere University, Finland)

This paper evaluates the functional reliability of self-healing passive UHF RFID tags under mechanical damage. We fabricated 39 dipole-type tags in five conductor-thickness groups (100–300 µm), using a self-healing elastomer blend. The primary performance metric, read range, was characterized within the 860–960 MHz band for pristine tags and after controlled damage, including cuts and natural cracking. Read range recovery was quantified at intervals over 24 hours. Our results demonstrate a strong dependence on conductor thickness: tags with thicker conductors (≥200 µm) retained measurable functionality, whereas thinner conductors were nearly non-functional after damage. While natural cracks proved most detrimental, reducing read range by over 70%, the self-healing mechanism successfully restored acceptable performance. These findings, supported by electromagnetic simulations, validate a robust and self-repairing antenna approach, despite the low polymer conductivity (~150 S/m) relative to metals. Future work will focus on improving conductivity, IC-radiator bonding, and developing water-resistant layouts to enhance durability.

3.04 Mechanical Tuning of a Rotationally Symmetrical 5.2 GHz High Radar Cross-Section Passive Tag for Small Insect Pollinator Tracking

Rachel F Ball, Kenneth Lee Ford and Stephen Henthorn (University of Sheffield, United Kingdom (Great Britain))

Insects are currently declining at a high rate, which will cause severe worldwide problems. This can be studied and addressed by the use of tracking. Historically harmonic RADAR was used due to its high range, however it required high power (~20 kW), this is due to the poor and highly non-linear conversion efficiencies of harmonic RADAR tags. This paper sets to devise a method of increasing signal visibility by using a mechanically tuned scatterer which could be used on an insect to modulate the signal using its wingbeat, thus increasing visibility of the back scattered signal and allowing for some behavioural analysis. Simulations show that tuning of over 2 GHz (40%) can be obtained with the RADAR cross-section (RCS) being over -32 dBsm for all resonant frequencies when illuminated at boresight.

3.05 A Fully Passive Approach for Real-Time Strain Sensing of LiFePO4 Cells in EV Battery Packs

Badar Muneer (University of Perugia, Italy & Mehran University of Engineering and Technology, Pakistan); Matteo Lame (Università degli studi di Perugia, Italy); Valentina Palazzi, Federico Alimenti and Luca Roselli (University of Perugia, Italy)

Monitoring mechanical strain in lithium-ion battery cells is critical for accurately assessing the state-of-charge (SoC) and state-of-health (SoH) in electric vehicle (EV) battery packs. This paper presents a novel, fully passive wireless strain sensing system that integrates a piezoresistive sensing element with ultrahigh-frequency (UHF) RFID technology. Utilizing the Magnus S3 RFID chip, the system operates without a dedicated power source, relying on energy harvested from the RFID reader. Changes in mechanical strain alter the impedance of the sensing element, which is encoded into a sensor code and transmitted wirelessly in real time. Experimental results from two experimental setups confirm the effectiveness of this approach for monitoring swelling-induced deformation in LiFePO4 cells. The proposed solution significantly reduces wiring complexity and energy consumption, offering a scalable and cost-effective option for next-generation wireless battery management systems (wBMS).

3.06 Frequency Domain Reading Method for Chipless RFID Tags

Jan Kracek, Milan Svanda and Karel Hoffmann (Czech Technical University in Prague, Czech Republic)

The novel implementation of the frequency domain reading method for chipless tags based only on a single scalar measurement of the magnitude of the transmission coefficient between two antennas by the presence of the tag is proposed and experimentally verified in the frequency band from 7 GHz to 11 GHz. The applied antennas are low-cost, simple, compact, formed by the R100 open-ended rectangular waveguide stubs. The drops and maxims of the measured frequency dependencies of the magnitude of the transmission coefficient, which encode the tag information, are clearly distinguishable and do not need any sophisticated method to be revealed. This scalar reading method in conjunction with the tags based on the dipole resonator array backed by the limited ground plane seems to be suitable for low-cost chipless RFID systems working in a real environment outside the anechoic chamber.

3.07 Meandered CSRR Microstrip Sensor for Characterization of Mixtures

Rami Zegadi (University of Ferhat Abbas, Sétif, Portugal); MoHamed Bouknia (University of Ferhat Abbas, Sétif, Algeria); Issa Elfergani (Instituto de Telecomunicações, Portugal); Said Mosbah (Farhat Abbas University Of Setif, Algeria); Djamel Sayad (University of 20 Aout 1955 - Skikda, Algeria); Almudena Rivadeneyra (University of Granada, Spain); Jonathan Rodriguez (Instituto de Telecomunicações, Portugal); Chemseddine Zebiri (Ferhat Abbas University of Setif, Algeria); Mohammad Alibakhshikenari (University of Galway, Ireland); Takfarinas Saber (National University of Ireland Galway, Ireland)

This work presents a novel compact meandered microstrip sensor integrated with a complementary split-ring resonator (CSRR) for the precise dielectric characterization of water-ethanol mixtures. The proposed structure is optimized using the High-Frequency Structure Simulator (HFSS), achieving enhanced sensitivity and a high quality factor through dual-band resonant behavior. The sensing performance is thoroughly assessed by combining full-wave electromagnetic simulations and experimental validation, demonstrating reliable extraction of the complex permittivity of liquid samples. The dual-band response, enabled by the engineered CSRR loading, offers improved discrimination capability and robustness, making the proposed sensor a strong candidate for advanced chemical and biomedical sensing applications.

3.08 Foldable MIMO Antenna with FSS-Based Reflector Layer for Enhanced Gain in Mangrove Seedling Growth Monitoring

Anikó Német, Mirza Shujaat Ali, Jalil ur Rehman Kazim, Muhammad Ali Imran and Qammer Abbasi (University of Glasgow, United Kingdom (Great Britain))

Accelerating sea-level rise threatens vital mangrove forests, critical for blue carbon sequestration. A novel, compact, foldable antenna sensor is presented for real-time growth sensing. The design introduces a 2x2 Multiple-Input Multiple-Output (MIMO) configuration on a flexible RT/Duroid-5880 substrate of size 160 mm × 160 mm. Utilizing four orthogonally positioned octagonal Split-Ring Resonator (SRR) elements and an RO3010 Frequency Selective Surface (FSS) based reflector array. The sensor resonates within the Industrial, Scientific, and Medical (ISM) band of 2.09-2.59 GHz, with a principal resonance at 2.34 GHz. The SRR elements localize the electromagnetic field making the resonance frequency sensitive to subtle shifts and changes in the surrounding permittivity. The FSS-based array achieves a significant gain enhancement from 3.06 dBi to 7.35 dBi, while maintaining total efficiency >80% across the band with peak efficiency of 92%.

3.09 A Scalable Hybrid ISAC Architecture with Simplified Front-End Design and Unified Antenna Aperture

Jeonghyo Lee (POSTECH, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))

For the first time, this paper presents a scalable hybrid Integrated Sensing and Communication (ISAC) architecture featuring a simplified front-end design and a unified antenna aperture that enables simultaneous operation across distinct frequency bands. The proposed system incorporates a dual-polarized 28 GHz multi-functional radiator (MFR) array for steerable communications, complemented by a pair of 60 GHz slot antennas designed for omnidirectional sensing. The MFR establishes both hard and soft surface boundaries, effectively suppressing radiation distortion and enhancing gain within the sensing band. The antenna demonstrates wide 3 dB dual-polarized scan coverage with a peak realized gain of 9.7 dBi at 28 GHz, while delivering 7.2 dBi omnidirectional performance at 60 GHz. This scalable and unified architecture offers a compact, low-profile solution that is suitable for expansion into large-scale ISAC applications, ensuring high hardware efficiency throughout.

3.10 Microwave Permittivity Sensor Using 1D Photonic Crystal Resonator

Ali Sameeh Saleh Alhaj Abbas (Interdisciplinary Research Center for Communication Systems and Sensing, Saudi Arabia & King Fahd University of Petroleum and Minerals, Saudi Arabia); Ibraheem Al-Naib (King Fahd University of Petroleum & Minerals, Saudi Arabia)

This paper presents a 3D-printed, all-dielectric, one-dimensional photonic crystal (1D PhC) resonator for wireless dielectric permittivity sensing. The structure consists of alternating high- and low-permittivity layers forming Bragg reflector pairs around a central defect layer. The 80 mm × 80 mm resonator is excited in free space, showing a backscattering notch near 14 GHz for a 5.5 mm-thick defect. Full-wave EM simulations are performed by placing thin dielectric layers (εr = 1.0-12.0) on the defect side, producing measurable resonance shifts that depend on both permittivity and thickness. Average sensitivities of 460 MHz/RIU and 718 MHz/RIU are obtained for 0.3 mm and 0.5 mm layers. The sensor is 3D-printed from low-loss cyclic olefin copolymer (COC) and experimentally validated using thin plastic layers. Clear resonance redshifts up to 495~MHz are observed for three stacked 0.5 mm layers.

Thursday, April 23 13:30 - 14:40

P3-AO2 Millimetre wave and THz for terrestrial networks

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 3

3.11 Exponentially Graded Periodic Patch Lattice Loaded 20-50 GHz Corrugated Horn Antenna with Stable Beam Shape

Youpeng Bao (South China University of Technology, China); Xue Ren (Shenzhen University, China); Yinghao Zhang, Shaowei Liao and Quan Xue (South China University of Technology, China)

TThis paper presents a compact 20-50 GHz corrugated horn antenna that achieves stable beamwidth in both E- and H-planes within the entire bandwidth. The antenna is excited via a coaxial connector, and a grounded coplanar waveguide (GCPW)-to-ridge line transition on the substrate enables a wideband interface between the coaxial feed and the horn. Corrugations at the aperture ensure stable H-plane beamwidth, while an exponentially graded periodic patch lattice, printed on the substrate beneath the ridge line, effectively excites and controls higher-order modes to stabilize the E-plane beamwidth across the operating band. The proposed design delivers consistent radiation performance with a small aperture of $1.3\lambda_0$ times $1.0\lambda_0$, where λ_0 is the free-space wavelength at 20 GHz. Measured results demonstrate a gain of 10-11.5 dBi over 20-50 GHz and stable 10-dB beamwidths in both principal planes, with beamwidth variation ratios of 1.08 (E-plane) and 1.25 (H-plane) across the band.

3.12 A Low-Profile Waveguide Antenna with Null-Free Pattern for D-Band 2-Dimensional Radar Sensing

Haowei Li (Queen's University Belfast, United Kingdom (Great Britain) & QUB, United Kingdom (Great Britain)); Chao Gu (Queen's University Belfast, United Kingdom (Great Britain)); Zhiwei Zhang (School of Electronics and Information, Hangzhou Dianzi University, China); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain))

This paper presents the design of a low-profile D-band waveguide antenna that realizes a null-free radiation pattern through metasurface-based surface-wave control. Corrugated metasurfaces are integrated along the co-polarization direction of the waveguide antenna, which corresponds to the linear array axis, to modify the E-plane radiation characteristics. This configuration results in a continuous magnitude distribution and a smooth phase response without pattern nulls. The concept is further extended to antenna arrays for multiple-input multiple-output (MIMO) applications, where the null-free radiation characteristic facilitates low-interference detection and two-dimensional (2D) continuous direction-of-arrival (DoA) estimation. Full-wave simulations demonstrate that, with four virtual arrays spaced at 0.5λ0 intervals (λ0 denoting the free-space wavelength at 120 GHz), the proposed antenna achieves a DoA estimation accuracy better than ±1° within a ±40° field of view in the co-polarization plane. These results demonstrate a promising approach for short-range sensing and detection.

3.13 Phased Array Antenna-in-Package Using 3D Integration Technology for 6G Applications

Victoria Gómez-Guillamón Buendía (TNO, The Netherlands); Alessandro Garufo (TNO Defense Safety and Security, The Netherlands); Ayad Ghannam (3DiS Technologies, France); Mustafa Acar (NXP Semiconductors, The Netherlands); Roland Bolt (TNO - Defence, Security and Safety, The Netherlands); Marcel Geurts (NXP Semiconductors, The Netherlands); Francesca Chiappini (Chip Integration Technology Centre CITC, The Netherlands); Stefania Monni (TNO Defence Security and Safety, The Netherlands)

A dual-polarised phased array antenna-in-package (AiP) for millimeter-wave and sub-THz 6G applications is proposed. The innovative 3D packaging technology allows for multilayer 3D coaxial interconnections and metallic vertical walls inside the package, improving field confinement and expanding design options compared to conventional AiP structures based on laminates. Test structures are manufactured to characterise the RF performance of this technology up to 110 GHz for accurate AiP design. Simulations for a dual-polarised infinite array with aperture coupled stacked patches at 96 GHz show -10 dB impedance bandwidth of 15% for a scanning range of ±50 ◦ in the E- and H-planes. This design has a significantly improved radiated efficiency due to the better field confinement, and wideband scanning performance compared to the state-of-the-art for phased array AiPs in the sub-THz band. The highly directive, wideband scanning and dualpolarisation capabilities of the proposed array make it suitable for the upcoming 6G communication applications.

3.14 Element Radiation Pattern Optimization for Phased Array Base Station in System Level Design

Xuankai Zhao, A. B. (Bart) Smolders and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

This paper presents a study on the radiation pattern optimization of the element antenna for the multiple user (MU) multiple input and multiple output (MIMO) base station in the system-level design. The system performance was evaluated by investigating the probability that a user experiences an outage. The results showed that when the radiation pattern is derived from the probability density function (PDF) of users, the array will achieve the best system performance with an outage probability of 0.17%, compared to the system performance of 0.82% from the traditional isotropic radiator and 0.51% from the hemispherical radiator. A radiation pattern based on the path loss difference inside a cell has also been derived. It shows identical behaviour as the PDF based pattern.

3.15 Millimeter-Wave Dual-Polarized Dynamic Metasurface Antenna with Spatial Decoupling

Rongguang Song, Haifan Yin, Xilong Pei and Lin Cao (Huazhong University of Science and Technology, China)

This paper presents a dual-polarized dynamic metasurface antenna based on a Fabry--Perot cavity with spatially decoupled transmissive amplitude and reflective phase. Varactor-loaded slotted units realize voltage-tuned transmission, while 1-bit PIN-switched reflective units provide independent phase control for two orthogonal polarizations. At 26GHz, full-wave simulations and measurements show a 19.2dB transmissive amplitude range and a 177° reflective phase jump, with less than 20° phase perturbation during amplitude tuning. Cross-polarization isolation on the transmissive path is better than -50dB, and reflective dual-polarization isolation is better than -20dB. A 9×9 array with a 6.3mm cavity height achieves 12.7 % impedance bandwidth and 12.7dBi peak gain with good port isolation. Phase-only control supports high-quality steering within 15°; for 30°-60°, adding transmissive amplitude shaping improves main-lobe pointing and profile. These results validate the effectiveness and practicality of the proposed architecture for millimeter-wave arrays.

3.16 High Polarization Purity 0.1 - 0.3 THz Frequency Selective Surface Polarizer in Reflection

Carlos Martínez Herreros, Roberto Garrote and Miguel Salas-Natera (Universidad Politécnica de Madrid, Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain); Alvaro Fernandez Tuesta, Sr (Universidad Politécnica Madrid, Spain); Ramón Martínez (Universidad Politécnica de Madrid, Spain)

The motivation behind this research stems from the need to identify practical indoor applications for 6G technology. While terahertz communications promise ultra-wide bandwidths and terabit-per-second speeds, a major challenge remains the realization of transceivers suitable for integration into indoor and pico-cell WLANs. The proposed FSS architecture tackles these issues through a compact, low-profile design that mitigates volumetric limitations, reduces system complexity, and improves cost-effectiveness, facilitating large-scale deployment. This innovative approach enables dual polarization in both Co-Polar (CP) and Cross-Polar (XP) modes without requiring complex multiport networks, simplifying the overall system and enhancing versatility. Operating in reflection mode, the FSS produces ultra-wideband circularly polarized fields with two distinct frequency bands for opposite circular polarizations. Consequently, both CP and XP operations become feasible with minimal phase variation, providing a practical pathway toward next-generation 6G communication systems operating in the sub-terahertz domain.

3.17 Sequentially Rotated 2x2 GW-Based Antenna Array at Q/V-Band

Iñigo Leoz-Beltrán (Public University of Navarre, Spain); JuanCarlos Iriarte (Public University of Navarra & Antenna Group, Spain); Dayan Pérez-Quintana (KTH Royal Institute of Technology, Sweden); Fernando Teberio (Anteral, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain)

This paper discusses a gap-waveguide circular-polarization array, based on a sequential rotation configuration. In order to reduce the number of layers required, a combination of half-mode and ridge gap-waveguide is proposed. The building blocks for a 2x2 array cell are presented and their design trade-offs discussed.

3.18 Comparison of Electrical and RF Characteristics with PCB Antenna and Micromachined Glass/PCB Antenna Bonded Using Solder Cream

Sung-min Sim (Jeonbuk National University, Korea (South)); Jeong-Ung Yoo (Agency for Defense Development, Korea (South)); Hae-Won Son (Jeonbuk National University, Korea (South)); Donggu Im (Chonbuk National University, Korea (South)); Jung-Mu Kim (Jeonbuk National University, Korea (South))

This paper presents 28 GHz 1×8 antennas fabricated using a conventional PCB process and an adhesive bonding process with micromachined glass and PCB substrate. We evaluate the sensing-port-to-sensing-patch path by measuring series resistance and inductance at 100 kHz. Impedance measurements from sensing-port-to-sensing-patch show R ≈ 2.38 mΩ, L ≈ 3.13 nH for the PCB antenna, and R ≈ 567 mΩ, L ≈ 3.25 nH for the micromachined glass/PCB antenna bonded using solder cream. We analyze the RF characteristics of both the PCB and the micromachined glass/PCB antenna. Measured results show that the micromachined glass/PCB antenna achieves a 29.2% 10-dB return-loss bandwidth (26.3-35.3 GHz), broader than 24% for the PCB antenna. Coupling between orthogonal ports is < -15 dB, and adjacent-element coupling remains < -20 dB across the band. The antenna realized with the micromachined glass/PCB process using the solder cream demonstrates a wideband operation.

3.19 Series-Fed Patch Array for D-Band Sensing in Low-Cost Single-Layer PCB Technology

Samuel Rimbaut (Universiteit Gent, Belgium); Hendrik Rogier (Ghent University, Belgium); Sam Lemey (Ghent University-imec, Belgium); Kamil Yavuz Kapusuz (Ghent University-Imec, Belgium); Pieterjan Roeykens (UGent, Belgium)

The design and experimental validation are presented of a D-band series-fed patch antenna array implemented on a low-cost single-layer Rogers RO4350B PCB. The array comprises ten patches excited through a microstrip series feed, offering a compact, low-profile and fabrication-tolerant architecture compatible with standard PCB processes. A PCB-to-waveguide transition is integrated to facilitate measurement and enable straightforward system integration. Experimental results show an bandwidth of 11GHz and realized gain above 11.5dBi, in good agreement with simulations, while revealing a slight underestimation of dielectric losses. The evaluation of multiple fabricated panels confirmed accurate via alignment but identified systematic overetching and a reduced effective dielectric constant of approximately epsilon_r of 3.4. These findings suggest the observed deviations are systematic and predictable, allowing compensation in future designs. Overall, the results demonstrate standard, low-cost PCB manufacturing using Rogers 4350B can reliably facilitate low-profile arrays at D-band frequencies, enabling practical and cost-effective solutions for next-generation radar.

3.20 A Dielectric Waveguide Based Sub-THz Repeater Leaky-Wave Antenna

Kevin K Mutai, Chloe Stults, Jeffrey Lei, Zhaoji Fang and Daniel M Mittleman (Brown University, USA)

In this paper, we propose an inexpensive dielectric waveguide based frequency scanning repeater designed to operate at 100 GHz. The repeater topology is based on a non-radiative dielectric waveguide, whereby a single dielectric rod made of low-loss polymer is sandwiched between two metal plates. The overall structure is carefully designed so that the guided wave propagating within the dielectric section is cutoff in the surrounding air region. The dielectric rod is curved and two slots are cut in the upper plate to couple the evanescent wave from the rod to free space. The resulting leaky-wave antenna (LWA) is capable of receiving or radiating toward both the forward and backward quadrants and we intend to use it in a repeater setup.

3.21 Via-Less Log-Periodic Antenna for Emerging Millimeter-Wave Applications

Matthieu Egels and Chaouki Hannachi (Aix Marseille University, IM2NP, France); Philippe Pannier (IM2NP, France)

This article proposes the design and implementation of a via-less Log-Periodic antenna for millimeter-wave emerging applications. In log-periodic configurations, the use of vias in the antenna design may result in high gain over a wide frequency band. However, at millimetre-wave frequencies, via-hole implementation is complex to achieve accurately, as it introduces parasitic elements and impacts the repeatability of measurements and fabrication costs. To address this issue, we propose a log-periodic antenna configuration involving a simplified ending technique based on a quarter-wave open-ended radial stub. The proposed concept is experimentally validated through the design and fabrication of a millimeter-wave Log-Periodic Antenna operating over the 57-66 GHz band. Simulations show that both via-terminated and quarter-wave open-ended radial stub antennas exhibit similar performance. The proposed prototype measurements indicate a maximum gain of 10.2 dB at 60.5 GHz, accompanied by good impedance matching over a frequency range of 55 to 70 GHz.

3.22 Design Optimization of a Shared-Aperture HMSIW Antenna for Dual-Band Microwave and Millimeter-Wave Applications Using BP-ANN

Saqer S Alja'afreh (American International University, Kuwait); Amjaad Altakhaineh (Khalifa University, United Arab Emirates); Yi Huang (University of Liverpool, United Kingdom (Great Britain)); Chaoyun Song (King's College London, United Kingdom (Great Britain))

The proposed antenna comprises of two QMSIW cavities, a U-shaped slot, and a small patch. The U-shaped slot divides the HMSIW cavity into two equal QMSIW sections, each excited by a 50 Ω feedline, enabling broadband operation from 39.5 to 43.5 GHz with MIMO operation. The fundamental microwave band at Port 3 is excited by reusing the overall HMSIW cavity via a small patch, achieving operation from 10.35 to 10.45 GHz. As the dual-band operation is primarily controlled by two design parameters, the U-shaped slot length and the gap between the QMSIW and the small patch, both influence the upper-band matching and the lower-band return loss. To optimize these parameters, a multi-output BP-ANN model is trained using CST Microwave Studio simulation samples, where Ls and g serve as inputs, and the figure of merit of the upper band and the absolute return loss (S33) of the lower band are outputs.

3.23 A Ka-Band 3-dB Coupler Based on E-Plane Groove Gap Waveguides

Davood Zarifi (Gdansk University of Technology, Poland); Ali Sabbaghi Saber (University of Kashan, Iran); Ali Farahbakhsh (Gdansk University of Technology, Poland & Graduate University of Technology, Iran); Michal Mrozowski (Gdansk University of Technology, Poland)

A compact 3-dB directional coupler utilizing E-plane groove gap waveguides is proposed for Ka-band applications. Simulation results demonstrate that the coupler achieves return loss and isolation levels exceeding 15 dB. Additionally, it maintains a power-split imbalance of ±0.8 dB across a wide frequency range of 26-35 GHz, corresponding to approximately 30% relative bandwidth. This coupler is highly suitable for integration into wideband and compact beamforming feed networks and Butler matrices used in millimeter-wave antenna arrays.

3.24 Design of Broadband Filtering Patch Antenna Based on Parasitic Mode Transition

Shi-Hang Yan, Qing Luo, Yi Gong and Xiaowei Zhu (Southeast University, China)

In this paper, a millimeter-wave filtering patch antenna with a broad band is presented. The filtering antenna is composed of a feeding microstrip, a radiation patch, and four parasitic patches. The radiation null at the upper band is introduced by the mode transition of the parasitic patches, and the transmission null at the lower band is introduced by the short-circuited SIR feeding microstrip. Furthermore, the open-ended branches on the feedline could suppress the upper-band radiation and improve the frequency selectivity of the filtering antenna. Additionally, the triangular notches on the parasitic patches could adjust the surface current and broaden the operating frequency bandwidth. The measured results show that the filtering antenna achieved a bandwidth of 19.9-28.1GHz (34% relative bandwidth) with the gain higher than 5 dBi, and the out-of-band suppression is higher than 21.5 dB.

3.25 Compact Low-Loss Frequency Switches for Broadband Multi-Service Automotive Antennas

Maximilian Holzner (Universität der Bundeswehr München, Germany); Juan Francisco Lentner Ibañez (Universitaet der Bundeswehr Muenchen, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

In automotive applications, antennas for lots of different services have to be integrated inside a small common mounting space. This leads to mutual coupling and distorted radiation patterns. In order to prevent these effects, we present an easy and fast way to convert a broadband or multi-band antenna to act as a multi-functional antenna with different ports for its services. For the example of a wideband terrestrial automotive antenna, different frequency switches are investigated to separate multiple signals at the feed point of one master antenna to connect the terrestrial mobile services 5G, V2X communications, WLAN and Bluetooth each at another port respectively. For these ports, the main intention is to achieve as much antenna gain as possible at the respective receiver together with simultaneous suppression of non-used frequencies. Different frequency switches and their influence on the antenna gain are investigated at the example of a wideband palm tree antenna.

3.26 Measured Performance and CST-Based Analysis of UWB Vivaldi Antenna for Wind Turbine Blade Health Monitoring

Sahar Saleh (Atlantic Technological University, Ireland & Aden University, Yemen); Tale Saeidi (Atlantic Technological University, Ireland); Qusay Shihab Hamad (University of Information Technology and Communications, Iraq & Universiti Sains Malaysia, Malaysia); Nick Timmons (Atlantic Technological University, Ireland); Faroq Razzaz (Prince Sattam Bin Abd, Saudi Arabia); Shahanawaz Kamal (Barkhausen Institut, Germany)

Monitoring wind turbine blade structural health reduces catastrophic failures and maintenance costs. Compact UWB Vivaldi antenna with radial-to-radial microstrip-to-slot transition (VTSAR) built and tested via CST simulations and tests. The proposed VTSAR has a 3.29-18.21 GHz impedance bandwidth (S11 < -11.13 dB), 7.2 dBi gain, and 65%-94.08% radiation efficiency. The design delivers 30.7% wider bandwidth, 27.8% higher gain, and 11.4% smaller size than typical VTSA, while maintaining continuous group delay (~1 ns) and guided radiation patterns for UWB applications. For structural monitoring applications, GFRP, CFRP, hybrid composites, and PETG blade shell materials were tested with the link budget (S21). Two VTSAR antennae were put at blade model tips and roots. Material properties strongly affect transmission, making PETG useful for laboratory prototyping and flaw detection studies. This CST-based study is the first to combine material variation analysis with UWB Vivaldi antenna simulated and observed validation for wind turbine blade monitoring.

3.27 Single-Feed Circularly Polarized Super Realized Gain Antenna

Georgia Psychogiou (University of Patras, Greece); Donal P Lynch (Queen's University Belfast, United Kingdom (Great Britain)); Spyridon Nektarios Daskalakis (Heriot-Watt University, United Kingdom (Great Britain)); Manos M Tentzeris (Georgia Institute of Technology, USA); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Stylianos D. Asimonis (University of Patras, Greece)

This paper presents a super realized gain, circularly polarized strip-crossed dipole antenna operating at 3.5 GHz. Superdirective behavior is achieved by leveraging strong interelement mutual coupling through careful adjustment of the strip dimensions. The antenna features a single driven element, with the other element passively loaded with a reactive impedance. The structure is optimized to maximize left-hand circularly polarized (LHCP) realized gain, ensuring high polarization purity and good impedance matching. The optimized design exhibits a 50 Ω impedance bandwidth of 3.29-4.17 GHz (23.75%) and an axialratio bandwidth of 3.43-3.57 GHz (4%). At 3.5 GHz, the antenna achieves a peak realized gain of 6.1 dB (ka ≈ 1.65), with an axial ratio of 1.4 dB. These results demonstrate that circular polarization and superdirectivity can be simultaneously realized in a geometrically simple, low-profile (0.15λ) antenna, rendering it suitable for integration into compact sub-6 GHz wireless and sensing platforms.

Thursday, April 23 13:30 - 14:40

P3-A03 Slotted-waveguide and leaky-wave antennas

TO4 RF sensing for automotive, security, IoT, and other applications / / Antennas

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 3

3.28 A Novel Irregular Ground Holographic Leaky Wave Antenna Design

Bilge Kaan Acikgoz (University of Birmingham, United Kingdom (Great Britain)); Irsat Gulen (University of Birmingham, United Kingdom (Great Britain) & University of Huddersfield, United Kingdom (Great Britain)); Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain))

A novel 2-D TM mode holographic leaky wave antenna is presented. In conventional holographic leaky wave antennas non-uniform metasurfaces are designed based on the holographic principle by varying the size of metallic patches to obtain the desired radiation angle. In this design, a novel method is proposed for designing holographic antennas, based on an irregular ground under a uniform metasurface. The calculated holographic pattern and required impedances are obtained by adjusting the distance between the metasurface and the non-planar ground plane. The new method may lead to a novel approach to antenna reconfiguration and a new design for holographic leaky wave antennas. Simulations in CST Microwave Studio demonstrate that the irregular ground holographic antenna achieves a directivity of approximately 18 dBi.

3.29 Analytical Investigation of a Single-Band L-Shaped Leaky-Wave Antenna for 2D Direction-of-Arrival Estimation

Tanguy Lopez, Aritra Roy, Amel Haddadi and Julien Sarrazin (Sorbonne Université, France)

An analytical model of a leaky-wave antenna (LWA), using an array factor formulation, is extended here to a dual-branch configuration forming an L-shaped radiating structure. This configuration enables two-dimensional (2D) beam scanning by exploiting the fundamental spatial harmonic in two orthogonal planes. The analytical model provides closed-form predictions of the antenna radiation pattern and directivity. A 2D autocorrelation technique is then applied to the calculated directivity maps perform the direction-of-arrival (DoA) estimation of a radiating source within the scanned angular region. The results demonstrate that the proposed L-shaped LWA can accurately determine the source location using only its intrinsic radiation characteristics, confirming the effectiveness of the analytical approach for spatial localization and DoA applications.

3.30 A 35-GHz Dual-Polarized Slotted Waveguide Array Antenna Design

Kyongnam Park (Korea Electronics Technology Institute (KETI), Korea (South)); Jongin Ryu (Korea Electronics Technology Institute, Korea (South))

This paper presents a dual-polarized slotted waveguide array antenna operating at 35 GHz. The radiating slots are designed using the Dolph-Chebyshev distribution to achieve low sidelobe levels (SLLs). The proposed structure integrates vertical and horizontal polarizations within a single metallic body, each independently excited by a dual-sided feeding network. Structural symmetry was maintained by inserting a dummy block and implementing sidewalls to compensate for feeding asymmetry. The antenna was fabricated from aluminum with a gold-plated finish, and slot corners were rounded to reduce computer numerical control (CNC) machining tolerances. Measurements show stable radiation characteristics at 35 GHz, achieving realized gains of 21.86 dBi and 21.35 dBi for the H- and V-polarized arrays, with corresponding SLLs of -26.3 dB and -21.9 dB. Cross-polarization levels remained below -25 dB, confirming the effectiveness of the proposed dual-polarized configuration.

3.31 Meandered Dispersive Ridge Gap Waveguide for Low-Loss Fast-Scanning Leaky-Wave Arrays

Marco Nieto-Perez (Universitat Politècnica de València & Antennas and Propagation Lab, Spain); Jose I. Herranz-Herruzo (Universitat Politècnica de València & APL - iTEAM, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València & Antennas and Propagation Lab, Spain)

This communication presents a modified ridge gap waveguide with highly dispersive behavior and low-loss propagation. This new waveguide, based on a corrugated ridge along a meandered path, permits the design of high-efficiency, yet fast frequency-scanning, leaky-wave arrays. A comparative loss study between the proposed geometry and a non-meandered corrugated ridge gap waveguide is presented. A design example of a linear slot array based on this new waveguide has been proposed. The linear slot array covers a field of view from -23° to +20° within 1-GHz bandwidth, while maintaining a radiation efficiency above 70%. The obtained results confirm the suitability of the proposed geometry for tailoring low-loss fast-scanning all-metal leaky-wave arrays in the mm-wave band.

3.32 A Half-Mode CSIW Leaky-Wave Antenna with Horizontal Beam-Scanning and Stable Radiation

Goksel Turan (Karadeniz Technical University, Turkey); Gokhan Cinar and Hayrettin Odabasi (Eskisehir Osmangazi University, Turkey); Ihsan Kanbaz (Gazi University, Turkey); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Conventional leaky-wave antennas (LWAs) typically scan their beams through the broadside direction, while designs capable of side-fire beam-scanning are significantly less common. This paper presents a wideband horizontal beam-scanning LWA with stable radiation characteristics, based on a half-mode corrugated substrate integrated waveguide (HMCSIW). The antenna's leaky-wave radiation response is realized by adding square rings to the ground plane of the HMCSIW. Furthermore, the incorporation of circular rings on the antenna's front surface enhances the stability of the side-fire beam-scanning performance. The proposed antenna achieves horizontal beam-scanning over a frequency range of 13 to 22.5 GHz, corresponding to a 53.5% bandwidth. It exhibits a peak gain of 12.7 dBi with a maximum variation of 2.1 dBi, a beam-scanning range from -35° to 35°, and an average efficiency of approximately 90%. The proposed antenna can be an intriguing choice for microwave imaging applications, spectrum analysers, and next-generation radar systems.

3.33 Broadband Frequency-Stable Monopulse Response in SIW End-Fire Leaky Horn Antennas

Andrés Biedma-Pérez and Cleofás Segura-Gómez (University of Granada, Spain); Lei Wang (Lancaster University, United Kingdom (Great Britain)); Angel Palomares-Caballero and Pablo Padilla (University of Granada, Spain)

This work presents a low-profile end-fire leaky horn antenna featuring frequency-stable monopulse behavior, based on substrate integrated waveguide (SIW) technology. The design integrates two SIW leaky-wave antennas (LWAs) angularly combined to form the horn flaring. The use of LWAs increases directivity without large feeding networks, while the mirror configuration compensates their dispersive effect, enabling broadband monopulse estimation for radar applications. A prototype was designed and fabricated at millimeter-wave frequencies, consisting of a hybrid coupler and phase shifters integrated on the same substrate. This configuration achieves in-phase and out-of-phase excitations of the LWAs, generating the sum (Σ) and difference (Δ) radiation patterns. Measurements show good agreement with simulations, with reflection and isolation coefficients better than -14 dB. A 10% bandwidth is achieved, limited only by the feeding network, and a null depth of -26 dB at 27.5 GHz enables accurate target detection with a 15° field of view.

3.34 Ultra-Wideband Inkjet Printed Grounded Coplanar Waveguide-to-Folded Waveguide Transition

Berkay Dogan (University College Cork, Ireland & Tyndall National Institute, Ireland); Dimitra Psychogiou (University College Cork and Tyndall National Institute, Ireland)

This paper presents the design and practical development of an ultra-wideband 3D grounded coplanar waveguide (GCPW)-to-folded waveguide (FWG) transition for beamforming antenna systems in X/Ku-band. It is based on a two-stage configuration comprising a three-dimensional (3D) vertical taper transition and a shielded stripline. A novel integration concept using a two-material piezo drop-on-demand process is proposed for ultra-compact 3D monolithic integration. For proof-of-concept validation purposes, a prototype comprising two transitions in a back-to-back configuration was designed and tested. It exhibited a center frequency of 13.3 GHz, a 10-dB return loss (RL) bandwidth (BW) from 9.08 GHz to 17.54 GHz, (i.e., absolute BW of 8.46 GHz) and a fractional BW (FBW) of 63.61 %. In this BW, the in-band insertion loss (IL) was measured between 1.05-3.66 dB.

3.35 Hollow-Core Waveguide for D-Band: A Low-Profile 3D-Printed Design

Shehab Khan Noor (University of New South Wales, Australia & Terahertz Innovation Group, Australia); Shaghik Atakaramians (University of New South Wales Sydney, Australia); Mengqin Gu (UNSW, Australia); Sining An (Ericsson Research, Sweden); Deepak Mishra (University of New South Wales (UNSW) Sydney, Australia); Heike Ebendorff-Heidepriem (University of Adelaide, Australia)

In this work, a hollow core fiber with circular structure and antiresonant guiding mechanism is 3D printed and characterised to operate at the D-band region of the Terahertz spectrum from 0.130 to 0.170 THz. In addition, aluminum foil was wrapped around the outer surface of the proposed fiber to act as a metallic layer. The dielectric material used is topas polymer and the fiber was printed using a fused deposition modelling 3D printer. The measured transmission spectrum demonstrated five antiresonance regions from 0.1 to 1 THz. With an outer diameter of 4.88 mm, the proposed fiber at 0.158 THz obtained the lowest simulated and measured loss of 5.6 dB/m and 11.9 dB/m, respectively. To the best of the authors' knowledge, the proposed fiber has the lowest loss and smallest fiber dimension among the reported 3D printed hollow core fibers.

3.36 Polarization Diverse Four-Port Leaky-Wave Antenna Offering Solar Cell Integration

Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain)); Iram Shahzadi (The University of Edinburgh, United Kingdom (Great Britain)); Davide Comite (Sapienza University of Rome, Italy); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

This work proposes a new 4-port dielectric-based leaky-wave antenna engineered for integration with solar panels. It operates within the K-band frequency range from about 19.5 to 22 GHz. The antenna features an agile feeding system capable of supporting single-port, dual-differential, and circular polarization operating states, thereby significantly enhancing its flexibility. Building upon prior designs, the antenna employs a substrate integrated waveguide feed structure, replacing the conventional partial reflective surface with a high dielectric constant material, suitable for solar panel integration. While optimized for operation at 20 GHz - chosen for satellite communication applications - it can be reconfigured to operate effectively at other frequencies. Moreover, the design offers a highly directive radiation pattern, effectively combining efficient antenna performance with solar power harvesting capabilities. Notably, the antenna achieves an efficiency of approximately 80%.

Thursday, April 23 13:30 - 14:40

P3-EO1 Computational and Numerical Techniques

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 3

3.49 Calculation Accuracy Improvement of FDTD Analysis Utilizing Bayesian Optimization

Haku Inanobe and Takuji Arima (Tokyo University of Agriculture and Technology, Japan); Wataru Yamada (NTT Corporation, Japan)

This study is motivated by problems that require high-accuracy electromagnetic analysis with low computational cost, such as base-station area optimization in wireless communications. In the finite-difference time-domain (FDTD) method, reducing the cell size improves accuracy but increases computational cost, whereas enlarging the cell size reduces calculation time, however, causes accuracy degradation near conductors where the electric field varies sharply. To address this issue, this study proposes a correction-coefficient method that minimizes the error calculated from the electric-field distribution on a two-dimensional plane near conductors, using Bayesian optimization. As a result, it was confirmed that the proposed method enables coarse-grid analyses to achieve electric-field distributions close to those of high-resolution reference models.

3.50 OpenBEM: A Flexible Open-Source Framework for Electromagnetic Simulation with the Boundary Element Method

Shashwat Sharma (University of Birmingham, United Kingdom (Great Britain))

An open-source framework, OpenBEM, for electromagnetic simulation with the boundary element method is introduced. OpenBEM is designed to be flexible and extensible, and is targeted at researchers, educators, and students in the field of computational electromagnetics. It provides implementations of standard algorithms for the building blocks of common surface integral equation formulations. The design philosophy and structure of OpenBEM is discussed, and canonical numerical examples are presented to verify the accuracy of the software.

3.51 Numerical Modelling of the Electromagnetic Fields of High Voltage Three-Phase Submarine Cables

Herman Alexander Jaeger (Tyndall National Institute, Ireland & University College Cork, Ireland); Anika Cho (University of Texas at Austin, USA); Alfonso Cohuo, Danielle Orrell and Damien Haberlin (University College Cork, Ireland)

Submarine power transmission cables give rise to extremely low frequency electromagnetic fields in the surrounding seawater. There is significant interest on the behavioural effects of these fields on aquatic wildlife and the impact that these fields may have on habitats over time as the development of offshore windfarms accelerates. The electromagnetic behaviour of such current-carrying structures in seawater is well established, however a direct validation of the theory with modern finite-element tooling is lacking. This paper validates the established theory against finite element simulations. Cables are modelled as quasi-static alternating current sources of infinite length. Analytical expressions for the electric and magnetic fields produced by a three-phase interconnector are presented and compared with results from commercially available finite element software. This work will be a useful resource for further investigations into the impact of offshore energy sources on aquatic wildlife and subsequent planning of future submarine transmission cables.

3.52 Exploring Diffraction and Frequency Conversion Mechanisms in Space-Time Dielectric Gratings

Antonio Alex-Amor and Pablo Andrés Carrión-Díaz (Universidad Autónoma de Madrid, Spain); Mario Pérez-Escribano (Universidad de Málaga, Spain); Carlos Molero Jiménez (Universidad de Sevilla, Spain); Alfonso Tomás Muriel-Barrado (Universidad Autónoma de Madrid, Spain)

Space-time modulation has enabled a new class of electromagnetic devices with capabilities beyond those of conventional time-invariant systems, including non-reciprocity, frequency conversion, and dynamic wave control. In this paper, we perform some preliminary studies on the diffraction and frequency conversion properties of space-time dielectric gratings. We develop and validate a simplified in-house finite-difference time-domain (FDTD) tool to analyze their electromagnetic response. Results demonstrate that these space-time metagratings can manipulate the frequency spectrum in ways not achievable with static gratings, showing promise for applications in RF, optics, and emerging technologies.

3.53 Modeling of Electromagnetic Attacks to Prevent Sensing or Communication Capabilities of Wi-Fi

William Alexander Taylor, Oluwakayode Onireti and Shuja Ansari (University of Glasgow, United Kingdom (Great Britain))

Wi-Fi networks can use radio-frequency (RF) signals not only for data transmission but also for environmental sensing, enabling joint communication-sensing functionality. This paper investigates electromagnetic (EM) attacks that selectively degrade either communication or sensing. A Raspberry Pi-based platform is configured to recognize three human activities while simultaneously streaming video. Activity classification uses six AI algorithms (CNN-LSTM, CNN, LSTM, k-Nearest Neighbors, Random Forest, and Support Vector Machine) applied to Wi-Fi signal data. Targeted EM attacks are launched to reduce either sensing accuracy or communication reliability. Experiments show that communication-focused attacks severely impair video streaming while only slightly affecting sensing, whereas sensing-focused attacks sharply reduce classification accuracy with minimal impact on data transmission. These findings demonstrate that EM attacks can be tailored to control the operational capabilities of Wi-Fi systems in complex electromagnetic environments.

3.54 Tunable THz Antenna Based on Dielectric Cylinder with Graphene Strips Inside

Mstyslav Kaliberda (Karazin National University of Kharkiv & Institute of Radio Astronomy of National Academy of Science of Ukraine, Ukraine); Sergey Pogarsky (Karazin National University of Kharkiv, Ukraine); Alexander I. Nosich (IRE NASU, Ukraine)

The terahertz range radiation of the H-polarized electromagnetic line source wave in the presence of a circular dielectric rod loaded with embedded coplanar graphene strips is studied. We cast the problem to a hypersingular integral equation for the strip currents and solved numerically using a Gauss-Chebyshev quadrature scheme. The results demonstrate that graphene strips enable dynamic tuning of dielectric rod's electromagnetic response through the chemical potential, including controllable switching of the main radiation beam between forward and backward directions near the plasmon-mode resonances of strips.

Thursday, April 23 13:30 - 14:40

P3-EO2 Other Topics on Electromagnetics

T07 Electromagnetic modelling and simulation tools / / Electromagnetics

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 4

4.01 Influence of Waterbolus on SAR Characteristics of Superficial Hyperthermia Applicator

Mable Alex (National Institute of Technology, Tiruchirappalli, India); Geetha Chakaravarthi (NITT, India)

This study presents the influence of water bolus (WB) shape, thickness, and water temperature on SAR matrices of superficial hyperthermia applicators. A 434 MHz circular ring antenna, made of Roger RO3010 substrate of dimension 54.5×54.5×1.524 mm³, is used for this study. Two different WB shapes, circular and square, are used for simulation and measurement, each with a thickness of 35 mm; the circular WB has a radius of 43 mm, while the square WB has dimensions of 80 mm × 80 mm. In simulation, the circular WB shows an impedance match (-30 dB) compared to the square WB (-23 dB) and achieves a penetration depth of 13.3 mm versus 12.8 mm, indicating improved coupling. Varying WB thickness from 10 mm to 40 mm enhances the effective field size by up to 66%. The thermal simulation shows that the maximum temperature rise in the tumor can be adjusted by varying the temperature of the WB between 15 ◦ C and 45 ◦ C. Thus, WB influences the SAR matrices of the applicator used in superficial hyperthermia treatment.

4.02 Matching Medium for Microwave Bone Imaging Systems: Evaluating Transmission Line and Quarter-Wavelength Approaches for Broadband Operation

Amra Mehboob and Bilal Amin (University of Galway, Ireland); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Martin O Halloran and Adnan Elahi (University of Galway, Ireland)

The performance of microwave bone imaging for disease diagnosis can be enhanced by minimising the impedance mismatch at the antenna-skin interface. Conventionally, a suitable matching medium is introduced to minimise this impedance mismatch and thereby ensure maximum electromagnetic wave penetration into the skin surface. In this study, two approaches were evaluated to determine the optimal relative permittivity of the matching medium over the 1-12 GHz frequency range: one based on the transmission-line formalism for the immersed imaging setup and the other on the quarter-wavelength impedance matching method for the non-immersed imaging setup. Full-wave near-field simulations showed that employing the matching medium permittivity calculated using the transmission-line formalism resulted in an average reduction of 5.3 dB (70.7%) in reflected power at the interface, whereas the quarter-wavelength impedance matching approach yielded an average reduction of 2.8 dB (47.5%).

4.03 Single-Layer Infrared-Radar Bi-Stealth Metasurface Design Using Micro Metal Patch

Cheongmin Lee (Yonsei University, Korea (South)); Sung Sil Cho and Ic-Pyo Hong (Kongju National University, Korea (South)); Jong-Gwan Yook (Yonsei University, Korea (South))

This paper proposes a novel design methodology for realizing an infrared (IR)-radar bi-stealth metasurface within a single-layer structure. The proposed approach employs a micro metal patch (MMP) array with a sufficiently small period compared to the wavelength, thereby providing low-emissivity properties in the IR regime while maintaining radar cross section (RCS) reduction performance comparable to conventional structures in the radar frequency band. To validate the design, MMPs were integrated into a checkerboard metasurface, which was subsequently fabricated and measured. The RCS measurements confirmed that the proposed structure exhibited radar stealth performance similar to that of a conventional checkerboard metasurface, whereas forward-looking infrared (FLIR) measurements demonstrated low-emissivity characteristics comparable to those of a copper plate. These results verify that the proposed design methodology enables the implementation of a lightweight and cost-effective IR-radar bi-stealth metasurface in a single-layer configuration, offering high scalability for application to a wide variety of metasurface designs.

4.04 Spatiotemporal Surrogate Model-Based Dynamic Radar Cross-Section Estimation of Chaff Clouds

Jun-Seon Kim, Uk Jin Jung, Su Hong Park, Donghyun Kim, Moonhong Kim, Dongwoo Sohn and Dong-Wook Seo (National Korea Maritime & Ocean University, Korea (South))

This paper proposes an efficient surrogate modeling framework for dynamic radar cross-section (RCS) estimation of chaff clouds under diverse launch and environmental conditions. A high-fidelity computational fluid dynamics-discrete element method (CFD-DEM) model simulates the multiphysics behavior of chaff released from naval and airborne dispensers, generating aerodynamic datasets for training a Gaussian process regression (GPR)-based surrogate model. The surrogate model predicts the spatiotemporal evolution of chaff clouds with respect to wind and launch parameters. Dynamic RCS is then estimated by integrating the predicted distributions with the generalized equivalent conductor (GEC) and vector radiative transfer (VRT) methods. A real-time simulator with a graphical interface combines aerodynamic modeling, RCS estimation, and signal fluctuation analysis. Results show that the surrogate model achieves high accuracy-normalized mean absolute errors (NMAE) of 0.0085 for naval chaff and 0.0176 for aircraft chaff-while drastically reducing computational cost, demonstrating its practicality for real-time applications.

4.05 The Thermal Noise at the Output of a Matched Transmission Line

Andrea Neto, Laurens F.E. Beijnen, Paolo Sberna and Marco Spirito (Delft University of Technology, The Netherlands)

We propose a novel procedure to estimate the noise per unit of bandwidth available at a the output of a matched line. According to the new procedure the noise available at the input of transmission lines depends on the type of loss mechanism considered. We show that the thermal noise available is not k_B T whenever the dominant ohmic losses are the ones in the dielectric material. To explain the result we identify the dominant TEM modal solution in a strip-line guide as the only type of degree of freedom. An equivalent impedance is associated to the such degree of freedom, and its real part is used to define an equivalent thermal noise generator. High resistivity background materials lead to Electromagnetic energy decreasing for increasing frequencies. At the conference we will present the results of a campaign of experiments that should confirm the theory presented in the paper.

4.06 The Mode-Specific Nature of Transducer Design and Impedance Matching for Diatomic Magnetoinductive Waveguides

Samuel J Coogle, Connor B. Jenkins and Asimina Kiourti (The Ohio State University, USA)

We present a novel transducer design model for chained L-C resonators with diatomic periodicity known as diatomic magnetoinductive waveguides. We derive the characteristic impedance of the waveguide, finding it to be mode-dependent. We explore how each mode can be excited, describing the concepts of anti-symmetric and symmetric transducers for the first time in this context. Combining the concepts of mode-selective transducer design and mode-dependent characteristic impedance, we then provide and numerically validate sample transducer designs for a diatomic magnetoinductive waveguide. Indeed, we achieve a 10-dB passband for each mode, with low minimum path loss (5.9 dB) and more than 40 dB of isolation between the transducers. This work is foundational to real-world deployable systems based upon the exciting dual-band nature of diatomic magnetoinductive waveguides.

4.07 Generalized Transition Matrix Formulation for Metasurface-Based Radar-Absorbing Structures Using Surface Susceptibility Model

Inhwan Kim and Youngjae Yu (Yonsei University, Korea (South)); Wonho Choi (Korean Air R&D Center, Korea (South)); Jong-Gwan Yook (Yonsei University, Korea (South))

This paper proposes a generalized transition matrix (GTM) model for radar-absorbing structures (RAS) incorporating arbitrary metasurfaces. In the proposed method, the metasurface is represented as a zero-thickness sheet characterized by surface susceptibilities that satisfy the generalized sheet transition conditions (GSTCs). The equivalent surface currents on the aperture of the RAS are expressed through the GTM formulation, thereby reducing the number of unknowns associated with the interior region of the structure. The detailed formulation of the GTM model combined with the integral-equation-based GSTC method is presented, and numerical results are provided to validate the proposed approach.

4.08 Efficient Analysis of PEC-Backed Multilayer Dielectric Structures Using the Generalized Transition Matrix and Characteristic Basis Function Method

Youngjae Yu and Inhwan Kim (Yonsei University, Korea (South)); Ic-Pyo Hong (Kongju National University, Korea (South)); Jong-Gwan Yook (Yonsei University, Korea (South))

This paper presents an efficient method for analyzing metal-multilayer dielectric composite structures using the Generalized Transition Matrix (GTM) technique. Conventional full-structure analyses face rapidly increasing memory demands as the electrical size and complexity grow. The proposed approach divides the structure into layers, computes the scattering matrix for each layer sequentially, and combines them to obtain the overall electromagnetic response. To further improve efficiency, the Characteristic Basis Function Method (CBFM) is integrated into GTM. CBFM represents current distributions in subdomains with characteristic basis functions, reducing the degrees of freedom, memory use, and computational cost. Comparisons with the PMCHWT formulation confirm the accuracy and efficiency of the method. Numerical results show that the GTM-CBFM approach effectively analyzes electromagnetic scattering in multilayer PEC-dielectric structures, including those with PEC backing.

4.09 Dual Circularly Polarized High Gain MIMO Resonance Cavity Antenna for 6G Next Generation Radio Applications

Muhammad Hussain (Electronics and Telecommunication Research Institute, Daejeon, Korea (South)); Jaeseong Kim (Electronics and Telecommunications Research Institute & Korea University, Korea (South)); Hyunjong Choi (Korea University, Korea (South)); Minhyup Song (Electronics and Telecommunications Research Institute, Korea (South))

The proposed design methodology significantly improves the performance of a dual circularly polarized resonance cavity antenna (CP-RCA) by enhancing realized gain, aperture efficiency, and axial ratio (AR). Conventional RCAs typically employ complex, multi-layered circularly polarized partially reflecting surface (CP-PRS) superstrates to achieve circular polarization. In contrast, this work introduces a simplified, single-layer dual CP-PRS that realizes circular polarization at the design frequency of 7 GHz by ensuring the equal magnitudes and a ±90° phase difference between the orthogonal components of the transmitted waves. To further enhance the broadside realized gain, the CP-PRS is integrated with artificial magnetic conduction (AMC) unit cells, designed in compliance with Trentini's beamforming conditions. The proposed CP-RCA achieves a realized gain of 12.7 dBi, aperture efficiency of 27 %, and a remarkably low AR of 0.64 dB. Simulated results strongly validate the effectiveness of the proposed design methodology, highlighting its potential for advanced wireless communication systems.

4.10 Acceleration of Physical Optics Integral with Relational Databases

David Cabornero Pascual (University of Alcala, Spain); Diego Paramés (University of Alcalá, Spain); Ivan Gonzalez (Universidad de Alcala, Spain); Lorena Lozano and Felipe Cátedra (University of Alcala, Spain)

This work presents a set of algorithmic and architectural improvements to the Physical Optics (PO) method, aimed at enhancing its applicability to industrial-scale electromagnetic simulations. Building on previous research in diffraction modeling, relational databases-specifically PostgreSQL with its geospatial extension PostGIS-have been adopted to manage large volumes of geometric and intermediate data efficiently. The Gordon integral has been implemented natively in C within the database engine, significantly reducing computation time. Additionally, native spatial indexing and memory-aware data structures have enabled the simulation of complex scenarios on standard desktop hardware. An interpolation strategy has been introduced to accelerate ISAR image generation, allowing the reuse of previously computed integrals under small variations in frequency and scattering direction. The proposed framework eliminates memory bottlenecks and improves scalability, demonstrating its effectiveness through radar cross-section (RCS) and ISAR benchmarks. These results confirm the viability of database-driven PO simulations for real-world applications.

4.11 Near-Field Microwave Imaging Antenna Array for Inline Intrusion Detection of Processed Products

Calin I Maraloiu and Juan Felipe Gonzalez-Pardo (Politecnico di Torino, Italy); Jorge Alberto Tobon Vasquez and Marco Ricci (Wavision srl, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

The presence of foreign bodies in packaged products can be assessed exploiting inline microwave imaging (MWI) inspection systems. The purpose is to illustrate an insight of the product's composition according to the dielectric properties of its constituents, by processing the scattering parameters of an array of antennas. This allows to unveil the position and shape of any potential extraneous material, with the advantage of a non-invasive, non-destructive and real-time testing. While the resulting dielectric contrast reconstructions depict a visual and qualitative overview of the analyzed item, quantitative metrics are essential to objectively evaluate their outcome. In this paper, we exploit size, overlap and boundary metrics to investigate the performances of a MWI system, made of an array of extended gap ridged slotted horn antennas, in locating a glass sphere, placed inside a commercial cocoa-spread jar, all numerically modeled.

4.12 Near-Field SAR Imaging by Means of Implicit Neural Representations

Alejandro del Hoyo Vijande and Jaime Laviada (Universidad de Oviedo, Spain); Yuri Alvarez-Lopez and Fernando Las-Heras (University of Oviedo, Spain)

An implicit neural representation (INR) is a continuous, differentiable representation of a signal parameterized by a neural network. In the field of image processing, INRs have been successfully applied for super-resolution, denoising, and inpainting purposes. This work shows that their benefits can be exploited in near-field electromagnetic imaging. By combining synthetic aperture radar (SAR) processing with a convolutional neural network, a complex reflectivity image is generated, enabling the reconstruction of both metallic and dielectric targets. Moreover, these representations are robust to noise in the scattered field measurements, as the inductive bias of a convolutional decoder favors smooth, natural structures over noisy patterns.

4.13 Hybrid Use of a Hyperthermic Applicator to Enhance Microwave Imaging Performance

Jakub Kollár and Barbora Šmahelová (Czech Technical University in Prague, Czech Republic); Jan Vrba (Faculty of Biomedical Engineering, Czech Technical University in Prague, Czech Republic); Ondrej Fiser, Jr. (Czech Technical University in Prague & Faculty of Biomedical Engineering, Czech Republic)

Microwave imaging (MWI) has emerged as a promising technique for non-invasive monitoring of temperature changes during hyperthermia (HT) treatments. In head and neck HT, large-area applicators limit the placement of imaging antennas, reducing reconstruction sensitivity. This study investigates the impact of antenna proximity on MWI performance and explores the feasibility of using a clinical HT applicator as an additional imaging element. Numerical simulations were conducted using a patient-derived neck model with a superficial applicator, evaluated at multiple frequencies. Results show that reconstruction quality decreases with increasing distance between the target and antennas. Incorporating the HT applicator as an imaging antenna significantly improved image quality, particularly for clinically relevant tumor positions, with the best performance observed at 434 and 1250 MHz. These findings suggest that hybrid use of therapeutic applicators can enhance MWI monitoring without additional patient instrumentation, offering a practical strategy for constrained clinical geometries.

4.14 Upper Bound on Power Transfer Efficiency for Shallow Implants

Jakub Liška (Polytechnique Montréal, Canada); Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mingxiang Gao (ETH Zurich, Switzerland & IT'IS Foundation, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

This paper derives theoretical upper bounds on communication power efficiency for shallow biomedical implants and their external wearable counterparts. We formulate electromagnetic optimization problems to quantify the maximum attainable radiation efficiency of an implanted antenna and the maximum effective gain of a wearable receiver operating over realistic lossy tissue backgrounds. Numerical examples of representative shallow implant geometries validate the bounds and illustrate practical design implications. The results provide actionable guidance for antenna designers seeking to minimize device power consumption while maintaining reliable wireless links for medical sensing and monitoring.

4.15 Geometry-Based Analytical Modeling for Effective Permittivity in Meshed Microstrip Structures

Amira Merainani (IETR, France)

The design of transparent and lightweight microwave components increasingly relies on meshed conductors. Since standard solid-line models cannot fully capture their electromagnetic behavior, designers often use full-wave simulations for accuracy, though these are computationally expensive and time-consuming. This work proposes a modified formulation of the effective permittivity model for meshed microstrip transmission lines using a corrected Hammerstad equation. A transparency-dependent parameter links the mesh geometry to the effective permittivity through an empirical correction based on the fill factor, derived from multiple simulation data points. The extraction procedure, employing simulated S-parameters and a chain-matrix formulation, validates the proposed model with an average error of 0.36%. The formulation accurately captures the dependence of model parameters on mesh geometry, effectively representing the variation of effective permittivity across different transparency levels within the 2-4 GHz frequency range.

4.16 A Fast Low-Frequency Inverse Source Solver Utilizing Multilevel FFT-Based Green's Function Interpolation

Mohammad Mirmohammadsadeghi (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

The fast irregular antenna field transformation algorithm (FIAFTA) is commonly used for high-frequency antenna measurements and diagnostics. However, because it is based on the multilevel fast multipole method (MLFMM), it suffers from its well-known low-frequency breakdown. To extend FIAFTA into the low-frequency regime, we propose a fast Fourier transform (FFT)-based multilevel Lagrange interpolation (MLIP) inverse source solver that is inherently free from low-frequency breakdown. In addition to the field integral operator factorized through the MLIP and the FFT, an efficient adjoint operator is formed to assemble the compressed normal system of equations and iteratively solve the inverse source problem. Numerical results and experimental measurements demonstrate the efficiency and low-frequency stability of the proposed method.

4.17 Calculation of the Propagation Constants of Non-Circular IBC Waveguides

Nikolaos V. Saltas (School of Electrical and Computer Engineering, National Technical University of Athens, Greece); Georgios Kolezas (National Technical University of Athens, Greece); Evangelos Almpanis (National Centre for Scientific Research, Greece); Grigorios P Zouros (National Technical University of Athens, Greece)

In this work, we calculate the propagation constants of arbitrarily shaped waveguides featuring an impedance boundary condition (IBC) on their surface. The IBC is described by a tensorial impedance matrix with diagonal elements. To solve the problem for non-circular boundaries, we utilize the extended boundary condition method. The electric and magnetic field is expanded in cylindrical vector wave functions, and by proper enforcement of the IBC on the integrand functions, we arrive at a determinantal equation for the calculation of the propagation constants. The method is validated by comparisons with the exact characteristic equation for circular IBC waveguides, and with COMSOL Multiphysics for non-circular IBC waveguides with diagonal impedance matrix. Numerical results are given for various values of the parameters.

Thursday, April 23 13:30 - 14:40

P3-MO1 **Measurement Topics 2**

TO8 Fundamental research and emerging technologies/processes / / Measurements
Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 4

4.18 Plane Wave and Antenna Measurements at W-Band of Airbus's Largest Ever Built Compensated Compact Antenna Test Range CCR 150/120

Björn Niclas Möhring (Airbus Defence and Space GmbH, Germany); Ulrich Bettin (Airbus Defence and Space, Germany); Andreas Röhrner (Airbus Defence and Space GmbH, Germany); Philipp Heine (Airbus Defence and Space, Germany); Josef Migl (Airbus DS GmbH, Germany)

First measurement results at W-band from Airbus Defence & Space's latest, most sophisticated, and largest ever built compensated compact antenna test range (CATR) of type CCR 150/120 with a quite zone (QZ) size of 10 meters are presented. This CCR 150/120 is designed and built for an Indian customer in a frequency range spanning from 1 to up to 110 GHz, installed and operated in an RF anechoic chamber. First, the system design is introduced, followed by the RF setup at W-band along with measurement results that demonstrate the remarkable plane wave quality in the QZ. Finally, results from a reference antenna measurement at W-band are presented to showcase the measurement accuracy achieved by this CCR 150/120 in terms of antenna pattern measurements at very high frequencies.

4.19 Improving Wideband Antenna Measurements by Time of Flight Phase Center Estimation in Robotic Antenna Characterization Systems

Tobias Körner, Kristof Dausien and Ilona Rolfes (Ruhr University Bochum, Germany); Jan Barowski (Ruhr-Universität Bochum, Germany)

One of the biggest challenges in antenna characterization is accurately identifying the phase center of the antenna under test. Misalignment of the antenna distorts the measured antenna pattern. This challenge is particularly critical at higher frequencies because shorter wavelengths reduce tolerances, making measurement setups more sensitive to misalignment. As a possible solution to this challenge, this paper presents a geometric least squares approach for estimating the phase center based on a single rotation measurement. Unlike conventional approaches, the proposed method derives the phase center directly from the measured radiation pattern. An optimization algorithm estimates the offset between the robotic tool center point and the antenna phase center, enabling precise alignment without additional hardware. Experimental validation with D-band horn antennas confirm high accuracy and significant improvement compared to manual positioning procedures. The approach provides highly accurate, versatile, and time efficient antenna measurements, supporting emerging millimeter-wave applications.

4.20 A High-Power RF Impedance Measurement Method Using Directional Coupler and Synchronous Sampling

Xu Qin (Guilin University of Aerospace Technology, China); Chao Gu (Queen's University Belfast, United Kingdom (Great Britain))

This paper presents a low-cost, high-power RF impedance measurement method employing a directional coupler and synchronous sampling to measure load impedance under high-power excitation, targeting applications such as plasma etching and wireless RF systems. The method is evaluated at 13.56 MHz using an ICOM-706 radio delivering 100 W, achieving impedance measurements consistent with those of a VNA. The synchronous sampling approach enhances ADC precision, significantly improving the phase and amplitude accuracy of the reflection coefficient. Experimental results demonstrate the method's efficacy for real-time impedance monitoring in dynamic, high-power RF systems, with errors below 5% compared to VNA. The design's scalability to 100W-2 kW, combined with its cost-effectiveness and compactness, positions it as a promising solution for industrial wireless RF applications, including radar, plasma processing, and beyond.

4.21 Metasurface-Based Ultra-Thin Human Phantom for FR3 6G Applications

Wenfu Fu (KTH Royal Institute of Technology, Sweden); Sailing He (Royal Institute of Technology, Sweden)

For the new frequency range 3 (FR3) from 7 to 24 GHz, realistic and reliable phantoms are required in human-involved scenarios, including over-the-air characterization, radar sensing, and exposure compliance. In this study, an ultra-thin metasurface-based human phantom that reproduces the reflection coefficient of human tissues is proposed. The prototype uses only patterned metal layers, a dielectric substrate, and thin resistive sheets, giving a total thickness of 1.4 mm. For both TE and TM polarizations, the phantom shows broadband agreement with muscle and maintains an accurate response at large incidence angles. By tuning the unit cell geometry to control the input impedance, the reflection can be precisely adjusted, enabling spatially graded electrical properties that emulate regional variation across the body. The phantom can be fabricated by conventional PCB technology or inkjet printing processes. These features make the approach well-suited for practical 6G measurements and applications.

4.22 A Compact Radio Frequency Surveillance System Capable of 3-D Direction-Finding

Zhuo Yang (Yangtze Delta Region Academy of Beijing Institute of Technology, Jiaxing, China); Hanqing Gu (Zhejiang University, China); Min Zhang and Qi Zhou (China); Peng Zhang (Beijing Institute of Technology, China); Xiaowen Wen (Yangtze Delta Region Academy of Beijing Institute of Technology, China)

Driven by the demanding requirements of anti- drone applications for long-range and wide-coverage surveillance, this paper presents a low-cost radio frequency (RF) system with three-dimensional (3-D) direction-finding (DF) capability. Based on signal modeling, parameter analysis and simulation, we designed a system that estimates both azimuth and elevation angles of arrival (AoAs). A prototype was fabricated and evaluated via field tests at specific frequencies. Measurement results show good agreement with simulations, thereby validating the system's 3-D DF capability. Finally, we discuss potential methodology extensions for further enhancing elevation estimation accuracy.

4.23 Sub-Terahertz Channel Measurements Using Low-Cost 3D Printed Lens Antenna

Valentina Cicchetti (Queen Mary University of London, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain)); Sana Salous and Jiahao Hu (Durham University, United Kingdom (Great Britain))

This paper presents sub-terahertz (220-300 GHz) channel measurements using a low-cost, wideband 3D printed lens antenna. Measurements were carried out in a hallway environment, with a directional horn antenna as transmitter and the 3D printed lens antenna as receiver. A wideband channel sounder was employed to record power delay profiles across multiple locations and distances, allowing evaluation of transmission loss and the impact of antenna configuration on sub-THz propagation. The results highlight the effectiveness of the low-cost 3D printed antenna for rapid and reliable channel characterization in high-frequency wireless systems.

4.24 Data-Driven Estimation of 5G Link Reliability from Multi-City Radio Signal Measurements

George Tsoulos and Georgia E. Athanasiadou (University of Peloponnese, Greece); Vassilis Tsoulos (University of Pelponnese, Greece); Sotirios Tsakalidis (University of Peloponnese, Greece)

Reliable evaluation of 5G network performance requires real-world measurements; however, such datasets often lack packet success information needed to assess service reliability directly. This paper presents a data-driven framework that addresses this limitation by inferring reliability from standard radio-layer indicators using a probabilistic logistic model calibrated to the empirical SINR distribution and mapped to RSRP. The method is applied to 5G field trial data collected across four representative cities and evaluated for different link requirements in the 3GPP service classes URLLC, eMBB, and mMTC. Results show that cities with strong SINR and well-aligned power-quality characteristics exhibit steep reliability transitions and compact coverage, whereas interference-limited areas display gradual reliability decay and inflated ranges. Analysis across macro-microcell regimes shows that the proposed framework, by integrating multi-city empirical data with logistic reliability inference and service-class coverage mapping, provides an interpretable, measurement-based approach for estimating 5G link reliability and coverage without packet-level data.

4.25 Analysis of the Monostatic-Bistatic Equivalence Theorem for Drone RCS Characterization in ISAC Channels

Shrayan Das (CWC-RT, University of Oulu); Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Veikko Hovinen, Marko E Leinonen and Aarno Pärssinen (University of Oulu, Finland); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland)

Integrated Sensing and Communication (ISAC) is central to 6G networks, requiring accurate radar crosssection (RCS) modeling for reliable sensing. While monostatic RCS of simple objects is well studied, RCS characterization of autonomous (unmanned) aerial vehicles (AAV or UAV) remains limited due to complexity and cost, especially in bistatic settings. The Monostatic-Bistatic Equivalence Theorem (MBET) and its variants are often used to estimate bistatic RCS, but their validity remains uncertain for complex targets and wide frequency bands. This work investigates the applicability of MBET and its variants for AAVs in ISAC scenarios, assessing their effectiveness in predicting bistatic RCS under non-ideal conditions.

4.26 Design of Sideband-Segmentation and Sampling Strategy for near-Field Passive Millimeter-Wave Fast Imaging

Ruochen Gu and Chen Dong (Beihang University, China); Hu Anyong (Beijing University of Aeronautics and Astronautics, China); Jungang Miao (Being University, China)

The phased array scanning scheme is commonly used in passive millimeter-wave imaging systems. Recent advancements in highly integrated silicon-based multi-channel phased array chips have demonstrated significant application potential for radio frequency front-ends. However, the phase shifting characteristics of these chips across the operating band cause significant beam broadening in the system pattern during scanning. To mitigate this effect, a frequency sideband segmentation design is proposed. And a corresponding scanning strategy is also designed to minimize the number of beam focusing operations. Simulations for a system with three 1-GHz sidebands (17.7-21.2 GHz total), scanning within a ±1m range at a distance of 2.5m, show that only 12 beam focusing directions are required to achieve an imaging resolution better than 0.087m.

4.27 Field Measurement and Performance Analysis of Maritime 5G Communications Based on UAV Platform

Kun Yang, Shuhao Zhang, Yuan Cheng Wen and Li Qin (Zhejiang Ocean University, China); Pan Tang (Beijing University of Posts and Telecommunications, China); Marion Berbineau (COSYS, Université Gustave Eiffel, IFSTTAR, Univ Lille & Railenium, France)

The potential of 5G-enabled Unmanned Aerial Vehicle (UAV) communication in maritime applications is immense. However, existing research and field tests predominantly focus on terrestrial environments. This paper presents the field measurements of 5G UAV communication conducted in real-world maritime scenarios. The experiments cover two representative environments: (a) the near-shore urban area, and (b) an uninhabited island lacking adequate radio coverage. Our study focuses on analyzing key performance indicators (KPIs), including Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Signal-to-Interference-plus-Noise Ratio (SINR). The results reveal the unique propagation characteristics and performance variations of UAV communication over the sea. These findings provide a theoretical foundation and practical guidance for the design and optimization of UAV 5G communication systems in complex maritime environments. Furthermore, these results offer valuable references for Base Station (BS) deployment, coverage extension, and network optimization in these challenging areas.

4.28 Machine Learning for 5G Signal Strength Forecasting Across Cities and Days from Field Trials

Vassilis Tsoulos (University of Pelponnese, Greece); George Tsoulos, Georgia E. Athanasiadou, Christos Kalogirou, G. Ntaltas and N. Mitrosilis (University of Peloponnese, Greece)

This paper presents a data-driven framework for forecasting 5G signal strength by integrating large-scale field measurements with time-aware machine learning models. A multi-operator drive-test campaign was conducted across three representative small cities in Greece, using handheld equipment to collect 5G key performance indicators under controlled spatial and temporal conditions. The curated datasets were processed through a standardized pipeline and modeled using XGBoost-based ensembles with temporal, spatial, and network-level descriptors. Comprehensive evaluations- including rolling-origin cross-validation, feature ablation, conformal uncertainty quantification, and leave-one-city-out testing- demonstrate that short-term temporal dynamics are the dominant predictors of 5G signal variation. The proposed framework achieves consistent accuracy gains over persistence baselines and generalizes effectively across cities and operators. These findings establish a reproducible methodology for spatio-temporal performance forecasting, contributing to data-driven characterization and optimization of next-generation cellular networks

4.29 MetaSecure: Dual-Channel Physical-Layer Security via Programmable Wave-Domain Modulation

Yufei Zhao, Qihao LV and Yujie Zhang (Nanyang Technological University, Singapore); Deyu Lin (Nanchang University, China)

This work introduces a secure dual-channel wireless transmission framework integrating spatial field modulation (SFM) with digital bandpass modulation (DBM) through the use of multimode vortex waves and programmable metasurfaces (PMS). The scheme leverages the orthogonality of vortex modes to form independent, high-capacity DBM subchannels while the PMS spatially maps these modes into distinct field distributions, generating a concurrent SFM channel. By transmitting dynamically mapped encrypted symbols via DBM and their mapping keys via SFM, the system achieves lightweight physical-layer encryption without joint decoding. A proof-of-concept prototype demonstrates reliable, confidential transmission under real-world conditions, validating the scalability and low complexity of the proposed architecture for future IoT networks demanding both efficiency and security.

Thursday, April 23 13:30 - 14:40

P3-PO1 Advances in Radar, Localisation and Sensing

TO5 Positioning, localization, identification & tracking / / Propagation

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 3

3.37 A Millimeter-Wave Wideband Passive Sensor for Remote Biosensing Applications

Gustavo Misawa Hama and Ariana Serrano (University of São Paulo, Brazil); Gustavo P. Rehder (University of São Paulo & Universidade de São Paulo, Brazil)

This paper presents the design and preliminary results of a complete passive sensor system for remote biosensing, operating in the millimeter-wave K-band. The system adapts a resonant stub biosensor, previously proposed for glucose detection, for wireless interrogation by an FMCW radar. To enable the remote reading of the stub's entire response range, a key challenge was the development of a wideband antenna. This work focuses on the design of a wideband patch antenna coupled by resonators on a Rogers RT/duroid 5880 substrate. Simulations demonstrate a significant bandwidth of 12.9% centered at 28 GHz, with stable gain and radiation patterns. The antenna was fabricated and measured, showing good agreement with simulations. A prototype of the integrated sensor was tested, and while direct communication between reader antennas was successful, challenges in impedance matching for the remote sensor reading were identified, setting a clear path for future optimizations.

3.38 DiffRadarPose: Diffusion-Guided 3D Human Pose Reconstruction from Sparse Radar Data

Kailu Guo (Queen Mary University of London, United Kingdom (Great Britain)); Elif Dogu (King's College London, United Kingdom (Great Britain)); Akram Alomainy and Khalid Z Rajab (Queen Mary University of London, United Kingdom (Great Britain))

Diffusion models have demonstrated a powerful capacity for generating high-quality, structured data from noisy or incomplete inputs, making them highly suitable for addressing the challenges in 3D human pose estimation from sparse radar point clouds. In this work, we propose DiffRadarPose, a diffusion-based framework that combines structural skeleton representations with radar feature guidance to enhance reconstruction quality. A hybrid training strategy, where latent skeleton representations are randomly dropped, improves robustness under noisy inputs, while multimodal conditioning ensures stable and structure-preserving reconstructions. Experiments show that DiffRadarPose performs competitively, achieving an average MPJPE of 50 mm. These results highlight the potential of integrating diffusion-based reconstruction with improved radar feature extraction and structural conditioning.

3.39 Exploration of Micro-Doppler Analysis on Radar Echoes in an ARoF-Based Radar System

Sandis Migla, Dmytro Vovchuk, Kristaps Rubuls and Darja Čirjuļina (Riga Technical University, Latvia); Mykola Khobzei and Vladyslav Tkach (Yuriy Fedkovych Chernivtsi National University, Ukraine); Ofek Dekel Harel (Tel Aviv University, Israel); Niks Krumins, Olesja Novikova and Deomits Andrejevs (Riga Technical University, Latvia); Toms Salgals (RTU, Latvia); Pavel Ginzburg (Tel Aviv University, Israel); Vjaceslavs Bobrovs (Riga Technical University, Latvia)

The recent increase in the use of unmanned aerial vehicles (UAVs) has led to a need for low-cost, widely deployable architectures for their detection and classification, particularly in urban and other environments where the use of multiple radar transceivers is advantageous. Analog radio-over-fiber (ARoF) technology is a practical way of transmitting radar signals to remote antenna units (RAUs) located across large areas. Additionally, micro-Doppler analysis is a valuable tool in radar systems for target detection and classification, particularly for low radar cross-section (RCS) objects. This research is devoted to investigating the impact of an ARoF-based fronthaul on a 6 GHz continuous-wave (CW) radar system. We provide the experimental setup of an ARoF-based CW radar and perform micro-Doppler analysis of the returned radar echoes via the optical fronthaul and without it. The results demonstrate that the ARoF-based fronthaul is well-suited for use with a CW radar system for micro-Doppler analysis.

3.40 Experimental Validations of an FDTD-Based Approach for Time-Varying Radar Signatures

Ridha Omrani (University of Quebec in Outaouais (UQO), Canada); Franky Dakam Wappi (University of Quebec in Outaouais, Canada); Mohammad Marvasti and Halim Boutayeb (Université du Québec en Outaouais, Canada)

This work proposes a combined Finite-Difference Time-Domain (FDTD) system for modeling and verifying radar signatures of complex moving scenes like drones and human falls. By incorporating actual video sequences into the FDTD computational region, natural time-dependent motion is simulated and mirrored against 24 GHz experimental Doppler radar data. Above methodology allows precise time-frequency signature reconstruction, implying high correlation between simulated and experimental data. It offers a generic methodology for the electromagnetic simulation of dynamic scenarios, with potential applications in human observation, autonomous observation, and smart radars.

3.41 UHF Digital Beamforming Antenna Array for MEOSAR Test Beacon

Sébastien Rougerie (Thales Alenia Space, France)

in the frame of the COSPAS SARSAT system, this paper presents a 32 Radiating Elements (RE) Digital Beamforming (DBF) antenna system able to emulate every kind of trajectories, thanks to the generation of SAR (Search and Rescue) signals embedding the effects corresponding to an emulated beacon motion. The main challenge of this ground station is the concurrent generation of more than 10 beams, where each beams target one MEO satellite and null the others. The design of this UHF antenna array and digital beamforming algorithms are presented here. After several validation tests in the THALES ALENIA SPACE facilities, the final end to end demonstration was perform, with broadcast towards MEOSAR satellites, and localisation of the emulated moving position by operational cospas sarsat ground stations (MEOLUT).

3.42 Phase-Based Multi-Target FMCW Radar Sensing for Robust Fire Detection and Monitoring

Francesca Schenkel (Ruhr Univerity Bochum, Germany); Tobias Körner and Ilona Rolfes (Ruhr University Bochum, Germany); Christian Schulz (Ruhr-Universität Bochum, Germany)

Reliable early detection and characterization of emerging fires remains challenging due to high false-alarm rates of point smoke detectors, which cannot reliably discriminate soot from benign aerosols. This paper investigates a zone-aware, multi-target FMCW radar approach to improve event characterization while preserving detection sensitivity. Experiments were performed with a commercial ultrawideband FMCW radar in the D-band range with a dielectric lens providing a large aperture angle, observing a measurement scene with three spatially separated fixed targets that simulate different environmental zones. Signal analysis focuses on multi-target phase dynamics and a combined frequency and phase processing chain to retain sensitivity to small dielectric-path perturbations. When exposed to boiling water and ethanol flames, the multi-target phase signatures change markedly and exhibit distinct temporal patterns. The results demonstrate that explicit spatial zoning combined with multi-target dynamical features can reduce ambiguity in realistic nuisance conditions.

3.43 NoLoRa: Ultra-Low-Power LoRa Transmissions Without Active Radios for Battery-Free Devices

Shayan Majumder (Heriot-Watt University, United Kingdom (Great Britain) & LibreCube, Germany); Julian Birk (Heriot-Watt University, United Kingdom (Great Britain)); Charles Lohr (Bellevue, Washington, United States); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Stylianos D. Asimonis (University of Patras, Greece); Spyridon Nektarios Daskalakis (Heriot-Watt University, United Kingdom (Great Britain))

This paper presents "NoLoRa", a new way to send LoRaWAN-compatible signals without using dedicated radio chips or batteries. The method works by using the natural electromagnetic emissions that come from digital signals in lowpower microcontrollers. NoLoRa creates proper LoRa chirps by using the 27th harmonic of square waves from Serial Peripheral Interface (SPI) and Inter-Integrated Circuit Sound (I2S) running at 16 MHz. Without any active RF components (like amplifiers at the receiver), we can receive the signals at 433 MHz using a commercial LoRa receiver. The NoLoRa system consumes an average of 27 µA at a 1% duty cycle, enabling it to operate using harvested energy without requiring batteries. We have built a working NoLoRa prototype enabling low-cost, long-distance wireless communication for applications like remote sensing, asset tracking and smart agriculture.

3.44 Assessment of Multilateration-Based Indoor Positioning Techniques for 5G Private Networks

Bernardo Santos (Polytechnic of Leiria and Instituto de Telecomunicações, Portugal); João José Ribeiro Domingos (Instituto Politécnico de Leiria, Portugal & Instituto de Telecomunicações, Portugal); Luis Diogo Medina Duarte (Polytechnic University of Leiria, Portugal & Instituto de Telecomunicações, Portugal); João Ricardo Reis (IT & IPL, Portugal); Samuel Rocha Madail and José Salgado (Altice Labs. SA, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

Indoor positioning remains one of the main challenges for location-based services in mobile networks, including 5G and beyond, due to multipath propagation and severe signal attenuation in complex environments. This paper investigates multilateration-based positioning methods, namely Time of Flight (ToF), Time of Arrival (ToA), and Time Difference of Arrival (TDoA). The algorithms were implemented and validated through MATLAB simulations and experimental measurements obtained using a Vector Network Analyser (VNA) with wideband antennas. The results demonstrate centimetre-level accuracy, with ToF and TDoA showing strong robustness in multipath conditions. Three-dimensional (3D) experiments further reveal the impact of anchor geometry and noise, quantified using Geometric Dilution of Precision (GDOP) metrics. The findings confirm the validity of the developed algorithms and their potential integration into private 5G networks, paving the way for advanced Industry 5.0 applications such as indoor navigation, asset tracking, and autonomous robotics.

3.45 Two-Port EIT-Based Millimeter-Wave Permittivity Sensor

Daniyal Ali Sehrai (Public University of Navarre (UPNA), Spain); JuanCarlos Iriarte (Public University of Navarra & Antenna Group, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain)

This paper presents a highly sensitive permittivity sensor based on the electromagnetically induced transparency (EIT) at the millimeter-wave frequency band. The proposed sensor consists of a microstrip line combined with a pair of open-circuit stubs of equal length. Moreover, introducing a similar slots configuration in the ground plane of same length with respect to the pair of open-circuit stub causes an interference to form an EIT-like passband. To verify the permittivity sensing performance of the proposed sensor, different dielectric samples are placed in the vicinity of the sensor, which show a significant frequency shift depending upon permittivity of the sample under test (SUT). Due to the simple and compact configuration, sensitivity to minor changes in permittivity is achieved.

3.46 Flying Under the Radar: Portable Pollinator Tracking with 60 GHz Technology

Pieter Barnard and Maryam Norouzi (Trinity College Dublin, Ireland); Ian Donohue (Professor in Environmental Science, Ireland); Adam Narbudowicz (Technical University of Denmark, Denmark)

Reliable labeling of radar data remains a major challenge in applying machine learning (ML) techniques to biological monitoring. This paper presents a novel multimodal data acquisition and synchronization framework for efficiently labeling radar measurements of pollinator insects. The system integrates a low-cost mmWave Doppler radar with dual cameras, a buzzer-microphone pair, timer displays, and a microcontroller. A synchronization scheme establishes a common time reference across radar, video, and audio data streams, while a graphical user interface supports semi-automated multimodal labeling for generating large, high-quality datasets. The methodology was validated through repeated experiments under controlled in-lab environment and a preliminary in-field deployment. Laboratory results demonstrated consistent three-dimensional trajectory tracking of individual bees, while field trials highlight the challenges of multi-target separation and background clutter suppression. These findings confirm the potential of the proposed framework to produce accurately labelled radar datasets and establish a foundation for robust ML-based pollinator tracking algorithms.

3.47 Automated Shape Classification for Non-Destructive Testing Using mmWave Synthetic Aperture Radar

Filipe Rodrigues Lopes and Tiago Frade (Polytechnic University of Leiria, Portugal); Luis Diogo Medina Duarte (Polytechnic University of Leiria, Portugal & Instituto de Telecomunicações, Portugal); João Ricardo Reis (IT & IPL, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

Additive manufacturing and advanced production management aligns with Industry 5.0 standards, requiring automated and cost-effective Non-Destructive Testing (NDT) solutions for in-line quality assurance. This paper proposes a near-field Synthetic Aperture Radar (SAR) framework for Non-Destructive Testing (NDT) applications using a Commercial Off-The-Shelf (COTS) radar solution together with automated shape classification algorithms for intelligent defect detection. This work integrates a cooperative robotic arm to accomplish a Synthetic Aperture from multiple backscattered perspectives. The acquired data is processed through a SAR algorithm followed by a blob-based post-processing module that automatically detects and classifies geometric shapes and structural features. A preliminary validation of the algorithms was carried out using samples containing various geometric shapes and symbols. Results confirm the feasibility of compact SAR imaging using low-cost COTS mmWave radars for practical NDT applications in Industry 5.0 manufacturing environments and establish a foundation for future multimodal inspection systems combining radar and depth sensing.

3.48 Quantifying Blockage Detection in 4D Automotive Radars

Henrik Toss (RISE Research Institutes of Sweden, Sweden); Martin Sanfridson (RISE, Research Institutes of Sweden, Sweden)

Contaminations, such as snow or dirt, on the surface or radome of an automotive radar may cause attenuation of the radar signal and thus degradation of the sensor performance. It is important to detect the degradation as well as understand how it could affect the performance of the sensor. In this paper we show how a 4D automotive radar can detect and use radar reflections from the road as a quantifiable indicator of sensor performance degradation.

Thursday, April 23 13:30 - 14:40

P3-PO2 Propagation for Smart Electromagnetic Environments

T07 Electromagnetic modelling and simulation tools / / Propagation

Chairs: Rola Saad (University College London, United Kingdom (Great Britain) & School of Electrical and Electronic Engineering, University of Sheffield, United Kingdom (Great Britain)), Jack Soh (University of Testing, Finland)

Room: Poster Level 4

4.30 Over-the-Air Measurements of a Scalable Sub-6 GHz Varactor-Based RIS Prototype

John Ritter, Robert Langwieser, Florian Kiss and Christoph F Mecklenbräuker (TU Wien, Austria)

In this paper, we present a scalable, sub-6 GHz, varactor diode based, reconfigurable intelligent surface (RIS) prototype. The easily scalable RIS prototype has been designed to be nearly borderless, supporting the investigation into the effects of different RIS sizes and configurations. The design supports both sub-array control, in groups of four unit cells, as well as individual unit cell control. The reflection coefficient was numerically computed using a finite element method software and is compared to the measured reflection coefficient using an automated measurement platform. The measurement of the reflection coefficient is in agreement with the numerically computed results, and shows that doubling the surface area of the RIS increases the reflection coefficient magnitude by close to 6 dB.

4.31 Semi-Transparent End-Fire Surface-Wave Antenna Using SIW Feeding and Finite Metasurface Matching for CubeSat Applications

Said Al Ismaili (University of Edinburgh, United Kingdom (Great Britain)); Khalid M Alrushud (King Abdulaziz City for Science and Technology (KACST), United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

This paper proposes a planar antenna that combines surface-wave (SW) excitation, a substrate-integrated waveguide (SIW) horn, a finite metasurface, and a dense air-via array to achieve high-gain, directive end-fire radiation at millimeter-wave frequencies. The SIW horn efficiently launches TM SWs, which are then guided across the ungrounded substrate. Moreover, the finite metasurface matching section, placed between the SIW horn and the radially-oriented air-via array, ensures a smooth transition for the phase constant across the guiding surface and this reduces aperture reflections and fosters improved radiation. Also, the air-via array with gradually varying diameters provides a controlled effective permittivity, enabling a focused end-fire pattern with gain in excess of 10 dBi and low sidelobe levels. Also, the design supports placement of a solar cell underneath making the structure well-suited for advanced downlink applications on compact satellites such as CubeSats as well as solar power energy harvesting.

4.32 Novel Hour-Glass-Shaped Reconfigurable Intelligent Surface (RIS) for Precise Real-Time Wide-Angle Scanning

Vedula Kiran Bharadwaj and Amartya Banerjee (TCS Research, India); Hemant Kumar Rath (Tata Consultancy Services, India); Tapas Chakravarty (Tata Consultancy Services Limited, India)

Reconfigurable Intelligent Surfaces (RIS) are conceived as a pivotal technology for future radio-networks, enabling dynamic manipulation of the electromagnetic wavefront, to enhance signal coverage and spectrum efficiency. This paper presents a novel modified-hourglass shaped unit cell, with periodicity of 0.23 lambda at 3.65 GHz, with a controllable phase variation of 320 degrees, for precise beam-steering operation over a wide scanning-range. A varactor diode is incorporated to control the phase-variation over the surface in real-time. An equivalent circuit is proposed for the unit-cell to further illuminate its principle of operation. Bistatic plane-wave analysis of the RIS, along with the biasing circuit, validated the beam-steering capability up to 60-degree with accuracy within 3-degrees, showcasing a precise wide-angle scan in real-time. The compact unit cell design enables the RIS to mimic the electromagnetic properties of a continuous-phase surface and facilitate the realization of spatially dense arrays, improving the electromagnetic performance of the configuration.

4.33 Modeling and Analyzing Scattering Fields for Reconfigurable Intelligent Surfaces (RIS) Using Matrices: Toward Passive Estimation of Radiation Parameters

Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France); Youssef Rammal (Institut Langevin, ESPCI Paris, Université PSL, CNRS & Xlim, France); Adel Sennouni (Institut Langevin, ESPCI Paris, Université PSL, CNRS, France); Abdelwaheb Ourir (Institut Langevin ESPCI Paris CNRS, France); Francois Sarrazin (Université de Rennes & IETR, France)

Reconfigurable intelligent surfaces (RIS) enhance communication by optimizing transmission links through adjustable components that control transmission and reflection. This study models the interaction between RIS and plane waves, analyzing the resulting scattering field using a matrix approach based on the superposition theorem. We discuss modeling challenges and electromagnetic characterization, examining scattering quantities like radar cross section (RCS), total scattering, and absorption cross section across different angles. Initial validation through full-wave simulations at 5.27 GHz suggests using this model to determine antenna parameters like scattering parameter (S parameter) or gain by estimating cross sections for various load states.

4.34 Absorption Cross Section Measurement of a Reconfigurable Intelligent Surface Based on Q-Factor Estimation in a Mode-Stirred Chamber

Adel Sennouni (Institut Langevin, ESPCI Paris, Université PSL, CNRS, France); Youssef Rammal (Institut Langevin, ESPCI Paris, Université PSL, CNRS & Xlim, France); Abdelwaheb Ourir (Institut Langevin ESPCI Paris CNRS, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France)

This paper presents a fast and efficient method to estimate the losses induced by a reconfigurable intelligent surface (RIS) within a mode-stirred chamber. The proposed technique leads to the estimation of the average absorption cross-section over all possible incident angles. The average ACS is deduced from the quality factor (Q-factor) of the mode-stirred chamber. By measuring Q-factor variations for different configurations of the RIS, the average ACS can be directly extracted without requiring complex anechoic chamber setups and exhaustive measurements. The proposed technique was first validated on a classical passive artificial magnetic conductor (AMC) metasurface and applied later to evaluate the averaged ACS of different states of a RIS working at 5.1 GHz.

4.35 RIS-Assisted Open RAN for Real-Time Teleoperation

Saber Hassouna, Jalil ur Rehman Kazim, Burak Kizilkaya and Shuja Ansari (University of Glasgow, United Kingdom (Great Britain)); Ali A Nasir (KFUPM, Saudi Arabia); Muhammad Ali Imran and Qammer Abbasi (University of Glasgow, United Kingdom (Great Britain))

Open Radio Access Networks (O-RAN) provide a modular and vendor-neutral framework for beyond-5G systems through software-defined control and open interfaces. However, their integration with latency-critical cyber-physical applications remains challenging, particularly under non-line-of-sight (NLoS) propagation. This paper presents a reconfigurable intelligent surface (RIS)-assisted O-RAN testbed enabling real-time haptic teleoperation in harsh indoor conditions. A programmable RIS is incorporated into the O-RAN architecture to support a remote dental-surgery scenario, where the haptic controller and robotic arm operate in separate rooms without direct visibility to the base station. By adaptively steering reflections, the RIS reconstructs virtual line-of-sight (LoS) links, achieving more than 2× improvement in data rate and reducing end-to-end latency below 50 ms compared to unconfigured links. Experimental results confirm smooth and stable robotic control, validating the effectiveness of RIS-enhanced O-RAN systems in supporting ultra-reliable low-latency communication (URLLC) for mission-critical industrial and healthcare applications.

4.36 Reliability Improvement of Wireless Communications with an ESPAR Antenna for Industry 5.0 Inspection Robots

Mateusz Groth, Hubert Tyburski, Krzysztof Nyka and Lukasz Kulas (Gdansk University of Technology, Poland)

Reliable wireless connectivity is critical for inspection robots operating in reflective, interference-prone industrial environments. We present a lightweight, protocol-agnostic approach that enhances link robustness using a switched-beam ESPAR antenna and a measurement-driven control loop. The solution includes periodically performed short beam sweeping, scoring each beam using link metrics and selecting the best beam under simple stabilizers. The method integrates with mobile robot mission scheduling, enabling predictable adaptations without disrupting motion. Two evaluation campaigns (outdoor grid and indoor corridor) confirm repeatable gains over an omnidirectional baseline: mean Received Signal Strength Indicator (RSSI) improved by 9.67 dB outdoors and 7.19 dB indoors, and Packet Error Rate (PER) improvement along the test path. Achieved results show that metrics-driven switched-beam operation provides a practical path to resilient wireless links for mobile inspection platforms aligned with Industry 5.0 requirements.

4.37 Influence of the Propeller Blade Orientation on the Micro-Doppler Signatures of UAVs

Sylvain Borderieux (Institut de Recherche et d'Etudes Navales, France); Jean-Christophe Cexus (National Institute of Advanced Technologies of Brittany, France); Ali Khenchaf (Lab-STICC UMR 6285, France); Pouliguen Philippe (DGA, France)

Radar detection of small aircrafts like drones represents a major security issue because of their low-radar echo. The Micro-Doppler signature of multicopter drones could potentially be helpful for the radar detection of UAV-drones. This work presents a study of the influence of drone blade orientation on the Micro-Doppler signature of drone-type targets. The signal is generated using a physical optics model of point scatterers and then analyzed with a time-frequency representation.

4.38 Genetically Designed Metasurface Micro-Doppler Enhancement

Sergey Geyman (Tel Aviv University, Israel); Dmytro Vovchuk (Riga Technical University, Latvia); Konstantin Grotov (Constructor University, Germany); Dmitry Dobrykh and Anton Kharchevskii (Tel Aviv University, Israel); Vjaceslavs Bobrovs (Riga Technical University, Latvia); Pavel Ginzburg (Tel Aviv University, Israel)

Rotational motion of scattering objects produces micro-Doppler frequency shifts that encode mechanical dynamics into the scattered field. Conventional dipolar scatterers generate only the 2Ω harmonic, limiting spectral richness and radar detectability. This work introduces a metamaterial-based approach for enhancing micro-Doppler responses through high-order multipole scattering. Arrays of coupled magneto-electric resonators were optimized using a covariance-matrix-adaptation genetic algorithm to maximize the rotational frequency span. The resulting five-element structure, fabricated on a Rogers 3003 substrate, exhibits sixteen distinct RCS maxima during rotation, indicating strong high-order multipolar coupling. Experimental measurements at 10 GHz agree well with full-wave simulations, revealing frequency shifts exceeding the dipolar limit by two orders of magnitude. This mapping of slow mechanical rotation (few Hz) into the kHz domain enables improved radar-based motion detection and clutter suppression.

Thursday, April 23 14:40 - 15:20

IN03 Christina Larsson - Channel models in 3GPP for 6G, with an emphasis on ISAC, integrated sensing and communication

/ / Propagation

Chair: Richard Rudd

Christina Larsson holds a master's degree in engineering physics and a PhD from Chalmers University of Technology, Gothenburg. She pursued postdoctoral research for two years at the Department of Physics, University of St Andrews, UK and spent four years at a startup focused on commercialization of nanowire technology for electronic and optoelectronic devices before joining Ericsson Research in Gothenburg in 2010. For the past 15 years, her work has spanned various aspects of radio propagation impacting present and future communication systems, including weather impacts on transport radio links, mm-wave coverage, and sub-THz propagation. The last years she has represented Ericsson as a 3GPP delegate, initially addressing updates to the 3GPP channel model for 6G and later covering study items on ISAC, integrated sensing and communication. Her research interests continue to cover most areas of propagation that influence radio performance.

Room: Edinburgh

14:40 Channel Models in 3GPP for 6G, with an Emphasis on ISAC, Integrated Sensing and Communication

Christina Larsson (Ericsson Research, Sweden & Ericsson AB, Sweden); Henrik Asplund (Ericsson Research, Ericsson AB, Sweden); Christopher Mollén and Magnus Thurfjell (Ericsson AB, Sweden)

Before each new 3GPP generation a general update of the 3GPP channel models is needed to facilitate the foreseen new features and use cases in the coming generation. For 6G this work was carried out during Release 19 (2024-2025). We will summarize the major changes and additions to the 3GPP propagation model, TR38.901, and try to explain the rationale for the updates. One of the major updates was a totally new chapter covering ISAC, integrated sensing and communication. Due to the stochastic nature of the 3GPP model and ISAC typically requiring known ground truth values of scatterers for evaluations, the ISAC model has intrinsic limitations, we will try to clarify what the model includes and how it is supposed to be used.

Thursday, April 23 14:40 - 15:20

IN12 Filiberto Bilotti - Metasurface-aided signal processing: new directions in communication and radar systems

/ / Electromagnetics

Chair: Rola Saad

Filiberto Bilotti is a Full Professor of Engineering Electromagnetics and the Director of the Antennas and Metamaterials Research Laboratory at ROMA TRE University, Rome, Italy. His main research interests include: design of microwave antennas and arrays and modeling of artificial electromagnetic materials, metamaterials, metasurfaces, and their applications in wireless, short-range, satellite communications and radar systems. The research activities developed in the last 25 years has resulted in 750+ papers in international journals, conference proceedings, book chapters, and 3 patents.
Prof. Bilotti was the recipient of a number of awards and recognitions, including the elevation to the IEEE Fellow Grade for contributions to metamaterials for electromagnetic and antenna applications in 2017, the IEEE Antennas and Propagation Chen-To-Tai Distinguished Educator Award in 2023, the NATO SET Panel Excellence Award in 2016, the Finmeccanica Group Innovation Prize in 2014. He was a Founding Member of the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials - METAMORPHOSE VI in 2007, was elected President of this society for two consecutive terms from 2013 to 2019 and currently serves the METAMORPHOSE VI as the Executive Director.

He hosted in 2007 the inaugural edition of the Metamaterials Congress, served as the Chair of the Steering Committee of the same conference for eight editions (2008-2014, and 2019), and was elected as the General Chair of the Metamaterials Congress for the period from 2015 to 2018.
He has been also serving as the Chair or a member of the Technical Program, Steering, and Organizing Committee of the main national and international conferences in the field of applied electromagnetics.

Room: Berlin

14:40 Metasurface-Aided Signal Processing: New Directions in Communication and Radar Systems

Filiberto Bilotti (Roma Tre University, Italy)
In this talk, we will review our recent work on metasurface-aided signal processing for wireless communications and radar systems. By enabling real-time control of metasurfaces at microwave and millimeter-wave frequencies we demonstrate simplified architectures, reduced costs, and ultra-low latency, all crucial for next-generation technologies. We will show how combining conventional antennas with intelligent metasurfaces creates a new class of smart antennas, enhancing coverage, supporting multi-channel operation, enabling near-zero-power IoT connectivity, and improving beam shaping and steering in satellite communications. The talk will also focus on radar applications, where space-time-modulated metasurfaces directly perform advanced functions such as Doppler compensation, direction of arrival estimation, false-target generation, second/third harmonic generation - bypassing or dramatically reducing heavy digital processing and enabling analog operations at the speed of light. Finally, we will discuss our recent findings in the field of time-varying metamaterials - including time interfaces, space-time interfaces, and slabs - which unlock advanced functionalities such as frequency conversion, and spatiotemporal beam control.

Thursday, April 23 15:50 - 17:30

A08 Antennas and Concepts for Communication, Radar and Sensing

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Ulf Johannsen (Eindhoven University of Technology, The Netherlands), Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))

Room: Madrid

15:50 Joint OFDM Radar-Communications in Complex mmWave Environments

Oleksandr Malyuskin (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & Centre for Wireless Innovation (CWI), United Kingdom (Great Britain)); Okan Yurduseven, Hien Ngo and Arif Ullah (Queen's University Belfast, United Kingdom (Great Britain))
High data rate millimetre-wave (mmWave) communication systems in dense, multi-user environments face major challenges, including strong interference, wideband noise, latency in mobile platforms, multipath reflections, and complex beamforming and hardware requirements. To tackle these issues, this paper explores a joint radar-communication (JRC) framework designed for highly dynamic scenarios involving mobile and aerial users. The proposed JRC system utilises radar's sensing capabilities to map the communication environment, enabling adaptive beamforming and optimising both phase-scanning and MIMO techniques. A central contribution of this work is the development of adaptive matched noise filters and techniques for scene reconstruction and interference cancellation, using blind source separation and successive interference cancellation. Additionally, the paper introduces radar waveform designs that improve signal orthogonality and separation between radar and communication functions. These advances demonstrate the potential of JRC systems for next-generation UAV communications and dense mmWave networks in fast-changing, complex environments.

16:10 An X-Band Leaky-Wave Dynamic Metasurface Antenna for Integrated Sensing and Communication

Praneet Jain (Queen's University Belfast, United Kingdom (Great Britain)); Trung Q. Duong (Memorial University of Newfoundland, Canada); Saptarshi Ghosh (Indian Institute of Technology Indore, India); PengYuan Wang (University of Nottingham Ningbo China, China); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast, United Kingdom (Great Britain))
The work demonstrates a dynamic metasurface antenna (DMA) that consists of hexagonal-shaped meta-atoms. The hexagonal-shaped meta-atoms are arranged in a diagonal fashion in the top layer of the substrate integrated waveguide (SIW). The SIW feeds an array of 32 such meta-atoms. By using p-i-n diodes, the radiation characteristic and the interaction with the propagating wave of each meta-atom are varied in two states. The DMA is capable of generating 7 distinct beam patterns by biasing the p-i-n diodes with the binary distributions obtained through holographic approximation. The DMA offers a wide beam coverage of 136° and an average gain of 6.3 dBi for all the binary distributions. Furthermore, the DMA demonstrates direction-of-arrival (DoA) detection for one or two simultaneous sources with an error as low as 1°. Full-wave simulations validate the design, highlighting its potential for integrated sensing and communication (ISAC) applications.

16:30 A Comprehensive Review of Recent D-Band Antenna Technologies for Integrated Sensing and Communication

Selome Getaneh Wubalem, Ulf Johannsen and Gabriele Federico (Eindhoven University of Technology, The Netherlands)
This study provides a comprehensive review of recent advancements in D-band antenna technologies, with a particular focus on Antenna-on-Chip (AoC), Antenna-in-Package (AiP), and Antenna-on-Board (AoB). It examines the evolution of these technologies along with emerging heterogeneous integration techniques that enhance performance by combining different antenna solutions. The review highlights key challenges and opportunities associated with each approach, addressing critical factors such as bandwidth, integration, and efficiency for high-frequency applications. Finally, the paper discusses future directions and technical hurdles in the development of D-band antenna systems.
Index Terms-Antenna-on-Chip (AoC), Antenna-in-Package (AiP), Antenna-on-Board (AoB), heterogeneous integrated antennas, D-band antennas.

16:50 OFDM-Based mmWave Wi-Fi ISAC System Implementation for Monostatic Human Sensing

Yazhou Zhu (Intel Corporation, Germany & Intel, USA); Rahul Shah (Intel Corp, USA); Valerio Frascolla (Intel Deutschland GmbH, Germany)
This work presents an OFDM-based mmWave Wi-Fi ISAC system that directly implements the mandatory waveform requirements of the IEEE 802.11 IMMW Study Group. Designed for monostatic human sensing at 60 GHz, the system integrates a four-stage static removal algorithm, adaptive 2D-CFAR detection, and the range-Doppler processing. It enables dual-functionality sensing and communication without additional spectrum or hardware, supporting IMMW standardization. Numerical validation achieves 0.2563 m range RMSE and 0.0798 m/s velocity RMSE at 20 dB SNR, with superior BER performance over Single Carrier (SC) baselines-demonstrating practical feasibility for next-generation IMMW-compliant Wi-Fi systems.

17:10 Dual-Array Large-Scale MIMO Architecture for Automotive TDMA-DDMA Radar

Jiayi Chen (Karlsruhe Institute of Technology, Germany); Reza Aliabadi (Offenburg University, Germany); Xueyun Long, Áron Szabó and Jiyeon Choi (Karlsruhe Institute of Technology, Germany); Benjamin Nuss (Technical University of Munich, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)
Large-scale automotive MIMO radars using TDMA-DDMA provide unambiguous range and velocity, but DDMA can fail when multiple targets share a range bin and their speed spacing equals the DDMA step, causing Doppler collisions. Power imbalance further makes conventional DoA estimators produce ghost returns. We propose a dual-array architecture: a sparse large-aperture array for high-resolution DoA and a compact uniform auxiliary array for reliable DDMA separation. A dedicated fusion pipeline realigns per-Tx Doppler bins, and a two-stage compressed-sensing algorithm first reconstructs and cancels strong scatterers, then recovers weak ones, suppressing leakage-induced ghosts. Simulations with realistic radar parameters validate the approach, showing robust separation at critical spacings and clear recovery of weak pedestrians near a strong truck reflector, with markedly fewer spurious points.

Thursday, April 23 15:50 - 17:30

A19 Implementation Methods for Sub-THz Antennas and Systems

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands), Dmitry E Zelenchuk (Queen's University of Belfast, United Kingdom (Great Britain))

Room: London

15:50 Low-Loss Dielectric Luneburg Lens Sub-THz Systems Using SU-8 Dry-Film Microfabrication

Dayan Pérez-Quintana (KTH Royal Institute of Technology, Sweden); Federico Giusti (University of Siena, Italy); Alicia E. Torres-García (Public University of Navarra, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain)
New antenna fabrication methods are required for the future of 6G communication systems operating in the subterahertz frequency range. This research presents the design of a dielectric Luneburg lens operating from 70 to 110 GHz, employing for the first time a microfabrication process based on SU-8 dry-film photoresist for gradient-index lenses. The evaluation of the losses of the unit cell used to mimic the Luneburg lens profile is accurately performed using the multimodal transfer matrix method (MMTMM). By applying the MMTMM, the unit cell, composed of a silicon substrate and an array of SU-8 pillars, was analyzed, confirming both its low-loss characteristics and its isotropic behavior throughout the whole frequency band. The lens is implemented within a parallel-plate waveguide, achieving a beam scanning range of ±59°. The realized gain remains above 19.5 dB across the entire band, and its comparison with the simulated directivity validates the low-loss performance.

16:10 A 100-GHz CMOS-Compatible RIS-on-Chip Based on Phase-Delay Lines for 6G Applications

Xiarui Su, Xihui Teng, Yiyang Yu, Yiming yang and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)
On-chip reconfigurable intelligent surfaces (RIS) are expected to play a vital role in future 6G communication systems. This work proposed a CMOS-compatible on-chip RIS capable of achieving beam steering for the first time. The proposed unit cell design is a combination of a slot, a phase-delay line with VO2, and a ground. Under the two states of the VO2, the unit cell has a 180-degree phase difference at the center frequency, while maintaining reflection magnitudes better than -1.2 dB. Moreover, a 60 by 60 RIS array based on the present novel unit is designed, demonstrating the beam-steering capability. Finally, to validate the design concept, a prototype is fabricated, and the detailed fabrication process is presented. The measurement result demonstrates a 27.1 dB enhancement between ON and OFF states. The proposed RIS has the advantages of low loss, CMOS-compatibility, providing a foundation for future 6G applications.

16:30 Differential Aperture-Coupled PCB-to-Waveguide Transition for Antenna-IC Integration at 100 GHz

Jan H. S. Bergman, Mohamed Räsänen and Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)
At millimeter wave (mmWave) frequencies, every millimeter of transmission line between the integrated circuits (ICs) and the antennas adds loss and, thus, degrades the system's performance. Therefore, we present a direct IC-antenna transition designed to be directly below a fully differential IC and to form a non-galvanic signal path through the printed circuit board (PCB) to a ridged-waveguide-based Vivaldi antenna. The transition is demonstrated through simulations and measurements to operate on a 60-100GHz band, covering most of the E- and W-bands.

16:50 Triple-Band THz Inverse Polarizer on Graphene-Strip-on-Substrate Grating

Fedir Yevtushenko (Institute of Radio-Physics and Electronics, Ukraine); Alexander I. Nosich (IRE NASU, Ukraine)
We investigate the polarization discrimination between the orthogonally polarized terahertz plane waves by a microsize graphene strip-on-substrate grating operating in the triple-band inverse-polarizer regime. The analysis employs the validated full-wave meshless algorithm based on the method of analytical regularization, which ensures mathematical convergence of the solution. Compared to the previously studied narrow-strip configurations, the present grating-with wide strips (70 μm) and period (80 μm) demonstrates a rich spectrum of plasmonic and lattice-mode resonances in the H-polarization case. The near-field maps confirm the formation of localized plasmon hot spots along the strip edges and standing-wave patterns associated with the ultrahigh-Q lattice-mode resonance. For the E-polarization, only the lattice resonances remain, providing a flat transmission background. These findings reveal that the broadband polarization selectivity in the THz range can be achieved by engineering the strip width and filling factor, thus extending the concept of the inverse polarizer to the multi-band regime.

17:10 Fabrication of Sub-Terahertz Directive Antennas via Micro-Additive Manufacturing

Sergio Garcia-Martinez (Universidad Politécnica de Madrid, Spain); Adrián Tamayo-Domínguez and Pablo Sanchez-Olivares (Universidad Politecnica de Madrid, Spain); Jose Luis Masa-Campos (Universidad Politécnica de Madrid, Spain)
This work explores the potential of micro-additive manufacturing for the realization of highly directive antennas in the sub-terahertz range. Two antenna topologies operating around 300 GHz are presented: a dielectric graded-index spherical lens and a metallic bull's eye antenna. Both are fabricated using two-photon polymerization (2PP) with the NanoOne 1000 system, achieving micrometer-scale precision. The lens demonstrates smooth refractive index control through sub-wavelength infill modulation, while the bull's eye antenna validates the possibility of obtaining a fully metallic surface via a copper coating process. The fabricated prototypes exhibit excellent dimensional accuracy and surface quality, confirming the suitability of 2PP 3D printing for compact and complex sub-THz antenna structures.

Thursday, April 23 15:50 - 17:30

CS21 AMTA Session: Select Best Measurement Paper Candidates from AMTA Authors at EuCAP - Updates in 2026 on...

T08 Fundamental research and emerging technologies/processes / Convened Session / Measurements
Chairs: Olav Breinbjerg (ElMaReCo, Denmark), Janet O'Neil (ETS-Lindgren, USA)

Room: Paris

15:50 Examination of the Behaviour of the AUT-to-Reflector VSWR of a Point Source Offset CATR

Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Sergiy Pivnenko (Antenna Systems Solutions, Denmark); Clive Parini (Queen Mary University of London, United Kingdom (Great Britain))
In any reflector antenna, a portion of the wave scattered by the reflector propagates back into the feed horn and manifests itself as a reflected wave at the feed's input port. This form of voltage standing wave ratio effect can seldom be compensated for across a reasonable bandwidth by the addition of matching components. In a Compact Antenna Test Range (CATR) where the test antenna and the parabolic reflector are physically in comparably close proximity to one another, a very similar phenomena can be observed between the reflector and the test antenna, only here, even the opportunity to augment the system with additional matching componentry is unavailable. This paper examines this effect, presenting analytical, computational, and experimental results, that confirm the extent to which this manifests itself within measurements and utilises simple design criteria that can be employed during the development of the CATR folded optics to manage these effects.

16:10 Derivative Sampling with Derivative Probes for Planar near-Field Antenna Measurements

Olav Breinbjerg (ElMaReCo, Denmark); Florindo Bevilacqua, Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy)
This work concerns an experimental-numerical investigation into the applicability of derivative sampling using derivative probes for planar near-field antenna measurements. Unlike for spherical near-field measurements, the planar near-field measurement probe does not maintain its pointing towards the antenna under test during scanning. It thus seems that the derivative probe difference port may not receive through both its oppositely phased radiation pattern lobes, on either side of the null direction, to form the signal derivative allowing for a doubling of the standard lambda/2-sampling step. However, this work demonstrates that, in spite of the above challenge, derivative sampling with a wide range of derivative probes is indeed possible for planar near-field antenna measurements and does indeed allow the double lambda-sampling step

16:30 Improving near-Field Measurements Using a Reduced-Order Model

Valentin Morin (IETR & Thales DMS, France); Samuel Corre (IETR, France); Renaud Loison (IETR & INSA, France); Laurent Le Coq (University of Rennes 1 & IETR, France); Eric Estebe (Thales DMS France, France)
Accurate characterization of antennas is challenging, particularly for Active Electronically Scanned Arrays (AESAs) with large electrical size, high directivity, and wide beam-steering capabilities. The classical Plane Wave Expansion (PWE) method for planar Near-Field (NF) measurements has limitations: it requires uniformly distributed samples over a finite aperture and is sensitive to truncation and aliasing effects. To overcome these constraints, this work proposes an alternative approach based on an equivalent model of the Antenna Under Test (AUT), represented by a distribution of infinitesimal dipoles. The model is coupled with a Reduced-Order Model (ROM) of the characterization problem, allowing the determination of the minimum number of NF samples needed for accurate Far-Field (FF) computation. This method relaxes the PWE constraints and supports non-conventional geometries, such as the half-box configuration. Experimental results show that up to 90% of NF samples can be removed without degrading FF accuracy, confirming the robustness of the proposed approach.

16:50 Some Experimental Results of Targets Imaging from Amplitude-Only Data

Florindo Bevilacqua, Amedeo Capozzoli and Claudio Curcio (Università di Napoli Federico II, Italy); Francesco D'Agostino, Flaminio Ferrara and Rocco Guerriero (University of Salerno, Italy); Angelo Liseno (Università di Napoli Federico II, Italy); Massimo Migliozzi (University of Salerno, Italy); John Ioannis Yiannis Vardaxoglou (South China University of Technology, China)
This paper deals with an approach to qualitatively estimate the reflectivity profile of a planar target, by exploiting single frequency multi-monostatic only amplitude acquisitions, with a non-redundant sampling grid. The solution strategy is based on an approximate scattering model, which reduces the computational burden, a smart scanning strategy that reduces the number of needed samples, a proper representation of the unknown reflectivity function and a suitable optimization approach. To fully evaluate the performance of the phaseless imaging method, an experimental validation has been carried out a some results are reported.

17:10 UAV-Based near-Field Measurements of the S68-30m Ground Station Antenna at the German Space Operations Center in Weilheim

Denis Unruh, Alexander H. Paulus and Thomas Mittereder (Technical University of Munich, Germany); Klaus Schlickenrieder (German Aersospace Center, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)
Fully coherent uninhabited aerial vehicle (UAV)-based near-field (NF) measurements of the S68-30m parabolic ground station antenna in Weilheim, Germany at L-band and X-band frequencies are presented. The utilized measurement setup involves a vector network analyzer (VNA), coaxial cable connections to the UAV with several amplifiers, a laser tracking device (LT), and specially designed very compact and light-weight dual-polarized probe antennas. The measurement data has been collected on a quasi-planar measurement surface in front of the reflector and the far-field (FF) patterns are obtained via spectrally filtered inverse source solutions. The obtained FF results show very good robustness and very good agreement with comparison data from exemplary FF pattern cut measurements towards another ground station on the mountain Hoernle. As can be expected, the results imply that temperature induced changes of the radiation behaviour of the antenna start to become noticeable in X-band.

Thursday, April 23 15:50 - 17:30

CS22 Antennas and RF propagation modeling for implants and wearable sensors

T06 Biomedical and health / Convened Session / Measurements
Chairs: Sema Dumanli (Bogazici University, Turkey), Kamran Sayrafian (NIST, USA)

Room: The Hague

15:50 Tailoring Synthetic Gel Phantoms for Wideband Microwave Sensors

Sergio Castelló-Palacios, Juan Gallego-Luchoro, Ana Valles-Lluch and Eva Antonino-Daviu (Universitat Politècnica de València, Spain); Concepcion Garcia-Pardo (Universitat Politècnica de València & Institute of Telecommunications and Multimedia Applications (iTEAM), Spain)
Accurate RF propagation modeling for implantable and wearable sensors is critically dependent on realistic experimental validation platforms. This work introduces a versatile methodology for creating mechanically robust and dielectrically stable synthetic gel phantoms for wideband antenna testing. Traditional phantoms often fail to replicate the complex, frequency-dependent dielectric properties of tissues over wide bandwidths. We demonstrate that synthetic polymers, such as poly(2-hydroxyethyl acrylate) (PHEA), can be tailored by controlling cross-linking density and by using water-acetonitrile swelling mixtures to precisely mimic human tissues from 5 GHz to over 67 GHz. The direct application of this technique to the challenges of propagation modeling is shown through two case studies: a three-layer phantom for validating the performance of wearable antennas, and a multilayer eye phantom for assessing exposure from near-body devices. These phantoms provide the antenna and propagation community with an essential tool for bridging the gap between electromagnetic simulations and real-world device performance.

16:10 Non-Invasive Biofluid Sensing Using Partially Symmetric Multi-Layered Metallic Metasurfaces

Behnaz Bakhtiari (Ecole Polytechnique Fédérale de Lausanne, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)
Blood tests are commonly used for disease diagnosis, but they are invasive, uncomfortable, and sometimes imprac- tical. This paper presents a non-invasive approach employing a partially symmetric, multilayered metasurface biosensor to detect subtle variations in key sweat analytes. Since sweat composition reflects various physiological and biochemical states, monitoring it can provide useful indicators of health conditions. The reflection response of the proposed structure is analyzed to identify small changes in sweat permittivity with high sensitivity. The results demonstrate that the biosensor effectively distin- guishes between normal and abnormal conditions, offering a simple and painless method for disease detection and monitoring. Moreover, its fully metallic structure combines low fabrication cost with mechanical robustness, long-term stability, and strong electromagnetic performance for reliable sweat analysis. These findings highlight the potential of metasurface-based sensing for continuous, wearable health monitoring and early diagnosis without invasive procedures or laboratory testing.

16:30 Machine Learning-Based Anchor-Aware Conditional Flow Matching for RF Localization in Wireless Capsule Endoscopy

Subramaniam Subramanian Murugesan and Muhammad Qamar (Queen Mary University of London, United Kingdom (Great Britain)); Kamil Yavuz Kapusuz (Ghent University-Imec, Belgium); Mohamed Thaha and Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))
This work presents an anchor-aware conditional flow matching framework for RF based localization in WCE. The proposed model learns an observation, conditioned velocity field that transports particles from a cylindrical prior to a feasible posterior, enabling robust position inference within the gastrointestinal tract. Multi-anchor measurements and anchor metadata, are encoded as per-anchor tokens and fused via cross-anchor attention, while geometric constraints maintain trajectories within a body-sized cylindrical domain. A heteroscedastic head provides calibrated per-axis uncertainty, supporting stochastic integration for predictive dispersion estimation. The framework is evaluated on a comprehensive dataset within cylindrical phantom that incorporates realistic propagation effects, including correlated shadowing, small-scale fading, anchor placement jitter, and 3D radiation patterns from physically modeled capsule and on-body antennas in EM solver. The proposed method achieves a mean localization error of 1.94~cm, a median of 1.88~cm, a 95th percentile of 3.29~cm, and 100% success within 5~cm, with near-isotropic per-axis errors of 1~cm.

16:50 A Wearable and Implantable UWB Antenna for Brain Computer Interface

Ahmet Bilir (EPFL, Switzerland); Katjana Ladic (Dakota Consulting, Inc., USA); Kamran Sayrafian (NIST, USA); Sema Dumanli (Bogazici University, Turkey)
In this paper, a pair of implant and wearable antennas for brain-computer interface applications is proposed. The implant is embedded within the human head, leaving no visible external components. A receiver antenna is placed on the body to enable wireless transmission of neural data. Both antennas operate in the lower ultra-wideband range, providing higher data rates than conventional Bluetooth communication. The implant antenna, designed as a slotted patch, operates between 3.6 and 5.6 GHz, with the electronic circuitry located under the ground plane. The implant's dimensions are 15 mm × 15 mm × 6 mm. The communication performance between the implant and wearable antennas is evaluated through simulations for two implant locations: on the top and side of the head. For the worst case scenario under 1.6 W/kg SAR limitation over 1 g tissue, the received power level at 4.5 GHz is -61.9 dBm, far above common receiver sensitivity.

17:10 Analytical Modeling of in-Body and on-Body Propagation of Electromagnetic Waves

Davorin Mikulic, Marko Bosiljevac, Davor Bonefačić and Zvonimir Sipus (University of Zagreb, Croatia)
Body-centric communication and sensor systems are becoming increasingly interesting due to the miniaturization and portability of devices, offering various applications in health monitoring and quality-of-life enhancement. Body-centric systems are typically categorized and analyzed as off-body, on-body, or in-body, each presenting distinct challenges in antenna design and propagation analysis. This work investigates on-body and in-body scenarios together using analytical and approximate models based on cylindrical phantoms. These models offer insights into electromagnetic field behavior within and around the body, with particular accent placed on study of creeping waves excited along the body. Creeping waves can be a dominant contributing factor for establishing links between non-optimally placed implanted and wearable devices, and presented analysis shows their impact in several application scenarios. Model results are validated using numerical solvers and measurements, and contribute to better understanding of body-centric propagation and offer approximate closed-form formulas for link design in implant-wearable communication scenarios.

Thursday, April 23 15:50 - 17:30

CS23 **Metamaterials for future industrial applications**

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Matthieu Bertrand (Thales Research and Technology, France), Francisco Mesa (University of Seville, Spain)

Room: Krakow

15:50 Contactless Air-Filled Waveguide Components Using Glide-Symmetric Stacked Mushroom EBGs

Ashray Ugle (Sorbonne University, France & IMST GmbH, Germany); Massimiliano Casaletti (Sorbonne University, France); Marta Arias Campo and Simona Bruni (IMST GmbH, Germany); Guido Valerio (Sorbonne Université, France)

A cost-effective alternative to traditional metallic waveguide technology for millimetre-wave (mmWave) automotive radar is proposed in this work. mmWave automotive radars are critical for driver-assistance systems due to their reliable performance under adverse conditions. Conventional Printed Circuit Board (PCB) transmission lines suffer from high losses at 76-81 GHz, while high-performance Radio Frequency (RF) substrates are costly. Contactless air-filled waveguide technology using glide-symmetric mushroom-type electromagnetic bandgap (EBG) materials, realised through standard PCB fabrication, is proposed for low-cost, low-loss signal propagation in mmWave automotive radar. Multi-layer PCB technology enables compact routing and inter-layer coupling through metallised slots, simplifying integration with radar chips. An average insertion loss of less than 0.1 dB was achieved in simulation for the inter-layer slot-coupling across the 76-81 GHz band.

16:10 H-Band SPDT Waveguide Switch Based on Glide-Symmetric Electromagnetic Bandgap Structures

Jorge Martin Villar, Francesca Vipiana, Jorge Tobon and Martin Petek (Politecnico di Torino, Italy); Zhongxia Simon He (SINOWAVE, Sweden)

This work presents the design and analysis of a single-pole double-throw (SPDT) waveguide switch imple- mented using multilayer waveguide (MLW) technology. The proposed fully metallic air-filled structure operates in the H-band (220-330 GHz) and employs a glide-symmetric unit cell acting as an electromagnetic bandgap (EBG) material to suppress leakage and improve manufacturing tolerance. The SPDT enables signal routing between two output branches through a rotating metallic part. The design achieves insertion losses below 2 dB and return losses better than 10 dB across most of the H-band.

16:30 Oblique Incidence Effective Parameter Retrieval Using the Multimodal Transfer-Matrix Method

Moises Tercero (KTH Royal Institute of Technology, Sweden & Thales Research and Technology, France); Francisco Mesa (University of Seville, Spain); Thi Quynh Van Hoang (Thales Research & Technology, France); Matthieu Bertrand (Thales Research and Technology, France); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

The multimodal transfer-matrix method (MMTMM) is applied to retrieve the effective refractive index and impedance for the general case of oblique incidence. The eigenvalue problem associated with an infinite cascade of periodic layers yields a set of eigenvalues and eigenvectors. The refractive index is computed from the longitudinal wavenumber, which is obtained from the eigenvalues. The eigenvectors allow for the calculation of the average fields inside the unit cell, from which the effective impedance of the structure is subsequently derived. The method is applied to a structure composed of glide-symmetric patches. As an application, we demonstrate the design of a flat graded-index cylindrical lens implemented with glide-symmetric patches, utilizing the computed parameters.

16:50 Enhancement of Metasurface-Based Absorption Through Surface-Wave Conversion

Raquel Arenas-Álvarez (Sorbonne Université, France & Thales Research & Technology, France); Julien Sarrazin (Sorbonne Université, France); Khai Tran Quang Nguyen (Thales Group, France & Thales Research and Technology, France); Thi Quynh Van Hoang (Thales Research & Technology, France); Guido Valerio (Sorbonne Université, France)

In this work, an enhancement of absorption of a metasurface absorber is numerically evaluated by tapering its response with a phase gradient (PG) that enables free-space wave to surface-wave (FSW-SW) conversion. This approach can be a promising mechanism to address common limitations of conventional microwave absorbers. The proposed structure consists of a grounded dielectric slab patterned with H-shaped patches. Fullwave periodic analysis at 20 GHz, with TM-polarized incidence, yields a S11 lower than -10 dB for incidence angles up to ±50 degrees. Introducing the PG further reduces the reflection, without changing the overall thickness. Under a finite-aperture Gaussian illumination, reduced specular reflection and lateral power flow are observed. Additionally, a guided-wave metasurface (GWM) with resistive loading efficiently extracts and dissipates the guided wave. Overall, the FSW-SW absorber achieves a backscatter reduction of 4.14 dB, indicating that this mechanism can serve as an effective tool to improve absorber performance.

17:10 Low-Loss Reflective Intelligent Surface Based on Polarization-Rotation for 6G FR3 Band Applications

Kaan Aktas and Enrico Tolin (IMST GmbH, Germany & Politecnico di Torino, Italy); Achim Bahr (IMST GmbH, Germany); Francesca Vipiana (Politecnico di Torino, Italy)

Addressing the need for efficient channel control in 6G networks, we introduce a novel 3-bit reflective intelligent surface (RIS) concept. It is compatible with low-cost FR4 printed circuit board technology and operates at the 7.125 - 8.4 GHz FR3 band. The core innovation proposed here is the use of internal reflections between a polarization rotator and a filter, which successfully enhances the phase shift up to 307°. The method allows an efficient unit cell design maintaining a high reflection coefficient above -0.9 dB. The final RIS panel demonstrates reliable beam steering up to 50°. It shows a minimal performance degradation, with a maximum amplitude difference below -1.1 dB relative to the theoretical scan loss.

Thursday, April 23 15:50 - 17:30

CS24 Analysis Methods and Emerging Applications of Novel 1D Periodic Structures

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Eva Rajo-Iglesias (University Carlos III of Madrid, Spain), Guido Valerio (Sorbonne Université, France)

Room: Gothenburg

15:50 Broadside Radiation Enhancement of Periodic Leaky-Wave Antennas with Open Stopband Suppression

Miguel Poveda-García (Technical University of Cartagena, Spain); Davide Comite (Sapienza University of Rome, Italy); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain)

The modulation of the attenuation constant in a periodic leaky-wave antenna (LWA) with open stopband (OSB) suppression is explored in this work. By properly adjusting the profile of the attenuation constant along the LWA aperture, the aperture efficiency can be improved, increasing the directivity. A bi-directional grounded dielectric slab with periodic metallic strips is used to demonstrate the possibility to taper the attenuation constant while mitigating the OSB. As demonstrated, the directivity at broadside is improved from 12.64 dB to 12.92 dB by only modifying the dimensions of the unit cells. Moreover, the broadside bandwidth is also improved from 0.78 GHz to 0.92 GHz.

16:10 Design of a Corrugated Parallel-Plate Waveguide Leaky-Wave Antenna

Yuhuan Tong (Sorbonne Université, France); Beatrice Ambrogi (Sapienza University, Italy); Davide Comite (Sapienza University of Rome, Italy); Guido Valerio (Sorbonne Université, France)

Corrugated metal surfaces are practical structures for the realization of a wide range of guiding and radiating devices thanks to their ease of fabrication, compact dimensions, and frequency-dispersion properties. Here, we present an original dispersive study of a parallel-plate waveguide with corrugated bottom plate radiating through slits on its top plate. A modal dispersive analysis is carried out using a method-of-moments approach, which allows for the investigation of both proper and improper leaky-wave regimes across the bandwidth where a single leaky wave is present. The leaky modal solution is studied, showing different behaviours around the broadside radiation frequency according to the geometrical parameters of the structure. By including two asymmetric slots in the same period at a suitably optimized distance, the stopband is suppressed and continuous scanning from backward to forward directions can be achieved.

16:30 Degenerate Band Edge in a Square Lattice of Metallic Pins: Extending from 1D Periodic Structures to 2D Periodic Structures

Nelson Castro (University Carlos III of Madrid, Spain); Miguel Saavedra-Melo and Filippo Capolino (University of California, Irvine, USA); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

We show that the dispersion of modes in a parallel-plate waveguide (PPW) loaded with a periodic array of metallic pins has a degenerate band edge (DBE) in two directions. The results show that four modes that are otherwise distinct coalesce at the degeneracy frequency, forming a single eigenmode-a phenomenon arising from the coupling between the structure's eigenmodes. This paper show how the concept previously obtained for waveguides in one direction has been extended to a two-dimensional (2D) waveguide with two-dimensional periodicity. We demonstrate-for the first time-that a lossless waveguide can support a DBE along every propagation direction forming a very flat band in 2D.

16:50 Novel Air-Filled Multilayer Metal-Plate Phase Shifter

Junliang Ou, Peng Wu and Peng Yue (Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing, China); Yu Ge (Chalmers, Electrical Engineering, Communication, Antennas and Optical Networks); Zhongxia Simon He (Aerospace and Informatics Domain, Beijing Institute of Technology, Zhuhai, China & ChalmersIndustriteknik, Sweden)

This paper presents a novel millimeter-wave and terahertz phase shifter topology with wide bandwidth and low insertion loss. The demonstration is implemented using an electromagnetic band-gap (EBG) based, two-layer transmission line structure comprising eleven thin metal plates. Movable metal plates are incorporated within the transmission line. The phase shift is achieved by mechanically adjusting the metal plates to vary the stretchable section width, which alters the effective electrical length. The two-layer transmission line structure incorporates 12 displacement stretchable sections. When all sections are actuated synchronously to the maximum displacement of 0.1 mm, a maximum differential phase shift of 180° is achieved around the center frequency. Simulation results show that the device operates across the 131-170 GHz band, with a reflection coefficient below -17 dB and an insertion loss better than 5.8 dB over the entire bandwidth.

17:10 Rigorous Coupled Wave Analysis: Paving the Way for Innovative Leaky-Wave Antennas

Dubravko Tomić and Zvonimir Sipus (University of Zagreb, Croatia)

This paper highlights the central role of Rigorous Coupled Wave Analysis (RCWA) in the design of innovative reconfigurable leaky-wave antennas (LWAs). We present an extended RCWA framework capable of modeling two-layer dielectric gratings with identical permittivity spatial modulation but have an arbitrary translational shift between them. This powerful semi-analytical method allows for precise prediction of the propagation properties of such periodic structures which is crucial in the leaky wave antenna designs. The analysis reveals that the mechanical shift not only serves as a robust mechanism for continuous beam steering at a fixed frequency but can also be used to suppress the open stopband. By selecting a specific asymmetrical shift, the antenna can achieve efficient broadside radiation. Validated by full-wave simulations, this work demonstrates that the extended RCWA method is a key enabler for designing a new class of mechanically reconfigurable LWAs with advanced functionalities.

Thursday, April 23 15:50 - 17:30

CS29 Wireless and Wave-Based Technologies for Harsh and Complex Environments

TO8 Fundamental research and emerging technologies/processes / Convened Session / Propagation
Chairs: Sergi Abadal (Universitat Politècnica de Catalunya (UPC) & NaNoNetwoking Center in Catalunya (N3Cat), Spain), Hamidreza Taghvaee (University of Surrey, United Kingdom (Great Britain))

Room: Prague

15:50 Chipless RFID-Based Sensing Under Varying Seedling Tray Density and Plant Water Content

Anil Tulu and Mehmet Emre Korkmaz (Bogazici University, Turkey); Qammer Abbasi (University of Glasgow, United Kingdom (Great Britain)); Sema Dumanli (Bogazici University, Turkey)

The integration of Chipless Radio Frequency Identification sensors offers a sustainable solution to traditional Internet of Things sensors in agricultural technologies. This paper analyses the backscatter link robustness for a C-like tag designed for plant growth monitoring. The readability of the tag is investigated under two environmental variables, planting density and plant water content. The tag is located in a 40 cm by 40 cm seedling tray, while the effect of variables is analysed using the decrease in peak height of the calibrated transmission coefficient data. As planting density increases from 5 by 5 to 9 by 9, the peak height drops by at least 3 dB. This drop tends to grow with higher plant water content, although at a fixed density, the effect of water content is modest. The results are crucial for understanding the environmental effects on sensing in real-life scenarios.

16:10 RIS-Aided Mitigation of Two-Ray Interference in Overwater Wireless Links

Sebastian Silva (Pontificia Universidad Católica de Chile, Chile); Luis M. Pessoa (INESC TEC & Faculty of Engineering, University of Porto, Portugal); Miguel Gutierrez Gaitan (Pontificia Universidad Catolica de Chile, Chile)

Overwater wireless links suffer from strong specular reflections that cause deep fading and instability, a phenomenon well described by the two-ray propagation model. This paper investigates the use of a shore-mounted Reconfigurable Intelligent Surface (RIS) to mitigate these effects by dynamically shaping the propagation environment. The RIS is configured to steer its beam toward the line-of-sight (LoS) direction, thereby reducing interference between direct and reflected components. A shore-to-vessel link is modeled through analytical simulations that integrate the RIS into the two-ray geometry. Performance is assessed in terms of excess path loss (EPL), spatial outage probability (OP), and the so-called first-null beamwidth (FNBW) distance. Results show that geometry-aware RIS beam steering smooths received-power oscillations by up to 6 dB, reduces outage probability, and extends the stable communication region, providing design insights into the trade-off among RIS array size, phase quantization, and link stability for overwater communication.

16:30 Performance Analysis of Underwater Optical Wireless Communications Under the Joint Impact of Disorientation and Misalignment

Evangelos Koutsonas (University of Western Macedonia, Greece); Alexandros Pitilakis (Aristotle University of Thessaloniki, Greece); Odysseas Tsilipakos (National Hellenic Research Foundation, Greece); Theodoros A. Tsiftsis (University of Thessaly, Greece); Alexandros-Apostolos A Boulogeorgos (University of Western Macedonia, Greece)

This paper is devoted to presenting a comprehensive and unified system and channel model for underwater optical wireless communications, which accounts for pathloss, scattering, turbulence, misalignment and disorientation. Building upon this model, we extract the instantaneous signal-to-noise ratio as well as a novel closed-form expression for the outage probability. Moreover, we derive an insightful expression for the outage probability for the special case in which the shape parameter's of the sum of Gamma distributed turbulence are positive integers. Monte Carlo simulations verify the theoretical framework and provide useful design guidelines.

16:50 Toward D-Band RIS-Parametrized Wireless Networks-on-Chip

Christos Monochristou (University of Rennes, France); Hugo Prodhomme (CNRS, France); David González-Ovejero (Université de Rennes, France); Philipp del Hougne (CNRS, Univ Rennes, France)

Wireless networks-on-chip (WNoCs) emerge as a promising technology to address the communication bottleneck of multi-core chips. However, WNoCs are typically limited to on-off-keying (OOK) modulation. Given the rich-scattering nature of the on-chip radio environment, OOK modulation suffers from strong inter-symbol interference at high modulation rates. Recently, the use of an on-chip reconfigurable intelligent surface (RIS) was proposed to equalize the on-chip wireless link in the wave domain. However, existing studies on this promising idea were limited to the 60~GHz regime, where the required bandwidth to operate WNoCs at competitive modulation rates is not easily available. To address this shortcoming, we present an RIS element designed for on-chip operation in the D-band (110-170~GHz). Then, we examine the ability of a 100-element RIS to equalize a wireless on-chip link. Our analysis relies on a compact multi-port network model of the RIS-parametrized wireless link, whose parameters we extract from a single full-wave simulation.

17:10 28 GHz Wireless Channel Characterization for a Quantum Computer Cryostat at 4 Kelvin

Ama Bandara (Universitat Politècnica de Catalunya, Spain); Viviana Centritto Arrojo (Nanonetworking Center in Catalunya, Spain); Heqi Deng, Masoud Babaie and Fabio Sebastiano (Delft University of Technology, The Netherlands); Edoardo Charbon (EPFL, Switzerland); Evgenii Vinogradov (Universitat Politècnica de Catalunya, Spain & KU Leuven, Belgium); Eduard Alarcon (Technical University of Catalunya, Spain); Sergi Abadal (Universitat Politècnica de Catalunya (UPC) & NaNoNetwoking Center in Catalunya (N3Cat), Spain)

The scalability of quantum computing system is constrained by the wiring complexity and thermal load introduced by dense wiring for control, readout and synchronization at cryogenic temperatures. To address this challenge, we explore the feasibility of wireless communication within a cryostat for a multi-core quantum computer, focusing on wireless channel characterization under cryogenic conditions. We propose to integrate an on-chip differential dipole antenna within the cryostat, designed to operate at 28 GHz in the temperatures as low as 4 K. Using full-wave electromagnetic simulations, we model the antenna inside a realistic cryostat, analyzing impedance matching, spatial field distribution, and energy reverberation due to metallic structures. The wireless channel is characterized through measured channel impulse response (CIR) across multiple receiver antenna positions. The results demonstrate potential for a reliable short-range communication with high Signal to Noise Ratio (SNR) and limited sensitivity to positional variation, despite significant multipath effects.

Thursday, April 23 15:50 - 17:30

CS33 Propagation data and modeling for NGSO-based systems

TO3 Aerospace, space and non-terrestrial networks / Convened Session / Propagation
Chairs: Marianna Biscarini (Sapienza University of Rome, Italy), Lorenzo Luini (Politecnico di Milano, Italy)

Room: Firenze

15:50 Weather-Forecast-Based Propagation Modeling for Deep-Space Links: From Feasibility to Operation

Marianna Biscarini and Davide Comite (Sapienza University of Rome, Italy)

RadioMetOP is a link-budget optimization chain designed to maximize data-return while minimizing losses in satellite communications. Unlike traditional approaches, based on fixed climatological statistics, which tend to be conservative at Ka-band, RadioMetOP uses numerical weather prediction (NWP) and radiative transfer modeling to forecast atmospheric channel conditions, enabling dynamic adaptation of downlink parameters. Originally developed for the ESA BepiColombo mission to Mercury, RadioMetOP integrates three modules: NWP, radio-propagation, and link-budget modeling. After a feasibility phase (2013-2016) and validation with JAXA Hayabusa-2 mission (2019-2020), the system was operated in support of BepiColombo (2021-2024). Across these phases, RadioMetOP achieved annual data-volume gains of 20-30% over classical techniques, with negligible losses and forecast accuracies above 98% for key propagation parameters. These results demonstrate its maturity for operational deployment in deep-space missions, as well as its applicability to non-geostationary satellite systems, where rapidly varying geometry and atmospheric conditions require accurate and high-resolution propagation forecasts.

16:10 A Study on Angular Correlation at Ka and Q Bands for NGSO Links Based on High-Resolution Meteorological Simulations

Arsim Kelmendi (The French Aerospace Lab - ONERA, France); Julien Queyrel (ONERA & Université de Toulouse, France); Jean-Pascal Monvoisin (Office national d'études et de recherches aérospatiales, France); Laurent Castanet (ONERA, France); Laurent Féral (Office national d'études et de recherches aérospatiales, France)

The rapid growth of LEO satellite constellations has made coordination and frequency sharing with GEO systems increasingly critical. To meet the rising demand for ultra-high data rates, future satellite communication networks are expected to use the large bandwidth available at Ka, Q band and beyond. However, at these frequencies, rain-induced attenuation poses a significant challenge, degrading reliability and availability. Among other factors, understanding the correlation of rain attenuation between GEO and LEO links is essential for designing resilient hybrid satellite systems. This paper investigates correlations using one-year time series of rain attenuation at 20.2 GHz and 39.4 GHz, generated through highresolution meteorological simulations for a hypothetical ground station in Toulouse. Pearson correlation coefficients are analyzed across multiple GEO viewing angles and the full OneWeb LEO constellation, contributing to the understanding of hybrid satellite links behavior under rainy conditions.

16:30 Fade Slope Investigation Based on Propagation Data Collected from a MEO Constellation

Enrico Polo and Lorenzo Luini (Politecnico di Milano, Italy)

This paper presents an analysis of the temporal rate of change of tropospheric attenuation, namely the fade slope, affecting Non-Geosynchronous (NGSO) satellite links. The study is based on propagation data collected over a period of 2.5 years, during an extensive experimental campaign conducted within the MEKaP project. Modulated telemetry signals transmitted by the O3b Ka-band Medium Earth Orbit (MEO) constellation were received at three ground stations in Milan, Rome and Aveiro. Dedicated signal processing was applied to extract the carrier power and isolate the corresponding atmospheric attenuation component, enabling a comparative analysis of fade slope distributions for different latitudes and climatic conditions. For each site, the derived fade slope statistics are compared with the model described in ITU-R Rec. P.1623-1, showing good agreement with the expected results.

16:50 Analysis of W-Band Channel Measurements from a LEO Satellite

Michael Schmidt, Ivana Stamenic and Eveline Greschitz (JOANNEUM RESEARCH, Austria)

The W-band has been allocated by the ITU for satellite communication uplink and downlink services. This allocation is essential to meet the growing demand for terabit-per-second (Tbit/s) capacities of high-throughput satellites (HTS), which require significantly wider bandwidths. Together with the Q-band, the W-band will serve as the frequency range for the feeder links of next-generation HTS systems. While the Q-band has already been extensively investigated and is in operational use, the W-band still lacks comprehensive space-to-ground propagation measurements necessary for accurate channel modeling. To address this gap, the European Space Agency (ESA) initiated an exploratory program, assigning a consortium consisting of VTT, KuvaSpace, LCT, Fraunhofer, the University of Stuttgart, and JOANNEUM RESEARCH (as project lead) to design, build, and operate a 3U CubeSat transmitting dual-polarized beacons at 75 GHz and 37.5 GHz. This configuration enables the derivation of the complete transfer matrix and frequency-scaling relationships between the Q- and W-bands. The satellite, launched in August 2021, successfully transmitted the world's first 75 GHz space-to-ground beacon. The mission ended on October 1st 2025 by deorbiting the satellite. This paper presents the system architecture, measurement methodology, and initial results, demonstrating the distinct attenuation characteristics between the two frequency bands. Furthermore, it discusses the challenges and lessons learned from conducting a wave propagation campaign using Low Earth Orbit (LEO) satellites at these high frequencies.

17:10 Comparison of Concurrent Ka-Band Tropospheric Attenuation on MEO and GEO Links Measured at the Same Site

Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); Armando Rocha (University of Aveiro, Portugal & Instituto de Telecomunicações, Portugal)

This paper presents preliminary results of a Ka-band propagation campaign carried out with medium Earth orbit satellites over a two-year period. Several rain fade events are analyzed and compared with concurrent attenuation measurements, taken at the same site and in the Ka-band, using a geostationary satellite, highlighting the differences between the two scenarios. Joint attenuation statistics for one year of measured data are then presented, followed by an analysis of attenuation distributions as a function of elevation and azimuth, with the ITU-R P.618 model being tested.

Thursday, April 23 15:50 - 17:30

CS47 Novel designs and applications of conformal metasurfaces and antennas

T03 Aerospace, space and non-terrestrial networks / Convened Session / Electromagnetics
Chairs: Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil), Zvonimir Sipus (University of Zagreb, Croatia)

Room: Barcelona

15:50 Feeding Network for Sparse-Array Metasurface

Victor Schoofs and Jonathan Dessy (UCLouvain, Belgium); Modeste Bodehou (Université d'Abomey-Calavi, Benin); Christophe Craeye (Université Catholique de Louvain, Belgium); David González-Ovejero (Université de Rennes, France)

This paper presents the design of a corporate feeding network (CFN) that enables the generation of a planar surface-wave (SW) wavefront to excite modulated metasurface (MTS) antennas with modulation along a single direction. Specifically, the CFN is adapted for the challenging case of a sparse-array MTS. To meet the unique requirements of this application, a novel design concept was developed with the goal of exciting the MTS using appropriate SWs. The design process considers all stages leading to prototype fabrication, ensuring that practical implementation aspects are fully integrated into the proposed feeding network.

16:10 Challenges in Realization of Curved Metasurfaces

Davorin Mikulic (University of Zagreb, Croatia); Tommy Cejmer, Emin Istif and Franziska Lissel (TU Hamburg, Germany); Thibault Boisseau, Maxime Harnois and David González-Ovejero (Université de Rennes, France); Victor Schoofs (UCLouvain, Belgium); Modeste Bodehou (Université d'Abomey-Calavi, Benin); Wane Sidina and Damienne Bajon (eV-Technologies, France); Andrej Konforta (Fraunhofer FHR, Germany); Alexander Balas, Johannes Bökler and Maurice Schepers (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Marko Bosiljevac and Zvonimir Sipus (University of Zagreb, Croatia); Christophe Craeye (Université Catholique de Louvain, Belgium)

Curved metasurfaces enable conformal and flexible antenna solutions but introduce challenges absent in planar designs. These include optimal surface reactance synthesis, mechanical flexibility of dielectric and metallization layers, RF integration on curved geometries, and complex experimental characterization. This paper addresses each of these aspects, providing design, fabrication, and validation methodologies for curved metasurface structures.

16:30 A mm-Wave Conformal Dual-Polarized 4x16 Hybrid Beamforming Array for 5G/6G Applications

Kussai Ali, Magomet Torschchojew, Clemens Kuch and Wilhelm Keusgen (Technische Universität Berlin, Germany)

A phased array for hybrid beamforming system with an unconventional array topology is discussed. The system is operating in the 5G-FR2 region and consists of 16 linear 4x1 patch antenna arrays, which are placed in a half-cylindrical order. The linear arrays consist of aperture coupled patch antennas with fractional BW > 10% and dual polarization. Each linear array is realized as a thin rectangular strip (array segment) with a width of approximately 0.8 wavelengths. The segments are connected via high-frequency coaxial connectors to a beamforming board containing 4 mm-wave quad-channel dual-polarization BFICs (Beamforming IC) from NXP. The array is sectorwise operated, with two sectors independently and simultaneously radiating and operating in both uplink and downlink. Each sector covers an azimuthal scan range of plus/minus 60° with fixed elevation on 90°. First measurements show good beamforming capabilities with minor error in scan angles, which needs further system calibration to correct it.

16:50 On the Characterization of Conformal Antennas Using Scaled Mock-Ups of Launching Vehicles

Clara Souza Franco (UNIPAMPA, Brazil); Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil); Alexis F. Tinoco-S. (Universidad de las Américas - UDLA & CICTE, Ecuador); Willian Fontella (UNIPAMPA, Brazil); Edson R. Schlosser (Universidade Federal do Pampa, Brazil); Juner M Vieira (Universidade Federal Do Pampa (Unipampa), Brazil); Daniel B. dos Santos (Universidade Federal do Pampa, Brazil); Abdou-Halique A. A. Bouari (Unipampa, Brazil); Lucas Santos Pereira (Universidade Federal do Pampa, Brazil)

The development of onboard communication systems is crucial for the success of aerospace endeavors, e.g. to perform the reception of GNSS signals. Microstrip patch antennas are a good choice for such applications. The characterization process of integrated radiators is challenging, if the vehicle on which they are installed has large dimensions, due to large costs and needed time. This paper discusses an alternative to overcome such limitation: characterizing the antennas on a down-scaled mock-up of a rocket, whilst maintaining all the electrical dimensions. The technique is demonstrated by integration of an antenna onto a rocket mock-up. Electromagnetic simulations were performed with the software ANSYS HFSS and the characterization was carried out inside an anechoic chamber. The results prove the efficiency of the designed antenna and its potential to bypass the problems of limited space, costs and time.

17:10 Dual-Polarized Conformal Active Phased Array Antenna with TRM Integration and RFSoC-Based Digital Beamforming for UAV Platforms

Mohammad Ameen (National University of Singapore, Singapore); Yiyang Bai (Viterbi School of Engineering, University of Southern California, USA); Peizhuo Yang (National University of Singapore, Singapore); Koen Mouthaan (NUS, Singapore)

A lightweight active phased-array antenna is presented, integrating transmit-receive modules and radiofrequency system on-chip (RFSoC) based digital beamforming. The radiating elements employ a corrugated structure for primary and secondary radiators, enabling lightweight, low-profile, and reliable conformal operation under bending along horizontal, vertical, and diagonal axes. Dual polarization is supported for both transmit and receive, with power amplification on the transmitter (TX) side and low noise amplification on the receiver (RX) side, while RFSoC provides digital beamforming. The active 4×4 antenna array achieves an effective peak array gain of 35.1 dB for the TX case and 36.2 dBi for the RX case. The antenna performance is validated at 1.175 GHz to 1.25 GHz, for single element, 1×4 subarray, and 4×4 array in flat configuration and on cylindrical surfaces with 50 cm radius, demonstrating robust beamforming and low performance degradation, making the approach well suited to size-, weight-, and power-limited UAV platforms.

Thursday, April 23 15:50 - 17:30

CS53 Advanced Direction-of-Arrival Estimation Techniques in Wireless Sensing and Communication

T05 Positioning, localization, identification & tracking / Convened Session / Propagation
Chairs: Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain), Julien Sarrazin (Sorbonne Université, France)

Room: Dusseldorf

15:50 Multiport Leaky-Wave Antenna (LWA) System for 2-D Analog Direction Finding

David F Hardy and Shulabh Gupta (Carleton University, Canada)
This paper presents a microstrip leaky-wave antenna (LWA) array architecture for two-dimensional (2-D) direction finding (DF) using two orthogonal LWA arrays operating at in the microwave frequency band. The proposed design uses an array of passive LWAs with varying periods to achieve a wide field of view. Monitoring the received signal strength (RSS) across the multi-port LWA array, the proposed system is used to estimate the direction-of-arrival (DoA) in each of the (bm{xz}) and (bm{yz}) planes. The overall angular direction ((\bm{\theta}, \bm{\phi})) is then obtained using projection equations as an initial estimation. A full-wave simulation in Ansys FEM-HFSS is performed to demonstrate the system performance.

16:10 DOA-Inspired TOF Estimation Enables Device-Free Human Positioning Using Amplitude-Only CSI in Ambient ISAC Devices

Naoki Honma, Kentaro Kikuta and Kentaro Murata (Iwate University, Japan); Takeshi Nakayama and Shoichi Iizuka (Panasonic Corporation, Japan)
Human localization using ambient wireless signals has long been challenging due to the unreliability of phase information in asynchronous environments. This paper presents a novel approach that enables accurate human positioning using only amplitude information derived from Wi-Fi Channel State Information (CSI). Inspired by Direction-of-Arrival (DOA) estimation techniques, the proposed method applies the Capon algorithm to micro-Doppler signals extracted across OFDM subcarriers, allowing Time-of-Flight (TOF) estimation in the power domain without requiring phase synchronization or antenna arrays. Simulation results demonstrate that the proposed phaseless method achieves a 75% localization error of 0.32~m, significantly outperforming a conventional MIMO-based approach (2.58~m) and approaching the accuracy of phase-aware TOF estimation (0.11~m). These results demonstrate that even randomly distributed single-antenna IoT devices can be repurposed for precise human sensing, opening new possibilities for low-cost, infrastructure-free ISAC applications in smart environments.

16:30 Use of Monopulse Comparator Networks with Leaky-Wave Antennas for Direction Finding

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Jose Antonio López Pastor (Universidad Politécnica de Cartagena, Spain); Francisco Salmeron Yuste (Advanced Algorithms for Radar (a4radar), Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain); David Cañete-Rebenaque and Rubén Pedreño Martínez (Universidad Politécnica de Cartagena, Spain)
The convenience of incorporating a monopulse comparator feeding network together with a bi-directionally fed microstrip leaky-wave antenna, is compared to the direct use of the two antenna ports. It is found that a wider field of view can be obtained when the monopulse network is added, at the expense of introducing a sign ambiguity in the difference pattern. Also, this performance is compared to the one of a conventional monopulse array composed of two microstrip patch antennas with similar dimensions and operating in the same design frequency of 2.4 GHz.

16:50 2D Direction-of-Arrival Estimation with a Fast-Scanning Single-Port Leaky Wave Antenna

Aritra Roy (IMT Atlantique, Brest); Tanguy Lopez and Julien Sarrazin (Sorbonne Université, France)
The article presents a two-dimensional (2D), four-quadrant, direction-of-arrival (DoA) estimation using a leaky wave antenna (LWA). The proposed antenna constructed by cascading two LWA radiating sections arranged in an L-shape, sweeps two orthogonal planes to scan a field-of-view (FoV) over $\theta \in [0, 60 \circ]$, $\phi \in [0, 359 \circ]$, with scanning rates of 73.6 ◦ /% and 77 ◦ /%. The scanning is intended for DoA estimation over a 400MHz channel in 5G+ mmWave systems. The working principle of the proposed antenna is discussed and validated with numerical results. DoA operations with a multiple signal classification (MUSIC) algorithm is also performed with the antenna responses to detect single and multiple sources on a 2D FoV.

17:10 Variational Bayesian Estimation of Low Earth Orbits for Satellite Communication

Anders Malthe Westerkam (Aalborg University, Denmark); Amélia Struyf (Université Libre de Bruxelles, Belgium); Dimitri Lederer (Université Catholique de Louvain, Belgium); Troels Pedersen (Aalborg University, Denmark); François Quitin (Université libre de Bruxelles, Belgium)
Low-earth-orbit (LEO) satellite communication systems that use millimeter-wave frequencies rely on large antenna arrays with hybrid analog-digital architectures for rapid beam steering. LEO satellites are only visible from the ground for short periods of time (a few tens of minutes) due to their high orbital speeds. This paper presents a variational message passing algorithm for joint localization and beam tracking of a LEO satellite from a ground station equipped with a hybrid transceiver architecture. The algorithm relies on estimating the parameters of the orbit, which is modelled as circular. Angles are then obtained from the orbit in a straightforward manner. Simulation results show that the proposed method is highly resilient to missed detections, enables reliable satellite tracking even near the horizon, and effectively alleviates the ambiguities inherent in hybrid architectures.

Thursday, April 23 15:50 - 17:30

E14 Metasurfaces Analysis and Design

T07 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Federico Giusti (University of Siena, Italy), Mario Phaneuf (University of Manitoba, Canada)

Room: Rome

15:50 Toward the Physical Realization of Microwave Hyperbolic Shear Metasurfaces

Veronika Batianova (Friedrich-Schiller-Universität Jena, Germany); Federico Giusti (University of Siena, Italy); Oleh Yermakov (Leibniz Institute of Photonic Technology, Germany); Enrica Martini (University of Siena, Italy)
Hyperbolic shear metasurfaces (MTSs) are engineered 2D structures that support highly anisotropic surface waves with tilted hyperbolic dispersion, enabling directional canalized control and asymmetric propagation of electromagnetic energy. In this paper, we propose an impedance-based approach for the design of hyperbolic shear MTSs through the accurate and efficient characterization of the frequency-dependent rotation of their isofrequency contours and asymmetric loss distribution. The proposed impedance-based framework retrieves the effective sheet parameters directly from full-wave simulated scattering data and predicts the resulting surface-wave dispersion characteristics. A 21x21 elements MTS operating at 6 GHz is designed through the proposed method, and the results are validated through a full-wave simulation of the finite structure. The good agreement confirms the validity of the approach and demonstrates its potential as a practical tool for the design and optimization of anisotropic MTSs.

16:10 Multilayer Reflectionless Metasurface Enabling Anomalous Transmission with Preserved Circular Polarization

Kioumars Pedram, Federico Giusti, Enrica Martini, Matteo Albani and Stefano Maci (University of Siena, Italy)
Metasurfaces (MTSs) are efficient tools for controlling electromagnetic radiation and manipulating local aperture fields. Anomalous reflectors and refractors, electromagnetic devices capable of altering the direction of scattered plane-waves, have become an engaging topic recently. This work focuses on the synthesis of an anisotropic three-layer MTS performing a 0°-to-55° anomalous transmission in dual polarization at 29GHz. The impedance profiles of the three layers are synthesized through a Floquet-modes optimization method. In this approach, the complex values coefficients of the electric field Floquet harmonics at each layer are employed as unknowns in an optimization procedure that minimizes the real part of each sheet impedance. Notably, when illuminated by a circularly polarized plane wave, this device enables azimuthal beam steering simply through its mechanical rotation, while preserving circular polarization and keeping the primary antenna fixed. The above mentioned properties of the synthesized MTS are verified at the homogenized level through full-wave simulations.

16:30 The Three-Dimensional Implicit IE-GSTC Metasurface Forward Solver

Mario Phaneuf and Puyan Mojabi (University of Manitoba, Canada)
Metasurface forward solvers are a key tool used to verify metasurface designs and enable iterative design algorithms. When high computational efficiency is desired, it is common to utilize methods based on a combination of the generalized sheet transition condition (GSTC) metasurface model and the field integral equations (IEs), which yields a class of algorithms known as IE-GSTC methods. Although efficient, most of the literature on the topic has been limited to two-dimensional wave propagation. To address this, the authors present the three-dimensional formulation and methodology for their own method known as the implicit IE-GSTC. This extended method is verified and evaluated by simulating several metasurface test cases that also demonstrate the capabilities of three-dimensional designs.

16:50 Beyond Hole in a Sheet: Homogenization of Dipolar Arrays of Non-Deep Subwavelength Periods

Jordan R. Dugan, Tom Smy and Shulabh Gupta (Carleton University, Canada)
Here we propose a simple metasurface homogenization procedure for a uniform array of dipolar particles. This procedure extends the "hole in a sheet" homogenization method so that unit cells that are not deeply subwavelength can be modeled. This method is then numerically validated using a simple 2D simulation of an array 2D "dipoles".

Thursday, April 23 15:50 - 17:30

IW7 **Industrial Workshop - Recent Advances in Synopsys HFSS (CADFEM)**

// Electromagnetics

Room: Stockholm

Alexander Shalaby (CADFEM)

EM simulations for antennas are a must-have rather than nice-to-have. Engineers are now going higher in frequencies, up to the THz range. With such high frequencies and more complex geometries, it is essential to balance accuracy with simulation time. In this workshop, we will introduce the latest and greatest of HFSS to help antenna engineers make the most of their designs. We will cover phased array design, dielectric lenses, 3D components, and answer your questions.

Workshop Outline: Alexander Shalaby and David Prestaux will cover different aspects of our product HFSS to help engineers working on electrically small and electrically large antennas achieve first-time-right designs.

Alexander Shalaby is Radio-Frequency Product Manager at CADFEM (Synopsys channel Partner) for Western Europe. With a background in electrical engineering and expertise in mmWave, phased arrays, and radar systems, he has worked on advanced projects for aerospace (DLR, Parker Aerospace), automotive, and medical applications (Cambridge Consultants). Today, he supports customers in designing and simulating cutting-edge high-frequency products with Synopsys HFSS.

Thursday, April 23 19:00 - 22:45

CD **Conference Dinner**

Room: Aviva Stadium

There will be food and drink as well as live music.

Friday, April 24

Friday, April 24 8:30 - 10:10

A20a Leaky Wave Antennas 1

TO2 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Jordan Budhu (Virginia Tech, USA), Davide Comite (Sapienza University of Rome, Italy)

Room: Rome

8:30 Substrate-Integrated Waveguide Leaky Horn Antenna with High Aperture Efficiency

Miguel Poveda-García (Technical University of Cartagena, Spain); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Francisco Mesa (University of Seville, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain)
This work presents the synthesis of leaky horn antennas (LHAs) with enhanced aperture efficiency. Although previous leaky horn antennas in the literature achieve a quasi-uniform phase distribution at the horn aperture, they suffer from a sub-optimal amplitude profile due to the exponential decay of the leaky fields, which reduces the overall aperture efficiency. This issue becomes more pronounced at high radiation efficiency, creating a trade-off between aperture and radiation performance. By properly tapering the leakage rate of the substrate-integrated waveguide (SIW) leaky arms while maintaining a constant leaky angle that matches the horn angle, a quasi-uniform phase and amplitude distribution is achieved across the horn aperture. This results in improved aperture efficiency and, consequently, higher directivity without compromising radiation efficiency.

8:50 Unidirectional Beam Scanning All-Dielectric Leaky-Wave Antenna at mm-Wave Frequencies

Guillaume François, Sofia Rodrigues and Henrik Jansen (RWTH Aachen University, Germany); Amar Al-Bassam (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Dirk Heberling (RWTH Aachen University, Germany)
An all-dielectric leaky wave antenna operating in the frequency range of 60 to 80 GHz is designed, simulated, and experimentally characterized. The antenna exhibits beam-scanning radiation in the transverse plane. Despite the absence of a metallic ground plane, measurements show that more than 80 percent of the radiated power is directed into a single hemisphere, with simulations indicating a potential exceeding 85 percent. The antenna achieves a directivity greater than 21 dBi across the entire frequency range while maintaining high radiation efficiency.

9:10 Dual-Polarized Leaky-Wave Antenna with High Isolation Crossover and Open-Stopband Suppression Enabling Dual-Fan Beams

Qifeng Shen and Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))
This paper presents a dual-polarized dual-scan dielectric image line (DIL) leaky-wave antenna (LWA) capable of independent and continuous beam scanning in two orthogonal planes. In particular, a DIL-based LWA employing periodic double-strip elements is first designed to achieve a wide beam-scanning range from -65 to +35 degrees with suppressed open-stopband (OSB) and a linear frequency-to-beam angle relationship. Building upon this design, a dual-polarized dual-scan-LWA is further developed by orthogonally intersecting two DIL-based LWAs at a common phase center. To mitigate coupling and impedance mismatch at the crossover, subwavelength dielectric gratings are introduced, enhancing channel isolation to 25 dB and reduced reflections. Full-wave simulations verify that the proposed antenna maintains high realized gain, exhibits smooth beam scanning across broadside, and eliminates OSB problems. The compact structure, linear beam-frequency response, and dual-axis scanning capability make the proposed antenna a promising candidate for broadband radar and millimeter-wave sensing applications.

9:30 Design of a Backward Radiation Leaky-Wave Antenna with Controllable Beamwidth and Sidelobe Level

Yuhuan Tong (Sorbonne Université, France); Nelson Castro (University Carlos III of Madrid, Spain); Guido Valerio (Sorbonne Université, France); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)
Leaky-wave antennas (LWAs) based on groove gap waveguide (GGWG) technology provide a compact, all-metal solution for millimeter-wave applications. This work explores generating a backward leaky mode in a GGWG using a double-ridge mirrored-corrugation design to slow the guided wave. The resulting periodic structure enables independent control of phase and attenuation constants for flexible beam shaping. A prototype achieves a beam with specified width, -18 dB sidelobes, and 90% radiation efficiency, validating the proposed design method.

9:50 Leaky-Wave Designs of Tapered Corrugated Antennas

Beatrice Ambrogi (Sapienza University, Italy); Guido Valerio and Yuhuan Tong (Sorbonne Université, France); Davide Comite (Sapienza University of Rome, Italy)
All-metal corrugated antennas offer compact and low-profile solutions well suited for space and aeronautic applications. In this work, a leaky-wave approach is employed to design and optimize such structures for improved broadside radiation performance. The modal dispersive behavior of a symmetric unit cell featuring complex-shaped corrugations, is analyzed using an in-house Method-of-Moments solver. Based on the dispersion, the broadside radiation of the corresponding radially periodic leaky-wave antenna is predicted and enhanced. Leaky-wave-based optimization techniques, namely open-stopband suppression and aperture-field tapering, are implemented to improve the gain/bandwidth trade-off for broadside radiation. An optimum corrugated tapered antenna is designed, which achieve a peak gain of about 29 dBi and a -3-dB broadside gain fractional bandwidth exceeding 6%.

Friday, April 24 8:30 - 10:10

A27a Patch Based and Electrically Small Antennas 1

TO1 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Adam Narbudowicz (Technical University of Denmark, Denmark), Divitha Seetharamdoo (Univ Gustave Eiffel COSYS LEOST Univ Lille Nord de France & Univ Lille Nord de France, France)

Room: Krakow

8:30 Dual-Circularly Polarized Bent-Patch Antenna for Foldable Smartphones: Leveraging an FPCB and Its Through-Aperture

Kanghyun Ryoo, Byeongjin Kim, Minkyu Park and Jungsuek Oh (Seoul National University, Korea (South))

This work demonstrates that the hinge-adjacent region-normally reserved for durability and repeated folding and therefore non-radiating-can be reactivated as an antenna. We exploit a flexible printed circuit board (FPCB) and a through-aperture to create an electrical link between the hinge-side segmented metal and the grounded-coplanar-waveguide (GCPW) top ground, extending the effective current path under strict size limits. Building on this mechanism, dual circular polarization with parallel feeds is achieved using half-diamond segmentation, intentional field bypass around the aperture, and participation of the PCB top ground to equalize the two modal paths. The aperture also aids impedance matching and stabilizes fringing fields against routing variability. Measurements agree with simulations, reporting 8.64-dBi peak realized gain at 5.5 GHz, ≤3-dB boresight axial ratio across the band, high cross-polarization discrimination, and robust performance with low-profile hinge routing. The approach activates an unused mechanical domain and enables compact dual-CP antennas for future foldable smartphones

8:50 A Low Cross-Polarization Huygens Source Antenna Using a Planar Dipole-Fed Dielectric Resonator

Audric Boiteau (ENAC, France & University of Toulouse, France); Christophe Morlaas (ENAC, France); Romain Pascaud (ISAE-SUPAERO, Université de Toulouse, France); Alexandre Chabory (ENAC, France); Vincent Laquerbe (CNES, France); Pouliguen Philippe (DGA, France)

This paper presents the design of a linearly polarized Huygens source antenna (HSA) in the 2.45 GHz ISM band with low cross-polarization. Unidirectional radiation in the far-field is obtained by exciting two resonant modes of an inhomogeneous rectangular dielectric resonator (IRDR). The modal distribution of the IRDR is controlled by its shape while the modal selectivity of the excitation is set by the feed location. Various geometrical parameters of the feeding structure present minimal effects on the resulting cardioid-shaped radiation pattern, which allows to separate the design of the IRDR and the impedance matching. The proposed antenna is numerically analyzed with simulations using Ansys HFSS. It achieves a maximum gain of 4.9 dBi and a front-to-back ratio (FTBR) larger than 15 dB over a 80 MHz operational bandwidth (OBW) with no ground plane.

9:10 Deep Learning-Driven Optimization for Dual-Band and Wideband Slotted Patch Antennas

Chandan Roy (Huawei Technologies Canada, Canada); Ming Jian (Huawei Technologies Co. LTD, Canada); Peyman Neshaastegaran (Technologies Canada, Co, Ltd., Canada); Wenyao Zhai (Huawei Technologies Canada Research Center, Canada)

In this paper, we present an inverse design methodology for vector graphics-based slotted patch structures in planar antennas, employing deep convolutional neural networks (CNNs) to achieve rapid and accurate prediction of antenna S11-parameters. Unlike conventional machine learning methods constrained by fixed-template geometries with limited design flexibility, our approach generalizes to vector graphics representations, significantly expanding the antenna design space beyond traditional library-optimized configurations. By replacing computationally intensive electromagnetic simulations with a machine learning-driven framework, we introduce an inverse design process augmented by a genetic algorithm for optimization. This methodology is validated through simulation and experimental results of double-band and wideband planar antennas, specifically targeting the X-band frequency range (8-12 GHz). The results demonstrate the potential of this approach to drive innovative antenna designs with enhanced performance and flexibility.

9:30 A Magnetoelectric Self-Dual Small Antenna

Vydehi Nitta, Ravikanth Thanikonda and Stefano Maci (University of Siena, Italy)

This paper presents a magnetoelectric self-dual electrically small Huygens antenna that achieves balanced electric and magnetic dipole radiation through material duality. The proposed hemispherical magneto-dielectric resonator, characterized by equal permittivity and permeability ($\varepsilon r = \mu r$), supports two in-phase modes with complementary field distributions. Excited by a 90-degree self-complementary bow-tie feed, it forms equivalent magnetic and electric dipoles that produce unidirectional Huygens-type radiation with minimal backscattering. To enhance directivity and stabilize reactive energy, two circular metallic rings with a single conductive link create capacitive coupling around the resonator, yielding a compact, self-resonant design (ka = 0.99 at 2.92 GHz). Full-wave simulations confirm excellent impedance matching (-10 dB S11) over a 4% bandwidth and a peak directivity of 6 dBi, reaching the Kildal-Yaghjian superdirectivity limit. The proposed concept demonstrates that passive material symmetry enables near-ideal Huygens radiation without active components or complex metamaterials.

9:50 Wideband Dual-Polarized Aperture-Coupled Patch with via Cavity for Millimeter-Wave Applications

Shu Jia Chin, Raza Ullah, Jiangcheng Chen, Marko E Leinonen, Aarno Pärssinen and Ping Jack Soh (Centre for Wireless Communications, University of Oulu, Finland)

A wideband dual-polarized aperture-coupled patch antenna with via cavity is proposed for millimeter-wave applications. This antenna operates in wideband mode across 35.7-49.5GHz, with 32.4% of fractional bandwidth. The square patch as a radiator, with the wideband performance is enabled by patch and slot modes. Next, dual-polarization feature is integrated by using substrate integrated coaxial line as feeding structures in two different layers, resulting in a high polarization isolation of greater than 46dB. Finally, an additional layer of via cavity underneath the patch is utilized to enable out-of-band gain suppression of up to 17.5dB with two radiation nulls occur at 31GH and 55GHz. A stable unidirectional pattern is also observed throughout the operating bandwidth with cross polarization discrimination more than 25dB at broadside direction. In overall, this proposed antenna can achieve wide bandwidth and dual polarization with high isolation, it also performs two radiation nulls with suppression level with via cavity.

Friday, April 24 8:30 - 10:10

A28a Phased Array Antenna Designs 1

T03 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Ulf Johannsen (Eindhoven University of Technology, The Netherlands), Cyrille Menudier (XLIM Université de Limoges, France)

Room: Barcelona

8:30 Design of a Wide-Beamwidth Circular Patch Antenna Element Based on TM21 Mode for Phased Array Applications

Burak Sevik (ASELSAN Inc., Turkey); Kamil Karacuha (Istanbul Technical University, Turkey); Galip Orkun Arican (Aselsan Inc., Turkey); Feza Turgay Çelik (Delft University of Technology, The Netherlands); Burak Alptug Yilmaz (Aselsan, Turkey)

This study presents a wide-beam circular microstrip patch element operating in the TM21 mode for Ku-band phased arrays. In this design, the TM21-mode conical radiation couples to symmetric parasitic dipoles on low-εr sidewalls, forming a Huygens type radiator with a stable wide-angle pattern. Fullwave simulations show a resonance at 13.35 GHz with a return loss below -25 dB and ~450 MHz bandwidth for $|S11| < -10$ dB. A flat-gain radiation pattern with a 3 dB beamwidth of ~ 275 ◦ is achieved, maintaining < 3 dB gain variation across -137.5 ◦ -+137.5 ◦ . Infinite-array analysis confirms matching better than -10 dB for elevation scans up to $\theta = 70$ ◦ within the band. The design provides a simple, array-compatible route toward wide-angle scanning arrays.

8:50 Design and Analysis of a Low-Profile Connected Slot Array with Polarization-Sensitive WAIM for Wide-Angle Scanning

Raza Ullah, Shu Jia Chin, Jiangcheng Chen, Marko E Leinonen, Aarno Pärssinen and Ping Jack Soh (Centre for Wireless Communications, University of Oulu, Finland)

A wideband planar connected slot array (CSA) antenna is proposed. The input resistance is effectively reduced by introducing capacitive gap between adjacent elements and implementing a stub-line feeding technique. These design strategies smoothen the input impedance and enable direct excitation through a simple (SMA) connector, thereby eliminating complex feed transitions. A single-layer, low-cost, and polarization-sensitive wide-angle impedance matching (WAIM) layer is then developed to further enhance wide-angle performance. Several key parameters in this CSA are systematically analyzed, including common-mode resonance (CMR), loop-mode resonance (LMR), the slot-to-reflector spacing (H2), and the WAIM-to-slot separation (H1). Finally, an 8 × 8 array is designed and optimized to feature a wide impedance bandwidth of 1.5 to 4.2 GHz at broadside. It achieved scanning angles of up to ±65° in the E- and D-planes, and up to ±55° in the H-plane, maintaining a VSWR of < 3 while scanning in all planes.

9:10 An Extremely Wideband Tightly Coupled Dipole Array Achieving over 80:1 Bandwidth

Rajbala Solanki, Peng-Khiang Tan, Cedric W. L. Lee and Theng Huat Gan (National University of Singapore, Singapore)

The rapid advancement of wireless communication technologies has intensified the need for antenna systems capable of operating efficiently over extremely wide frequency ranges. Traditional narrowband antennas are increasingly inadequate, leading to spectrum inefficiencies and added system complexity. Ultra-wideband (UWB) and Extremely wideband (EWB) antenna arrays offer a promising solution by enabling seamless multiband operation while reducing size, weight, power consumption, and cost. Among these, tightly coupled dipole arrays (TCDAs) stand-out for their low-profile, high efficiency, and wide-angle scanning capability. This paper presents an extremely wideband TCDA with an impedance bandwidth exceeding 80:1. The design integrates a single-layer frequency selective surface (FSS) to suppress ground reflections and a metasurface superstrate to enhance impedance matching across the band. Each unit cell employs a tapered microstrip-fed dipole optimized for extreme wideband performance. Full-wave simulations demonstrate an average radiation efficiency of 71%, validating the proposed array as an efficient solution for next-generation wideband applications.

9:30 Electronically Steerable Parasitic Array Radiator (ESPAR) Based on Microstrip Patches with 2D Beamsteering or Hemispherical Radiation Patterns in Circular Polarization

Charles Couty (University of Limoges, France); Silvia Hernandez Rodriguez (XLIM - University of Limoges, France); Marc Thevenot (XLIM-UMR CNRS 7252, University of Limoges, France); Eric Arnaud (XLIM, France); Nathalie Lecerf (Arianegroup, France); Anthony Disserand (CRT Cisteme, France); Cyrille Menudier (XLIM Université de Limoges, France)

This work presents the design and measurements of a 37-microstrip-patch ESPAR (electronically steerable parasitic array radiator) operating in the S band and exhibiting circular polarization. The antenna can create beam steering between ±75° for all azimuth planes and offers the possibility of creating a hemispherical radiation pattern. The axial ratio is below 2 dB for the different configurations, with a gain of between 7 and 12 dBi for beam steering of up to ±70°. This ESPAR antenna has an efficiency of between 35% and 45%, which is a good value for this type of antenna compared to current state of the art

9:50 High-Performance 60 GHz Circularly Polarized Array Antenna Manufactured via Metallized Stereolithography: A Comparison with DMLS

Jorge Sanchez-Castillo and Jose Luis Masa-Campos (Universidad Politécnica de Madrid, Spain); Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Jorge A Ruiz-Cruz (Universidad Politécnica de Madrid, Spain)

This paper compares an 8x8 circularly polarized (CP) array antenna optimized for the 60 GHz (V-band) spectrum, aimed at high-capacity systems like WiGig and FWA backhaul. The design, a waveguide corporate-fed structure with bowtie polarizers, was fabricated using a novel Stereolithography (SLA) process by Golden Devices and benchmarked against a Direct Metal Laser Sintering (DMLS) prototype. The SLA method builds the antenna as a monolithic block with access holes for copper electroplating, preventing leakage through SLA's high precision. Measurements show the SLA antenna achieves about 0.5 dB higher gain and a more centered Axial Ratio bandwidth, closely matching simulations. These improvements result from copper's higher conductivity, SLA's smoother surface finish, and tighter tolerances. The findings confirm SLA-based fabrication as a cost-effective and efficient alternative for high-performance millimeter-wave antennas.

Friday, April 24 8:30 - 10:10

CS12a Advances in Channel Sounding and Measurements for 6G: From cm-Wave to sub-THz 1

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Diego Andrés Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany), Wei Fan (Southeast University, China)

Room: Copenhagen

8:30 Wideband Channel Measurements for Indoor Short-Range Wireless Networks in the Upper Mid-Band

Nektarios Moraitis (National Technical University of Athens & Institute of Communications and Computers Systems, Greece); Alexandros Rogaris, Ileana Popescu and Konstantina Nikita (National Technical University of Athens, Greece)

In this paper a wideband channel measurement campaign is presented at diverse frequencies in the upper mid-band. The experiments are carried out in indoor locations for line-of-sight (LOS) and non-line-of-sight (NLOS) propagation scenarios. According to the preliminary statistical analysis, the wideband temporal properties depend directly on the selected frequency. The root-mean-square delay spread varies between 6.9 and 23.0 ns in LOS, and between 21.7 and 41.9 ns in NLOS conditions, respectively. Low K-factor values were encountered, remaining below 6.5 dB in LOS, with negative values in NLOS scenarios, which can be credited to the reflective indoor surfaces and the omnidirectional antennas. The specific upper mid-band channel can accommodate, on average, bandwidths up to 84.5 MHz in LOS conditions, values that are reduced about 62% in NLOS positions.

8:50 Fast Estimation of mmWave Power-Angular Spectrum Using Leaky-Wave Antennas

Rida Maydani (Nantes Université, CNRS, IETR, UMR 6164, F-44000 Nantes, France); Julien Sarrazin (Sorbonne Université, CNRS, Laboratoire de Génie Electrique et Electronique de Paris (GeePS), 75252, Paris, France, Un); Aritra Roy (Institut Mines-Telecom Atlantique, Brest, France); Yide Wang (Nantes Université, CNRS, IETR, UMR 6164, F-44000 Nantes, France)

Leaky-wave antennas (LWAs) provide compact and cost-effective solutions for direction-of-arrival (DoA) estimation due to their frequency-dependent beam-scanning characteristics. However, in coherent multipath environments, the source covariance matrix becomes rank-deficient, which limits the performance of conventional subspace-based methods. Interpolation-based spatial smoothing (SSP) can restore the rank and recover DoAs, but accurate power estimation remains difficult, hindering the acquisition of the power angular spectrum (PAS). In this work, we propose an on-grid sparse Bayesian learning (SBL) approach that operates directly on the fast frequency-scanning responses of meandered waveguide-based LWAs. The method jointly estimates DoAs and their corresponding powers without requiring rank-restoration techniques. Simulation results demonstrate that the SBL-based approach provides robust and accurate PAS estimation, even in the presence of fully coherent sources.

9:10 Field Trials for Realistic Deployment of Massive Metasurface Reflectors in Millimeter-Wave Bands

Takumi Yoneda (NTT, Inc., Japan); Tomoki Murakami (NTT Corporation, Japan); Sho Yoshida, Toshiki Sayama, Osamu Kagaya and Sangmun Lee (AGC Inc., Japan); Dan Mohri, Satoshi Suyama and Yuyuan Chang (NTT DOCOMO, INC, Japan); Huiling Jiang (NTT DOCOMO, INC., Japan); Riichi Kudo (NTT Corporation, Japan)

In high-frequency bands, propagation and shaddowing losses become significant issues. To address these challenges, passive metasurface reflectors have been investigated. A metasurface reflector is a device capable of reflecting electromagnetic waves toward a desired direction; however, since its reflection angle cannot be controlled after installation, its coverage enhancement effect is limited. This paper presents the results of outdoor experiments conducted to maximize the coverage improvement by simulating the large-scale deployment of metasurface reflectors on building windows. We evaluated the characteristics of the angle of arrival. The experimental results confirmed that reflected waves corresponding to the designed reflection angles were observed at multiple points within the measurement area. Furthermore, we evaluated the improvement in received signal strength provided by the metasurface reflectors when installed in a building-surrounded environment, and confirmed that the received power was enhanced by approximately 1.2 times through the use of the metasurfaces.

9:30 RIS Beam Squint at 300 GHz: Modeling and Experimental Validation

Lorenz H. W. Loeser, Tobias Doeker and Thomas Kürner (Technische Universität Braunschweig, Germany)

The terahertz (THz) band offers vast bandwidth for future wireless systems but suffers from a strong line-of-sight (LOS) dependency. Reconfigurable intelligent surfaces (RISs) can overcome this limitation by enabling controllable reflections. This paper extends a previously validated narrowband model for predicting the primary reflection direction of an RIS based on its phase configuration and the angle of incidence. The extension incorporates the beam squint effect, which is a frequency-dependent shift of the reflection direction when the used frequency deviates from the frequency the RIS is designed for. The model is validated through measurements at 300 GHz using an RIS prototype, by limiting the processed bandwidth to narrow windows around different center frequencies during post-processing.

9:50 Multi-Beam Channel Measurement and Characterization in Commercial 5G Network Based on Passive Channel Sounding

Hao Sun (National Mobile Communications Research Laboratory, School of Information Science and Engineering, Southeast Un); Runnan Liu, Yani Chi and Lei Li (China Academy of Information and Communications Technology, China); Wei Fan (SouthEast University, China)

By utilizing the downlink signal for channel sounding purpose, passive channel sounding has been regraded as a crucial method to investigate the channel characteristics of realistic communication network. In the 5G fifth generation (5G) network, the emitted downlink signals have been steered by the implemented beams of 5G base station (BS). However, the state-of-the-art passive channel sounding campaign in 5G network ignores the effect of BS beams on the radio channel. This paper conducts a multi-beam channel measurement for the live 5G network with the proposed passive channel sounder. The channel measurement campaign is performed under a typical city street scenario along a 138 m route. The multipath parameters in the deployed network, including angular, delay and power profiles, have been thoroughly resolved and analyzed. The measurement results indicate that BS beam effect has a considerable influence on the recorded radio channel in 5G network.

Friday, April 24 8:30 - 10:10

CS3a Advanced Beam Manipulation with Metamaterial, Lenses, and Phased Arrays for 6G Communication and Sensing 1

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Can Ding (University of Technology Sydney (UTS), Australia), Alessio Monti (Roma Tre University, Italy)

Room: Paris

8:30 Beam Launchers for Secure and Resilient Wireless Communications at Millimeter Waves and Beyond

Walter Fuscaldo (National Research Council (CNR), Italy); Edoardo Negri (Consiglio Nazionale delle Ricerche, Italy); Jérôme Taillieu (Université de Rennes 1, France); David González-Ovejero (Université de Rennes, France); Luca Del Biondo (Michigan State University, USA); Adam Narbudowicz (Technical University of Denmark, Denmark); Mauro Ettorre (Michigan State University, Electrical and Computer Engineering, USA)

he security of wireless communications is typically ensured at software level through complex and energy-hungry encryption algorithms. The generation of localized beams at millimeter and sub-millimeter waves thus represents a revolutionary-yet challenging-approach to transferring information while ensuring security at the hardware level. This paper presents an overview of recent enabling technologies for generating localized beams at millimeter and sub-millimeter waves, with a focus on the realization of wireless near-field links. Simulations and experiments on several case studies are discussed along with an outlook on promising future directions in the context of wireless power and information transfer.

8:50 Reconfigurable Metasurface-Antennas for SatCom and 5G

Nicola Bartolomei (Wave Up srl, Italy); Cristian Della Giovampaola (Wave Up Srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Dona Joseph (Wave-Up Srl, Italy); Arya Kanathil (University of Siena, Italy); Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy); Stefano Maci (University of Siena, Italy)

Reconfigurable metasurface antennas are gaining increasing attention as enablers of adaptable and efficient solutions for satellite communications (SatCom) and 5G systems. By tailoring the electromagnetic response of engineered surfaces, these antennas can achieve dynamic beam control, frequency tuning, and polarization agility without bulky mechanical structures. This paper presents an overview of several reconfiguration approaches, including multiplexing through multiport architectures, mechanical beam steering via metasurface rotation, electronic beam scanning by switching networks, and continuous reconfigurability using varactor and PIN-diode tuning elements. Such techniques enable compact, lightweight, and versatile antennas capable of supporting diverse link and coverage requirements across terrestrial and non-terrestrial networks. The review highlights recent advances and practical implementations done by our group, emphasizing the potential of reconfigurable metasurface antennas for future communication platforms.

9:10 Sub-THz SSPP Leaky-Wave Antenna with 2-D Beam Scanning Capability

Yuanxi Cao, Jianxi Gao and Wencheng Hou (Xi'an Jiaotong University, China); Kai Zhang (Xi'an University of Technology, China); Fei Yang and Sen Yan (Xi'an Jiaotong University, China)

In this paper, a spoof surface plasmon polariton (SSPP) leaky-wave antenna (LWA) is designed to realize passive 2-D frequency beam scanning in the sub-terahertz (sub-THz) band, which consists of two layers of waveguide elements, i.e., an LWA array and a series-fed network. The LWAs in the upper layer are connected in a front-to-end series configuration via the bottom-layer series-fed network to achieve a compact structural design. Orthogonal phase gradients derived respectively from the LWA itself and the series-fed network enable the antenna to generate scanned beams with varying directions in both the pitch and azimuth planes. Moreover, to expand the beam scanning range, SSPP is employed to boost the dispersion characteristics of both the LWA units and the series-fed network, allowing the design to achieve 2-D beam steering of -25° to 30° within the frequency range of 0.26 to 0.33 THz.

9:30 Dual-Band Active Array Concept for JCAS Integrating LTCC and CMOS

Kevin Adrianus Petrus van Hastenberg (University of Technology Eindhoven, The Netherlands); Yiqin Hou, Vojkan Vidojkovic, Pavan Telluri, Dusan Milosevic and A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

Joint communication and sensing systems will play a pivotal role in future 6G systems, particularly in automotive and radar-centric applications. This paper addresses integration challenges of dual-band active antenna arrays at 77 GHz and 130 GHz. A hybrid array architecture is proposed, combining dual-band and high-band antennas in a 1:3 ratio optimizing grid utilization and performance across both bands. A comparison for different technologies for antenna integration and interconnection resulted in low temperature co-fired ceramics technology being selected for its gain and loss performance, manufacturability, and multilayer integration. Simulations of the implemented concept show realized gains of 9.8 dBi and 15.4 dBi at 77 GHz and 130 GHz. A dual-band power amplifier implemented in TSMC28nm CMOS is introduced, featuring a novel coupled resonator for efficient dual-band matching. Measurement results demonstrate gains of 22 dB and 11.5 dB at 77 GHz and 130 GHz, respectively.

9:50 A Compact 2D Polarization-Mixing Beamforming Antenna Array with Controllable Beamwidth

Fanchao Zeng (University of Technology Sydney, Australia); Can Ding (University of Technology Sydney (UTS), Australia); Y. Jay Guo (University of Technology Sydney, Australia)

This paper presents a compact and power-efficient millimeter-wave antenna array that enables two-dimensional (2D) controllable beamwidth through a novel polarization-mixing analog beamforming (PMBF) technique. The proposed 4*4 dual-polarized array achieves wide-range beamwidth tuning (21°-90°) and full-space beam steering using only phase control, without any amplitude modulation. A unified coding-matrix framework is developed to independently adjust beamwidth and direction across both azimuth and elevation planes, supporting multiple beam types including boresight, tilted, and split beams. A fully integrated prototype incorporating phase shifters and an FPGA controller is designed and tested, demonstrating excellent agreement between measured and simulated results. The proposed PMBF array offers a cost-effective and energy-efficient solution for future 6G small-cell and vehicle-mounted communication systems requiring flexible and reconfigurable beam control.

Friday, April 24 8:30 - 10:10

CS43a Characterisation of biological tissues and tissue mimicking materials for electromagnetic medical applications 1

T06 Biomedical and health / Convened Session / Propagation
Chairs: Julian Bonello (University of Malta, Malta), Daniela M Godinho (Universidade de Lisboa, Portugal)

Room: Prague

8:30 Microwave Range Dielectric Characterization of GelMA Tissue-Mimicking Phantoms

Fadilah Khan and Sidrah Alousi-Jones (McGill University, Canada); Emily Porter (McGill University, Canada & RI-MUHC, Canada)

Microwave medical technologies require validation and testing before moving to clinical studies. Typical pre-clinical testing is performed through experimental testing using phantoms, materials constructed to mimic the dielectric properties of human tissues. However, current methods for creating phantoms face challenges such as dehydration, limited reusability, and the use of toxic materials. In this work, gelatin methacryloyl (GelMA) is studied as a promising prospective biomaterial for phantoms due to its biocompatibility, longevity, tunable properties, and ability to be 3-D printed.

8:50 Ad-Hoc Double-Extended-Bitten Ridge Waveguide for Broadband Dielectric Characterization of Lossy Dispersive Solid and Semi-Solid Materials

Martina Gugliermino (Politecnico di Torino, Italy); Nelson Castro (University Carlos III of Madrid, Spain); David O. Rodriguez-Duarte (Politecnico di Torino, Italy); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain); Francesca Vipiana (Politecnico di Torino, Italy)

Dielectric characterization of materials is an essential component of a wide range of applications, from antenna design to biomedical modeling. However, it might be susceptible to sample manufacturing and procedural errors that affect the reproducibility, reliability, and accuracy. To mitigate these issues, this paper proposes and examines an ad-hoc double-extended bitten ridge waveguide (DEB-RW) aimed for broadband dielectric characterization of lossy dispersive materials, and compares it with a baseline double-ridge waveguide (D-RW). The DEB-RW reduces field instabilities in the high-sensitivity region due to sample misalignment and air gaps, enhancing both the accuracy and repeatability of dielectric property retrieval, retaining the advantages of the D-RW in terms of operational frequency band, 1-4 GHz. Finally, a gap waveguide implementation is proposed to simplify the measurement system while maintaining performance.

9:10 Development and Characterisation of Brain Tissue Mimicking Phantoms for Microwave-Based Medical Applications

Bilal Amin and M Inzamamul Haque (University of Galway, Ireland); Martin O'Halloran (National University of Ireland, Galway, Ireland); Adnan Elahi (University of Galway, Ireland); Atif Shahzad (University of Birmingham, United Kingdom (Great Britain) & University of Galway, Ireland)

Liquid tissue-mimicking phantoms are essential tools for validating microwave imaging systems, calibrating setups, and ensuring safety, as they provide reproducible and controlled surrogates of biological tissue. This study presents the development and characterisation of liquid tissue-mimicking mixtures (TMMs) formulated from Triton X-100, deionised water, and sodium chloride to replicate the dielectric properties of brain tissues across 0.5-8.5 GHz. The dielectric properties were measured using an open-ended coaxial probe and compared with reference data. The 14% Triton X-100 solution closely replicated cerebrospinal fluid, while the 30% formulation approximated grey matter. The 35% mixture showed strong correspondence with both the average head phantom and white matter. Across all formulations, measurement errors remained within acceptable limits, confirming the homogeneity and reproducibility of the mixtures. These findings demonstrate that Triton X-100-based liquid phantoms provide an effective and reliable approach for emulating brain tissue dielectric behaviour in microwave-based medical applications.

9:30 Overview of Main Constituents and Their Role in Phantoms for EMF-Based Biomedical Applications

Marco Di Cristofano (Sapienza University of Rome, Italy); Flavia Liporace (Bambino Gesù Children's Hospital, Italy); Klementina Vidjak (University of Split, Croatia); Fabiana Capitanio (Sapienza, University of Rome, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy)

The further the development of electromagnetic field-based (EMF) therapeutic techniques, the greater the inherent need for elaborate, accurate tissue phantoms or dielectric simulators. At present, there are many recipes available in literature, discerning one from another based on the targeted tissue, accuracy at a specific frequency / frequency range and constituents. More interestingly, there are often recipes targeting the same tissue type and frequency but using completely different ingredients to achieve the desired properties. Therefore, the aim of this study was to catalogue the most common constituents and their role to enable easier phantom designs in the future.

9:50 Morphological Breast Phantoms Based on Ex Vivo Measurements of Healthy and Tumor Tissues with Resin Structures for Dielectric Characterization

E Fernandez-Aranzamendi (Universidad Carlos III de Madrid, Spain & Universidad Católica San Pablo, Peru); Patricia Castillo and Ebert G San Roman Castillo (Universidad Católica San Pablo, Peru); Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)
We present a compact breast phantom platform for dielectric characterization from 1 to 8 GHz. A low-permittivity resin backbone contains morphology-guided cavities filled with liquid tissue mimics. The resin provides a flat seating plane for an open-ended coaxial probe, controlled normal force, fixed geometry, and optional sealing to limit evaporation, bubbles, and poor geometric control. Target bands for fat, gland, skin, and tumor classes are derived from our prior \emph{ex vivo} database. The workflow uses OSL calibration at the probe aperture, temperature and force checks, and and triplicate re-seats. Results show good tracking of real permittivity across the band and preservation of tumor ordering. Anchor deviations at 1, 3, 6, and 8 GHz meet a practical 10 percent goal for baseline tissues. A biopsy slot ensures repeatable placement with fixed depth and lateral alignment. The database stores raw (S_{11}), derived permittivity curves, anchor values, and quality-assurance flags.

Friday, April 24 8:30 - 10:10

EO2 Computational and Numerical Techniques: Array Analysis and Design

TO7 Electromagnetic modelling and simulation tools / / Electromagnetics
Chairs: Ic-Pyo Hong (Kongju National University, Korea (South)), Fitim Maxharraj (Chalmers University of Technology, Sweden)

Room: Gothenburg

8:30 On the Maximum Number of Orthogonal Ports in Antenna Arrays Based on Characteristic Modes

Tim Hahn (Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)
The maximum number of orthogonal ports of antenna arrays are investigated based on group theory applied to characteristic modes. It is found that the maximum number of orthogonal ports of an antenna array is determined by the array symmetry as well as the element symmetry. A concept for the realization of such an antenna array with orthogonal ports is given. The theory is applied to a symmetrical crossed-dipole array with slant polarization to validate the claims. The orthogonality of ports is verified by calculation of the current correlation coefficient.

8:50 Efficient Simulation of Multi-Band Arrays Using an Array Decomposition Method

Lucas Åkerstedt (KTH Royal Institute of Technology, Sweden); Harald Hultin (KTH Royal Institute of Technology & Saab AB, Sweden); Lars Jonsson (KTH Royal Institute of Technology, Sweden)
Design and simulation of multi-band shared-aperture array antennas are often challenging. It incorporates multiple kinds of elements, and their position is interleaved. Designs often have strong cross-band coupling, and wideband full-wave simulations are required for assessment of their behavior. Here, we show how a combined mesh decomposition and reusing method can be utilized to effectively investigate how two different edge (margin) elements impact the array behavior. Utilizing the inherent partial Toeplitz structure of the impedance matrix, we demonstrate that non-conforming margin elements can be effectively included in the calculation framework to a marginal additional computational cost. This work develops an effective combination of our earlier proposed nine-component decomposition and the mesh reusing approach to store a minimal number of submatrices. This enables efficient full-wave analysis of multi-band arrays.

9:10 A Low-Profile Metasurface Feed for Transmitarray Antennas Using Ray-Tracing-Based Synthesis

Adrian Diepolder (Ulm University, Germany); Thomas Frey (University Ulm - Institute of Microwave Engineering, Germany); Christian Waldschmidt (University of Ulm, Germany); Christian Damm (Ulm University, Germany)
In this work, a low-loss, low-profile feed architecture for transmitarrays (TAs) utilizing a metasurface antenna (MS) is presented. With a separation distance of one wavelength, the TA is placed in the near-field region of the MS, eliminating the need for large separation distances typical for conventional horn antenna feeds. Uniform illumination of the TA is achieved by the nearly planar radiating wave of the MS. A reflecting metal wall at the MS's boundaries improves the aperture efficiency to \SI{55.4}{\percent} by eliminating spillover losses. A novel ray-tracing-based synthesis approach is used to generate the impedance tensor of the MS, which allows for arbitrary exciting surface waves. Experimental results validate the performance of the proposed design for several fixed-beam TAs, suggesting its suitability for both fixed and reconfigurable TAs.

9:30 On RIS Macromodeling of a Large Holographic-Inspired Beamforming Panel

Morteza Ghaderi Aram and Fitim Maxharraj (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Tommy Svensson (Chalmers University of Technology, Sweden)
Beamforming metasurfaces have opened up new research avenues in the design of next-generation wireless networks, especially in the potential deployment of reconfigurable intelligent surfaces (RIS) for 5G and beyond. Challenges, however, remain to be addressed regarding a robust unit cell (UC) design for these panels that can guarantee angular reciprocity. Moreover, there are open questions on the viability of a low-complexity surrogate model that can not only obviate the need for bulky full-wave simulations but can also guarantee an EM-compliant model for fast system integration. Along this line, by selecting a viable varactor-based UC design and a surrogate macromodel for it from the literature, this study first presents a holographic-inspired beamforming panel. Then it applies macromodeling (MM) to both UC characterization and array performance prediction of the panel. Specific comments on full-wave simulation precision vs runtime of a commercial EM solver are also made, and comparisons with macromodeling are drawn.

9:50 Design and Analysis of an S-Band Energy-Selective Antenna Array Using PIN Diodes for High-Power Microwave Protection

Rana Biswarup (Kongju National University, Korea (South)); Jong Hwa Kwon (ETRI, Korea (South)); Ic-Pyo Hong (Kongju National University, Korea (South))
In this paper, a novel concept of an energy selective antenna array (ESAA) operating at the S-band is proposed. First, an S-band power divider was designed, followed by a 1×4 microstrip antenna array. PIN diodes were then integrated on each microstrip patch and near the feed line to form the ESAA, enabling protection against high-power microwave (HPM) signals by blocking them from reaching other system components. The proposed ESAA exhibited a gain of 10.3 dBi under normal conditions, while the gain dropped to -10.9 dBi in the presence of HPM at the broadside direction. An isolation level of 21.2 dB was achieved between the "On" and "Off" states of the PIN diodes. By controlling the surface current distributions through the PIN diodes, the TM01 mode was disrupted, leading to the energy-selective behavior of the proposed array.

Friday, April 24 8:30 - 10:10

MO5a Recent advances in antenna measurement and over the air testing 1

TO8 Fundamental research and emerging technologies/processes / / Measurements
Chairs: Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany), Matthias Hein (Technische Universität Ilmenau, Germany)

Room: Dusseldorf

8:30 Comparison of Point-to-Point Scanning Strategies for 220-330 GHz Holography with a Robot Arm

Rustam Balafendiev (University of Iceland, Iceland & ITMO University, Russia); Thomas Jacky Louis Joel Gascard and Jon E Gudmundsson (University of Iceland, Iceland)

In this paper, we present our work on investigating the relative positioning errors encountered while extending an existing 6-axis robot arm-based holography setup to the 220-330 GHz range using custom frequency extenders assembled from commercially available components. Two types of relative positioning errors observed in the phase measurements are described. We compare several point-to-point scanning strategies in terms of mean relative error, relative error dispersion and the increase in scan time.

8:50 Embedded-Pattern Correlation Operator for Polarimetric Array Calibration and Diagnostics

Jeffrey P. Massman (Analog Devices, USA)

Large phased arrays demand calibration methods that scale without dense sampling. This paper develops a theoretical framework for probe-weighted radiation operators that address this need. An array-native correlation operator, C, is formed by normalizing a probe-weighted Gram matrix of embedded patterns. The receive chain induces an angular weight, defining a matrix-weighted inner product that yields C. Novelty lies in modeling per-port calibration as a diagonal congruence on C. This approach yields linear relations for gains and phases, enabling diagnostics like node-energy maps, cross-polar leakage, and an effective modal count to be computed directly from correlation data, bypassing beam synthesis. The formulation is polarization-aware, portable across ranges, and compatible with sparse-angle acquisition. Minimal synthetic verification and a noise-sensitivity check validate the operator's invariants and show the diagnostics respond to shape-only perturbations. Application to full-scale arrays with realistic patterns is identified as future work.

9:10 Mode Filtering for Accurate Group Delay Calibration of GNSS Antennas

Jannis Röder (German Aerospace Center, Institute of Communications and Navigation, Germany); Wahid Elmarissi and Stefano Caizzone (German Aerospace Center (DLR), Germany)

User antennas play an important role in the achievable positioning performance of Global Navigation Satellite Systems (GNSS) systems. Their importance is particularly relevant for geodetic or reference station applications, where high positioning accuracy up to the mm level is aimed at.
In order to remove antenna-induced errors on GNSS measurements of reference stations, antennas are calibrated in terms of phase center and group delay variations (PCV/GDV). While PCV calibration is now state-of-the-art, the calibration of GDV is still posing measurement-based challenges, due to its extreme sensitivity to measurement system inaccuracies. This paper shows a technique to improve such accuracy when using near field spherical anechoic chambers for the antenna calibration. In particular, by making use of mode filtering, an improvement in the accuracy and repeatability of the measurement can be achieved.

9:30 Experimental Investigation of Signal Derivative Sampling Using Oscillating Scans for Robot-Based Spherical near-Field Antenna Measurements

Henrik Jansen (RWTH Aachen University, Germany); Olav Breinbjerg (ElMaReCo, Denmark); Dirk Heberling (RWTH Aachen University, Germany)

Sampling the spatial derivative of the probe signal in spherical near-field antenna measurements can theoretically reduce measurement time by 50 %. While feasibility has been demonstrated, no efficient practical method for derivative measurements has been established yet. This work introduces oscillating scanning trajectories with a robot-based antenna measurement system to estimate the derivative via finite-difference approximation. An oscillating cut is only slightly longer than a standard spherical cut, yet reduces the overall path length by up to 45 %, since every second cut can be skipped with derivative sampling. While the derivative sampling theorem is exact, the practical measurement accuracy is generally lower; however, it is demonstrated that the method can achieve an average equivalent error signal of up to -52 dB for radiation patterns and directivity error of 0.06 dB. These results demonstrate that derivative sampling with oscillating scans is a promising fast alternative to conventional spherical antenna measurements.

9:50 Fast, Densely-Sampled near-Field Imaging of Sub-10 GHz Devices via Infrared Metasurfaces

Johan Lundgren (Lund University, Sweden); Hamza Khalid (Linköping University, Sweden); Daniel Sjöberg (Lund University, Sweden); Deyu Tu (Linköping University, Sweden); Mats Gustafsson (Lund University, Sweden); Isak Engquist (Linköping University, Sweden)

We present an infrared (IR) metasurface-based method for rapid near-field characterization of sub-10 GHz radiating devices. Incident electromagnetic energy is converted into localized heating on a metasurface, which is captured by an IR camera to produce a spatial map of the power density. The approach enables simultaneous measurement of multiple sample points, providing fast, scalable, and wide-area near-field imaging without mechanical scanning. We demonstrate the technique on a 7.7 GHz patch antenna, using multiple shifted measurements to achieve dense spatial sampling. Comparison with a commercial probe-based system shows good agreement at close distances, while the proposed method remains reliable in scenarios where conventional systems fail. These results highlight the potential of IR metasurface imaging for antenna design verification and high-throughput production testing, offering a practical and efficient solution for extended-area near-field mapping at longer wavelengths.

Friday, April 24 8:30 - 10:10

PO2a AI techniques for radio propagation assessment 1

TO7 Electromagnetic modelling and simulation tools / / Propagation
Chairs: Miyuki Hirose (Kyushu Institute of Technology, Japan), Vasilii Semkin (New York University Abu Dhabi, United Arab Emirates)

Room: London

8:30 UWB Transformer-Based Encoder for NLOS Detection and Single-Bounce Path Identification

Xueli Xu (Singapore Institute of Technology - University of Glasgow Joint Degree, Singapore); Chee Kiat Seow (University of Glasgow, United Kingdom (Great Britain)); Jun Hao Jeff Lee (Singapore Institute of Technology, Singapore & University of Glasgow, United Kingdom (Great Britain)); Xin Lou (Singapore Institute of Technology & Illinois Advanced Research Center Singapore (IARCS), Singapore)

Indoor localization is essential when GPS signals are unavailable, such as during emergencies. Indoor environments often involve complex propagation paths due to Line-of-Sight (LOS) blockages, resulting in Non-Line-of-Sight (NLOS) conditions. Conventional methods struggle to detect NLOS and utilize single-bounce reflections. This paper introduces a Transformer encoder to enhance localization by detecting NLOS and identifying single-bounce path signals using real Channel Impulse Response (CIR) data collected across fourteen scenarios in two indoor environments. The multi-model framework integrates a modified Transformer encoder with statistical binning, two-stage neural networks, and a regression layer for distance estimation. Compared to baseline encoders and Convolutional Neural Networks (CNN) show that the two-stage design improves single-bounce classification accuracy by at least 21%. For regression, the Random Forest achieves the best distance estimation (R2=0.62, RMSE=0.60). These findings demonstrate the potential of transformer-based architectures when combined with statistical binning to improve robustness and generalization in GNSS-denied environments.

8:50 Access Points Placement Predictor for Indoor Optimal Coverage Based on a Modified U-NET Neural Network

Edoardo Giusti, Pierpaolo Usai and Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (Pisa University & CNIT, Sweden)

This article presents an indoor access points placement strategy using a modified U-NET Neural Network (U-NET NN) for signal spatial coverage maximization. We trained a properly modified neural network (U-NET NN) to learn a policy for optimally distributing routers on a given floorplan. After training, the performance of the network was evaluated for four different U-NET NNs, each corresponding to a different number of routers configuration. We analysed the results comparing the U-NET NN approach against a standard optimizer. While the spatial coverage percentage difference, ΔCov, ranges from -10% to +3.5%, conversely, the computational time, R_t, required with U-NET NNs approach is thousands time faster compared to the standard optimizer. Therefore, the potential of deep learning models to significantly reduce the computational costs while maintaining acceptable coverage performance in indoor network planning was clearly demonstrated.

9:10 Impact of Spatial Coverage Range on Deep Learning-Based Wireless Channel Prediction

Zhicheng Qiu, Ruisi He, Mi Yang, Yuan Yuan, Xuejian Zhang and Keying Guo (Beijing Jiaotong University, China)

Accurate channel model is vital for wireless system design and performance optimization. Deep learning enables data-driven prediction of propagation behavior directly from environmental data, offering greater flexibility than traditional analytical models. However, the performance of such models largely depends on the spatial characteristics of the input, especially the spatial coverage considered during training. This paper investigates the impact of spatial coverage on deep learning-based channel prediction using measurement-based datasets with different coverage definitions. A unified neural network with spatial pyramid pooling is employed to handle variable input sizes and extract multiscale spatial features. Results show that spatial coverage influences prediction accuracy. Narrow coverage limits environmental awareness, whereas overly wide coverage yields diminishing gains. Orientation normalization further improves stability, identifying spatial coverage as a critical but previously underexplored factor in data-driven wireless channel prediction.

9:30 Neural Electrostatics: A 3D Physics-Informed Poisson Equation Solver for Exterior Fields

Samuel J Audia (University of Maryland, USA); Matthias Zwicker (University of Maryland, College Park, USA); Dinesh Manocha (University of Maryland, USA)

Electrostatic solvers relate an imposed voltage to a corresponding charge density. Current methods require fine discretization and scale poorly due to the construction of a large matrix. We recast the problem using neural networks and introduce neural electrostatics, a hybrid 3D method of moments (MoM) solver. We overcome many limitations of previous neural solvers, such as learning trivial solutions and balancing loss terms, at the cost of introducing an integral containing a singular kernel, which we handle by locally transforming the integral into polar coordinates. Furthermore, previous sampling methods are unable to minimize the physics-informed residual. We propose a variational adaptive sampling method, which reduces mean absolute error by 5 times without increasing training time. Empirical results show that our method learns a charge distribution within 1.2 picocoulombs per square meter of mean absolute error from a classical MoM solver, while using 25 times fewer rectangular elements.

9:50 Impact of Propagation Path Spatial Resolution on the Performance of CNN Models for Rain Attenuation Prediction

Edgar Mujuni and Miyuki Hirose (Kyushu Institute of Technology, Japan); Tetsuro Imai (Tokyo Denki University, Japan)

Rain attenuation poses a major challenge for High Altitude Platform Stations (HAPS) operating at 38 GHz. Accurate prediction of rain-induced signal loss is essential for reliable communication. This study combines analytical and machine learning methods to examine rain attenuation along the propagation path. Measured attenuation data are compared with ITU-R P.618-14 estimates at four receiving sites to assess model error. A Convolutional Neural Network (CNN) model is also evaluated against measured data to analyze spatial rainfall effects and prediction accuracy under different spatial point distributions. Results show higher accuracy when data points are denser near the transmitter. The study further investigates various spatial resolutions of rainfall maps to determine optimal resolution, underscoring the role of spatial rainfall characteristics and the potential of machine learning for adaptive HAPS communication systems.

Friday, April 24 8:30 - 10:10

PO9a RIS modelling and design for smart propagation environments 1

T07 Electromagnetic modelling and simulation tools / / Propagation
Chairs: Anikó Német (University of Glasgow, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Madrid

8:30 Inverse Design of Loaded-Wire Metasurfaces Using the Scattering Matrix Method

Renat Abdullin (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy)

This work presents an inverse design approach for metasurfaces composed of loaded wires near a perfectly conducting plane. The method uses the Combined Image Theory Scattering Matrix Method to determine the wire positions and per-unit-length impedances required to produce a desired near-field distribution. A key feature of the proposed approach is that the problem is analytically formulated as an overdetermined matrix equation, which enables an efficient and transparent least-squares solution. A comparison with full-wave simulations confirms excellent agreement between the metasurface configuration obtained using the proposed method and the numerical results.

8:50 Modeling of Quantized RIS Reradiation: A Fourier-Based Method

Nicolò Cenni and Elena Bernardi (University of Bologna, Italy); Matteo Albani (University of Siena, Italy); Enrico M Vitucci and Vittorio Degli-Esposti (University of Bologna, Italy)

Reconfigurable Intelligent Surfaces (RIS) are emerging as a key enabling technology for next-generation wireless networks. However, most analytical and ray-based models rely on the assumption of continuous and differentiable phase functions across the RIS surface, while real RISs are inherently composed of discrete unit cells with quantized phase responses. This paper proposes a methodology to extend ray-based simulation models to account for discrete and quantized phase profiles, by exploiting a Fourier-optics interpretation of the re-radiated field. The approach enables the identification of the main propagation modes and their associated powers, allowing quantization effects to be represented within a ray-based framework. A reference example demonstrates the appearance of undesired spectral modes as the quantization resolution decreases. The proposed method is validated against a reference Huygens-based model, showing good agreement and reduced computational complexity.

9:10 A Highly Isolated 25-27 GHz Active RIS Using Aperture-Coupled Antennas and RFIC-Based Phase-Controlled Amplification

Patchara Sawakewang and Ilhami Unal (University College Dublin, Ireland); Apisak Worapishet (Mahanakorn University of Technology, Thailand); Pingda Guan, Zhiyuan Shao, Chawin Khongprasongsiri and Robert Bogdan Staszewski (University College Dublin, Ireland); Teerachot Siriburanon (University Dublin, Ireland)

This paper presents the design of a 25-27 GHz active reconfigurable intelligent surface (RIS) that integrates a compact radio-frequency integrated circuit (RFIC) fabricated in 22-nm FD-SOI CMOS technology. The proposed RIS incorporates on-chip amplification and phase control, enabling the surface to simultaneously receive, beamform, amplify, and retransmit incident signals, making it suitable for 5G mm-wave applications. A 1×8 array with integration of the RFIC demonstrates a 15.8- dB enhancement in the radiated power density at 26 GHz. The array operates with an off-chip orthogonally polarized, aperture-coupled patch antenna pair that provides transmitter (TX)-receiver (RX) isolation exceeding 55 dB, validating the high-isolation performance. Each RFIC comprises one independent receive-transmit chain, each incorporating a 3-bit phase shifter and a two-stage power amplifier (PA), achieving a total gain of 17.4 dB at 26 GHz. Furthermore, beam steering over ±35 ◦ is demonstrated with the 1×8 array for various phase differences via simulations.

9:30 An X-Band Reconfigurable Reflective Surface with Energy Harvesting Feature

Amartya Das, Ilhami Unal, Avishek Nag and Robert Bogdan Staszewski (University College Dublin, Ireland)

This paper presents a novel Reconfigurable Intelligent Surface (RIS) operating in the X-band (9.5-10.7 GHz), designed to achieve dual functionality for electromagnetic energy harvesting and communication enhancement. The structure exhibits two distinct resonant bands: an absorption band between 10.45-10.55 GHz for efficient energy harvesting and a reflection band between 9.88-9.95 GHz optimized for signal redirection. The reflective mode provides a stable phase shift of approximately 180 degrees, enabling controllable backscattering suitable for beam steering and communication optimization. The simulated reflection and absorption bandwidths, approximately 80 MHz and 100 MHz, respectively, align closely with single-channel allocations in 5G spectrum. This dual-response capability within a single, compact unit cell represents a significant advancement over conventional metasurface designs that typically provide either reflection or absorption alone. The proposed RIS can be seamlessly integrated into platforms offering a scalable and energy-efficient pathway toward reconfigurable and self-sustaining electromagnetic environments for future wireless networks.

9:50 Double Layer Phase Gradient Surface for Dual-Band Shared Aperture RIS Applications

Sylvie Rana, Rishi Mishra and A. r. Harish (Indian Institute of Technology Kanpur, India)

A passive dual-band shared aperture unit cell for a phase gradient surface is proposed to cover two frequency bands: 4.34 - 4.72 GHz and 11.85 - 12.14 GHz. The proposed design has a top layer that acts as a high-pass filter and reflects signals of the lower frequency band, and a bottom layer that works as a phase gradient surface for the higher frequency band. An air gap separates the two layers, allowing each band to operate independently. The simulation and experimental results demonstrate effective anomalous reflection capabilities at 4.5GHz and 12GHz. This work can play a pivotal role in facilitating the development of dual-band and multiband RIS, capable of steering beams toward desired directions in next- generation environments like 6G, where multiband devices are expected to be integrated.

Friday, April 24 8:30 - 10:10

SW9a Efficient Wireless Power Transfer for Sustainable Smart Environment Sensors

/ / Antennas

Room: Firenze

Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain)
George Shaker (University of Waterloo, Canada)
Will Whittow (Loughborough University, England)
Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)
Mahmoud Wagih (University of Glasgow, Scotland)
Spyros Daskalakis (Green IoT Solutions Ltd, Scotland)
Manos Tentzeris (Georgia Tech, USA)

This workshop addresses self-powered sensors for smart environments to solve the strong sustainability problem of standard wireless sensors, which, as expected by the European Innovation Council-European Union, will require 80 million batteries to be changed daily by 2040. Challenges and opportunities of the different microwave wireless power transfer (WPT) subsystems (antennas, harvesting circuits, wireless sensing, and energy management) will be discussed with novel solutions towards making them suitable for various sensor systems, such as environmental monitoring and smart homes/cities. It will feature perspectives from both academia and industry, complemented by insights from the IEEE AP-S Environment Technical Committee.

Workshop outline: The workshop will combine technical presentations, each followed by interactive discussions. Then, a panel with all speakers to foster collaboration within the community working on these domains.

08:30 - 08:40 Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain) George Shaker (University of Waterloo, Canada) Welcome and Workshop Scope Insights from the IEEE AP-S Environment Technical Committee.
08:40 - 09:05 George Shaker (University of Waterloo, Canada) Fluid-Activated Matter: Toward Battery-Free Intelligence and Universal Connectivity
09:05 - 09:30 Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain) Compact Liquid Dielectric Antennas for Wireless Power Transfer
09:30 - 09:55 Will Whittow (Loughborough University, England) 3D printed RF devices and optically transparent antennas and metasurfaces
09:55 - 10:10 Panel with all speakers Discussion / Q&A
10:40 - 11:05 Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain) Miniaturized Microwave Wireless Power Transfer Systems
11:05 - 11:30 Mahmoud Wagih (University of Glasgow, Scotland) Making RF Wireless Power Sustainable? From Quantifying Impact to Circular Electronics

11:30 - 11:55 Spyros Daskalakis (Green IoT Solutions Ltd, Scotland) Manos Tentzeris (Georgia Tech, USA) Green IoT Solutions and Global Environmental Responsibility
11:55 - 12:10 Panel with all speakers Discussion / Q&A
12:10 - 12:20 Chairs Wrap-Up and Outlook

Dr. Kerlos Atia Abdalmalak (Organizer) is an assistant professor at Universidad Carlos III de Madrid, Spain. He has authored 1 book chapter and 80+ reviewed papers. Participated in 21 R&D and industrial projects (total fund +3.2 M€) where he led two of them. Co-organizer of European School of Antennas (ESoA) fundamental-of-the-Antenna course in 2025.
Dr. Abdalmalak received several prestigious awards (examples in last 4 years): best Ph.D. Thesis in the aerospace by Madrid City Council, best Ph.D. thesis in signal processing and communications in Spain from IEEE Spain Section, finalist in EuCAP Best-Paper, IEEE/AP-S Postdoc Fellowship, MDPI Symmetry Travel-Award, IEEE/AESS Young Professionals Travel Grant, and Fulbright short-stay for young doctors.
Prof. George Shaker (Co-organizer) is the lab director of the Wireless Sensors and Devices Laboratory at the University of Waterloo, where he is an adjunct associate professor with +200 peer-reviewed publications and +35 patents/patent applications. He has +20 years industrial experience with many commercial products available from startups and multinationals includes Apple, Amazon, Google, and Blackberry. He is currently an IEEE AP-S Distinguished Industry Speaker and IEEE Sensors Council Distinguished Lecturer. Received multiple awards, including IEEE/AP-S Best Paper Award, IEEE/AP-S Honorable Mention Best Paper Award (4 times), IEEE/MTT-S Graduate Fellowship, IEEE Sensors most-popular-paper award, NASA Tech-Briefs-HM Award, and Nature-Communications-Engineering Top25-downloaded-papers.
Prof. Will Whittow FIET, AFWES, SFHEA, SMIEEE (WW) is Professor of Radiofrequency Materials and leads the Wireless Communications Research Group at Loughborough University. He is a named PI/CI on grants totalling > £17m: 3D Metamaterials (SYMETA) (PI, EP/N010493/1), Anisotropic metasurfaces (ANISAT) (PI, EP/S030301/1); and Transparent metasurfaces (PI, EP/W037734/1). He has > 350 peer-reviewed publications (~ 130 journal papers) (> 6,500 citations, h-index = 41): including metasurfaces; dielectric lenses, and dielectric characterisation. He is an IEEE Distinguished Lecturer in Additively Manufactured RF Devices. WW won the inaugural Women's Engineering Society (WES) Men As Allies Award (2017) for outreach.
Prof. Daniel Segovia-Vargas is a full Professor at Universidad Carlos III de Madrid, Spain and the Chair of the Radiofrequency, Electromagnetics, Microwaves and Antennas Group (GREMA) and a former head of Telecommunications Engineering. Has authored or co-authored more than 350 publications in scientific journals and international conferences. His areas of research include antennas, active antennas, metamaterials, energy harvesting, and THz technologies. He was a Treasurer of the European Microwave Conference2018 and EuCAP2022, the Chairperson of URSI2011. He has organized several international workshops and chaired courses in European School of Antennas since 2013. He has chaired more than 90 R&D projects.
Dr. Mahmoud Wagih is a reader at the University of Glasgow, leading the Green RF-Enabled Electronics Lab, holds a UKIC Fellowship from the Royal Academy of Engineering, and is the Founder of RX Watt Ltd. His interests cover RF-enabled sustainable systems for energy harvesting, sensing, and wearable applications. He has published 130 journal and conference publications and 3 patents and has been principal/co-investigator on over £15M research projects. He is an IEEE Distinguished Microwave Lecturer, received 20+ awards, including multiple IEEE Best Paper, EurAAP Per-Simon Kildal, 2 URSI Young Scientist Award, and was listed in Forbes 30 Under 30 in 2024.
Dr. Spyros Daskalakis is co-founder of Green IoT Solutions Ltd (UK) and Assistant Professor at Heriot-Watt University, UK, specializing in radio electronics for sensors and wireless communications. His research focuses on environmental sensing, batteryless sensors, RF energy harvesting, ambient backscatter communications, ultra-low-power embedded systems, and agricultural IoT applications, with over 8 years dedicated to design, integration, fabrication, and testing of hardware for wireless sensing devices and RF applications. He serves as Associate Vice President of Conferences for IEEE Council on RFID (2025-2027) and vice chair of Subcommittee 17, WiSNet-Wireless Sensors for IoT Applications, Radio and Wireless Week 2026 (RWW2026).

ABSTRACTS: Fluid-Activated Matter: Toward Battery-Free Intelligence and Universal Connectivity: As billions of sensors blanket our built environment, battery dependency emerges as an unsustainable paradigm, burdening ecosystems with toxic waste, costly replacements, and recycling complexities. Batteries further introduce fire hazards in thermally dense AI data centers and detectable thermal signatures compromising military concealment. We present a self-powered water leak detection platform harvesting hydroelectric energy for perpetual, maintenance-free operation. Remarkably, this harvested energy powers wireless radios from short-range to satellite connectivity over Low Earth Orbit constellations. This battery-free architecture unlocks transformative applications across residential towers, industrial facilities, military installations, and smart city grids, envisioning a future of resilient, self-sustaining, planet-scale monitoring.
Compact Liquid Dielectric Antennas for Wireless Power Transfer: This presentation addresses self-powered sensors to solve the strong sustainability problem of standard wireless sensors, which, as expected by the European Innovation Council-European Union, will require 80 million batteries to be changed daily by 2040. The focus will be directed to antennas working at lower frequencies (<1GHz) for far-field Microwave wireless power transfer (WPT) systems. Novel solutions for compact high-gain designs will be discussed, such as constructing high-permittivity liquids to be injected into 3-D-printed shells, along with a WPT demo based on these liquid solutions. This provides sufficient power over larger distances, required for various applications such as environmental monitoring, smart homes/cities, and industry.
3D printed RF devices and optically transparent antennas and metasurfaces: 3D printing not only allows control of the external shape, the local relative permittivity can be tailored to precise specifications by controlling the internal geometry and hence varying the ratio of air and filament.
The local relative permittivity can then be graded in all three axes for extra degrees of freedom. This can be exploited to create flat grade index lenses as well as hybrid lenses. By using specialist printers and careful control of the settings, filaments with relative permittivities up to 15 can be printed. The talk will demonstrate how these RF materials can be used to create artificial dielectrics, filters, metamaterials, and bespoke antennas. The talk will also cover the challenges of measuring dielectric properties. A current ongoing project is exploring optically transparent conductors to fabricate antennas and metasurfaces.

Miniaturized Microwave Wireless Power Transfer Systems: The development of miniaturized wireless power transfer (WPT) has recently attracted huge interest, especially for implantable antennas. Thus, a miniaturized dual-band implantable antenna, combining meandered line and spiral techniques to achieve wide impedance bandwidths, is proposed. Furthermore, the proposed WPT system achieves a power transfer efficiency (PTE) of 1.15% by improving the coupling between the receiving (Rx) and transmitting (Tx) antennas using magnetic-based designs, thereby reducing human tissue losses. Finally, the measured results obtained inside minced pork show a high degree of agreement with the expected performance, validating the system's performance in realistic biological environments.

Making RF Wireless Power Sustainable? From Quantifying Impact to Circular Electronics: RF power delivery to rectennas could enable battery-free devices, but its environmental impacts are not clearly understood. This talk will review the sustainability of different RF power delivery scenarios and more broadly the underpinning components' sustainability, through Life Cycle Assessment (LCA). Efficiency improvement approaches and also associated antenna-IC co-design will be discussed. Finally, fabrication processes and materials for zero-waste and fully recyclable antennas and RF power harvesting frontends will be introduced.

Green IoT Solutions and Global Environmental Responsibility: Batteries are one of the biggest barriers to large-scale wireless sensor deployment, they need replacing, they fail, and they create waste. This talk presents work from Heriot-Watt University, Green IoT Solutions Ltd, and Georgia Tech on sensors that run without batteries, harvesting energy from ambient RF and solar sources. We cover the underlying RF energy harvesting and backscatter communication techniques, as well as real-world deployments in precision agriculture and environmental monitoring. The goal is simple: sensors that just work, indefinitely, with no maintenance, and a smaller environmental footprint to match the "green" in Green IoT.

Friday, April 24 8:30 - 10:10

SW1a AMTA Workshop: Toward Improved Standardization of RCS Measurements.

/ / Measurements

Room: The Hague

Lars Jacob Foged, MVG, Italy,
Peter Collins, Resonant Sciences, USA,
Brian Fischer, Resonant Sciences, USA,
Christer Larsson, Lund University, Sweden,
Paul J DeGroot, Boeing, USA,
Amedeo Capozzoli, University of Naples, Italy
Ivan Lahaie, Retired, USA

In this AMTA-supported workshop, we aim to provide an overview and facilitate discussion on widely accepted practices for conducting and reporting monostatic and bistatic radar cross-section (RCS) measurements in both near-field (NF) and far-field (FF) configurations. Topics will include calibration procedures, measurement configurations, data transformation techniques, and uncertainty evaluation, key elements in ensuring repeatable and traceable results across different facilities. By engaging experts from academia, industry, and government, this effort seeks to harmonize best practices, strengthen the foundation for global RCS measurement standardization, and provide valuable input to the update and review of IEEE Std 1502-2020 "Recommended Practice for Radar Cross-Section Test Procedures". Workshop Outline: The workshop will feature a series of invited presentations, each addressing a key aspect of radar cross section (RCS) measurements, with particular emphasis on topics relevant to upcoming revisions of the IEEE 1502 standard. Confirmed speakers include Pete Collins, Brian Fisher (Resonance Science, USA), and Ivan LaHaie (retired, USA), with additional contributions from Lars Foged (MVG, Italy) and Paul DeGroot (Boeing, USA) in support of the ongoing standardization effort. The program will cover complementary subjects spanning measurement methodologies, signal processing, error mitigation, and standardization insights. The workshop format is designed to encourage active discussion and knowledge exchange among leading experts from both industry and academia.

BIOGRAPHIES: Lars Foged received his M.S. degree in Electrical Engineering from the California Institute of Technology (Caltech), USA, in 1990. He is currently Vice President of Research and Development at the Microwave Vision Group (MVG). He has held several leadership positions within the IEEE Antennas and Propagation Society (AP-S), including Chair of the Industry Initiatives Committee (IIC) and current Chair of the Antenna Standards Committee (ASC). In 2023, he received the IEEE AP-S Industrial Innovation Award. He served as Vice-Chair of the European Conference on Antennas and Propagation (EuCAP) in both 2011 and 2022, and is course organizer, and board member of the European School of Antennas (ESoA). He served as President of the Antenna Measurement Techniques Association (AMTA) in 2023 and is AMTA Fellow and Distinguished Achievement Award recipient. He is the author of two books and numerous scientific papers on antennas and measurement techniques. His work has earned multiple distinctions, including Best Technical Paper Awards at AMTA (2013) and EuCAP (2021).
Paul De Groot is a Technical Fellow at The Boeing Company and an Antenna Measurement Techniques Association (AMTA) Edmond S. Gillespie Fellow with expertise in RADAR Cross Section (RCS) and Antenna measurements and frequency spectrum management. For over 35 years, Paul has engineered complex systems and lead teams to conduct RCS and antenna measurements at both the Boeing Enterprise and national levels. Paul was AMTA Vice President while serving on the AMTA Board of Directors and is a member of IEEE, IEEE Antennas and Propagation Standards Committee and chairing the review of RCS standard IEEE Std 1502-2020.
Ivan J. LaHaie received his BS degree from Michigan State University in 1976 and his MS and Ph. D. degrees from the University of Michigan in 1977 and 1981, respectively, all in electrical engineering. He joined the Environmental Research Institute of Michigan (ERIM) in 1980 and worked there for 30 years during its various incarnations as ERIM International, Veridian Systems, and General Dynamics Advanced Information Systems. He joined Integrity Applications Incorporated (later Centauri and KBR) in 2010 as a Senior Principal Scientist and Technical Fellow until his retirement in 2021. Dr. LaHaie is an internationally-recognized authority in the development of techniques for RCS measurement error mitigation, near field-to-far field RCS transformations, and RCS uncertainty analysis. Dr. LaHaie is an IEEE life fellow and an AMTA fellow. In 1991, he received the IEEE Aerospace and Electronic Systems Society Radar Systems Panel Award, given annually to the nation's leading radar engineer under 40 years of age, for his contributions to synthetic aperture systems and electromagnetic modeling. He received the AMTA Distinguished Achievement award in 2004 for his pioneering work in the development of automated radar signature imaging technology, RCS measurement technology and standards, the design and evaluation of electromagnetic interference and error source mitigation techniques, and for his contributions to the field of radar signature target support interaction modeling
Brian E. Fischer is a Chief Engineer at Resonant Sciences in Dayton, Ohio. His research interests have focused on the development of electromagnetic optimization methods, signal processing, measurements, predictions, and associated uncertainty. Applications are in areas of synthetic aperture radar, antenna direction finding, and near-field measurements supporting a variety of US Government sponsors. His current technical focus is in the areas of high-speed electronic sensing and signal exploitation using adaptive antenna methods and generalized near-field RCS transformation. Dr. Fischer is a Distinguished Achievement Award recipient and Fellow of the Antenna Measurement Techniques Association (AMTA), and served as AMTA President in 2012. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), and served as Associate Editor for the Measurements Corner in the IEEE Antennas and Propagation Society Magazine from 2007-2019. He is a retired US Air Force officer. Dr. Fischer received the BSEE from Michigan Technological University in 1988, the MSEE from the Air Force Institute of Technology in 1992, and the Ph.D. in Signal Processing from the University of Michigan in 2005.
Peter J. Collins is currently a senior staff engineer with Resonant Sciences (RS), Dayton, Ohio. He is a Fellow of the Antenna Measurement Techniques Association (AMTA), Senior Member of the IEEE, and a member of the Eta Kappa Nu and Tau Beta Pi honor societies. With over 35 years of government subject matter expert experience, Dr. Collins has served in many positions throughout the Department of Defense (DoD). Highlights include a term as commander of the National RCS Test Facility (NRTF), where he led a diverse team of government and contractor scientists, engineers, and technicians to ensure testing and upgrades at the Air Force's premiere outdoor static RCS range. Upon retirement from active duty, Dr. Collins joined the Air Force Institute of Technology (AFIT) where he served as Professor of Electrical Engineering. In addition to advising over 50 graduate students, Dr. Collins was the Low Observables (LO) Curriculum Chair responsible for ensuring AFIT's LO program met the needs of the Air Force and broader DoD. While at AFIT, Dr. Collins received the 2013 Secretary of the Air Force Harold Brown Award for survivability technology development including efforts to develop low-frequency noise radar-enabled RCS measurement systems and a patented low clutter bistatic measurement concept for indoor RCS measurement. In addition to his academic service, Dr. Collins served the National RCS Measurement Facility Certification Program as an Executive Committee Member for five years, pushing for balance in QA best practices and test cost. His long association with the certification program includes time as an RCS range reviewer for the Air Force Research Laboratory's Advanced Compact Range, the AFRL Mobile Diagnostic Radar and Dynamic Measurement System, and Boeing management of the UK Ministry of Defense's Range and Dynamics Measurement System at the Ministry's SAF II Compact Range and the Tejon Outdoor Far-field Range.

Friday, April 24 10:40 - 12:20

A20b Leaky Wave Antennas 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / / Antennas
Chairs: Jordan Budhu (Virginia Tech, USA), Davide Comite (Sapienza University of Rome, Italy)

Room: Rome

10:40 All-Metal Corrugated Antenna with Optimized Leaky-Wave Feeder: Far- and near-Field Properties

Giorgia Flaviani (Sapienza University of Rome, Italy); Beatrice Ambrogi (Sapienza University, Italy); Guido Valerio (Sorbonne Université, France); Davide Comite (Sapienza University of Rome, Italy)
All-metal corrugated leaky-wave antennas lend themselves to the realization of efficient and low-profile radiating devices thanks to their low material losses, compactness, and robust structure. This work investigates the far-field and near-field radiation characteristics of annular, radially periodic corrugated configurations, designed based on a dispersive analysis of the leaky-wave mode supported by the corresponding linear structure, which allows optimization of broadside gain and bandwidth. We propose the study and design of an optimized leaky-wave launcher to significantly improve both near- and far-field radiation performance. Two different feeders incorporating a metallic covering structure are introduced, which effectively suppress direct feed radiation. Following this approach, the analysis confirms enhanced, high-gain, and wideband broadside radiation, and demonstrates the possibility of generating a non-diffracting beam in the form of a zeroth-order Bessel beam. This opens new and promising opportunities for generating focused beams using compact and efficient devices at millimeter-wave frequencies and beyond.

11:00 Efficient Modal Analysis of Uniform and Quasi-Uniform Acoustic Leaky-Wave Antennas

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain); Jens Forssen and Matthew Polidano (Chalmers University of Technology, Sweden); Pablo Antonio Martinez-Vicente (Technical University of Cartagena, Spain)
The efficient leaky-mode analysis of uniform and quasi-uniform acoustic leaky waveguides using transverse equivalent networks (TENs) is presented in this work. As an example, two basic types of acoustic leaky-wave antennas (ALWAs) using open perturbations in the broad wall of rectangular waveguide are analyzed. The first is the slitted waveguide which belongs to the uniform ALWA type, and the second is the holey waveguide as an example of quasi-uniform acoustic LWA. The TENs are constructed using equivalent electro-acoustic impedances, and the leaky-mode dispersion curves are obtained and compared to full-wave simulations, observing good agreement for the two main modes of the two types of acoustic leaky waveguides.

11:20 Bi-Directionally Fed Leaky-Wave Antenna as a Phase Interferometer for Direction Finding Applications

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Rubén Pedreño Martínez (Universidad Politécnica de Cartagena, Spain); Astrid Algaba-Brazález (Technical University of Cartagena, Spain)
The application of bi-directionally fed leaky-wave antennas for phase-difference direction finding is proposed for the first time. Compared to conventional phase interferometer systems composed by two independent antennas, it is shown how the phase ambiguities associated to a large baseline distance can be resolved using a narrower fractional bandwidth. In this way, high angular resolution without ambiguities using only two synchronized receivers and two nearby frequency channels is achieved. These features are important for low-cost direction finding systems operating with wireless personal and local area networks, such as Bluetooth (BLE) or Wi-Fi. Theoretical and simulated results of a two-port microstrip leaky-wave antenna operating in the 2.4 GHz BLE band are reported to demonstrate the interest of this novel phase interferometric antenna system.

11:40 A 77 GHz Beam-Scanning Leaky-Wave Antenna

Joaquín García Fernández (WAVE UP SRL & University of Siena, Italy); Nicola Bartolomei (Wave Up srl, Italy); Cristian Della Giovampaola (Wave Up Srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Erio Gandini (ESA - European Space Agency, The Netherlands); Arya Kanathil (University of Siena, Italy); Dona Joseph (Wave-Up Srl, Italy); Stefano Maci (University of Siena, Italy)
This paper presents the design, fabrication, and testing of a 77 GHz mechanically reconfigurable metasurface radar antenna developed within the ESA MetaSense project. The antenna employs a corrugated metallic metasurface covered by a movable dielectric slab to achieve dynamic beam steering through controlled variation of the air gap. The design targets long-range automotive radar applications requiring narrow beamwidths and high gain. Experimental validation demonstrates beam scanning over a 40° range with a realized gain above 25 dB, confirming the viability of metasurface-based mechanical reconfiguration for millimeter-wave radar sensors.

Friday, April 24 10:40 - 12:20

A27b Patch Based and Electrically Small Antennas 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / / Antennas
Chairs: Adam Narbudowicz (Technical University of Denmark, Denmark), Divitha Seetharamdoo (Univ Gustave Eiffel COSYS LEOST Univ Lille Nord de France & Univ Lille Nord de France, France)

Room: Krakow

10:40 Ceramic Chip Antenna for 433 MHz LPWA Applications

Jaime Molins Benlliure (Taoglas, Ireland)
This paper presents a compact, low-profile, easy-fabrication chip antenna with a volume of 30×10×5 mm. It is designed to be installed in size-limited devices printed circuit board (PCB), operating at the 433 MHz ISM band for low-power wideband applications (LPWA). The antenna has been fabricated with a ceramic block and metallic elements only on the external faces, avoiding vias or complex elements through the ceramic block. Simulated and experimental results are presented with high correlation. Measured results show a 10 MHz (2.3%) impedance bandwidth (S11(dB)<-6 dB), a total efficiency of 38%, and an omnidirectional radiation pattern when it is installed in a 50×165×0.8 mm FR4 evaluation board.

11:00 A Novel Meandering Technique for the Miniaturization of (Micro-) Stripline Circuits

Simon P Hehenberger (DLR- German Aerospace Center, Germany & TU Delft, The Netherlands); Stefano Caizzone (German Aerospace Center (DLR), Germany)
A novel miniaturization technique for (micro-) stripline circuits based on the meandering of transmission lines on a hexagonal grid is proposed and fundamental implementation aspects discussed. The proposed method is used to design a miniaturized two-stage 180 degree hybrid coupler operating across the global navigation satellite systems (GNSS) frequency bands (1.15-1.65 GHz). The proposed design is manufactured and measured characteristics compared to results obtained from numerical simulations. The proposed miniaturized 180° hybrid achieves an amplitude unbalance less than 0.2dB and a phase unbalance of 2 degrees throughout the targeted frequency band.

11:20 A New MTK-LA Antenna Configuration

Alfrêdo Gomes Neto (Federal Institute of Paraíba & Grupo de Telecomunicações e Eletromagnetismo Aplicado - GTEMA, Brazil); Marcus Vinicius Rocha Cohen (Federal Institute of Paraiba, Brazil); Gabriel Oliveira Do Nascimento (Federal Institute of Paraíba, Brazil); Priscilla Kadja Pontes de Melo Carneiro (Federal Institute of Paraíba, IFPB, Brazil); Jefferson Costa Silva (Federal Institute of Paraiba - IFPB, Brazil)
The matryoshka-like antenna, MTK-LA, is a planar antenna that is especially attractive due to its small dimensions. One characteristic is its narrow bandwidth, which can be a disadvantage in certain applications. To address this issue, a new configuration of the MTK-LA is presented in this paper, maintaining the same geometry for the radiating element while modifying the partial ground plane geometry. The initial design equations are presented. To verify the expected characteristics, a prototype operating at 0.93 GHz was designed, fabricated and characterized, demonstrating a good agreement between numerical and measured results. The achieved bandwidth of 50 MHz was approximately eight times greater than that of the original MTK-LA, which had a bandwidth of 7 MHz. This result indicates that the new configuration can be used to control the bandwidth of the MTK-LA.

11:40 Optimization of Return Loss and Q-Factor Using Auxiliary Edge Resistivities

Stepan Bosak and Miloslav Capek (Czech Technical University in Prague, Czech Republic); Rasmus Christiansen and Ole Sigmund (Technical University of Denmark, Denmark)
An inverse design algorithm based on auxiliary edge resistivities within the method-of-moments electric-field integral equation framework is presented to minimize the antenna Q-factor and return loss. The optimization process is demonstrated for a rectangular electrically small design region. The antennas obtained in the rectangular design region show that an inherent property of the topology optimization framework (manipulating the resistivity) creates an obstacle when optimizing the antenna input impedance. The optimization obstacle is addressed in this submission.

12:00 A Passive Dual-Band Dual-Circularly Polarized Antenna Element with Independent Polarization Control

Zhiheng Liu (University College Dublin, Ireland); Shu Lin (Haerbin Institude of Technology, China); Pingyu Li (Harbin Institute of Technology, China); Tianqi Ao (University College Dublin, Ireland); Xingqi Zhang (University of Alberta, Canada); Xinyue Zhang (University College Dublin, Ireland)
This paper presents a compact passive dual-band dual-circularly polarized antenna element for K/Ka-band applications. Unlike conventional designs that support only one circular polarization per band, the proposed antenna enables independent generation of left- and right-handed circular polarizations through a fully passive coupling network. Stripline couplers and blind vias provide 90 degree phase-shifted orthogonal excitations without active components, ensuring high stability and low cost. The stripline configuration minimizes inter-band coupling, and the surrounding via ring enhances isolation. Operating at 19.5 GHz and 28.25 GHz, the antenna achieves impedance bandwidths of 24% and 7% and realized gains of 7.05 dBic and 5.05 dBic, respectively. With its compact and symmetric structure, the proposed element offers independent polarization control, high polarization purity, and suitability for dual-band satellite communication and radar systems.

Friday, April 24 10:40 - 12:20

A28b Phased Array Antenna Designs 2

T03 Aerospace, space and non-terrestrial networks / / Antennas
Chairs: Ulf Johannsen (Eindhoven University of Technology, The Netherlands), Cyrille Menudier (XLIM Université de Limoges, France)

Room: Barcelona

10:40 Individually-Steerable Analog Multi-Beamforming Antenna with Wide-Angle Coverage

Ming Li, Shu-Lin Chen and Y. Jay Guo (University of Technology Sydney, Australia)
Wide-angle, individually-steerable (WAIS) multibeam antennas hold significant potential for future wireless communications. This paper presents an innovative circuit-based analog WAIS multi-beamforming antenna enabled by a reconfigurable generalized joined coupler (GJC) matrix. We first develop a wide-beam edge-truncated rectangular dielectric resonator antenna (ET-RDRA) to support broad angular coverage. Then, a 2-bit reconfigurable phase shifter is developed and integrated into a 3 × 9 Nolen-like GJC matrix, which is dynamically controlled via an FPGA to enable WAIS multibeams. Measurements confirm that, the developed antenna achieves multibeam scanning across ±70° with a peak gain variation of 1.1 dB and a collective half-power beamwidth (HPBW) coverage of ±78°. The developed antenna represents the first demonstration of a low-cost, low-complexity, and energy-efficient WAIS multibeam design, offering strong potential for 5G-Advanced and 6G wireless communication systems.

11:00 Design and Fabrication of a Corrugated Corporate-Feed 32x32-Slot Array Antenna for X-Band Synthetic Aperture Radar

Naoto Onodera, Shuntaro Omi and Prilando Rizki Akbar (Synspective, Japan); Budhaditya Pyne (Synspective Inc. & Japan Aerospace Exploration Agency, Japan); Daisuke Ito and Masato Tanaka (Synspective, Japan); Jiro Hirokawa (Institute of Science Tokyo, Japan)
A wideband and lightweight passive slot-array antenna is designed for high resolution space-borne synthetic aperture radar with center frequency 9.8 GHz. Measurement results of the 32 × 32-slot array prototype antenna fabricated by friction stir welding confirmed achievement of 78.9% antenna efficiency and reflection coefficient below -15 dB across the desired 1.2 GHz bandwidth, thereby validating the design.

11:20 A High Gain Multi-Polarization L-Band Phased Array with Full Digital Beamforming Using RFSoC

Gong Chen and Peizhuo Yang (National University of Singapore, Singapore); Koen Mouthaan (NUS, Singapore)
A 4x4 L-band high gain phased array with full digital beamforming for four polarizations is presented. The array is based on a reconfigurable quad-polarization antenna consisting of four quarter-ring patches with secondary patches to increase the bandwidth as well as the gain. The resulting 64 channels are combined into sixteen channels using 4-way power dividers to provide the same amplitude and phase. The sixteen channels are digitized using a AMD radio frequency system-on chip (RFSoC). The polarizer for four different polarizations and the beamformer are implemented in the RFSoC. Digital beamforming performance for the four simultaneous polarizations is demonstrated at L-band.

11:40 A High Power L-Band Dual-Polarized Active Phased Array with Heatsink Integration and Digital Beamforming Using RFSoC

Haoze Luan, Shiwen Tang and Peizhuo Yang (National University of Singapore, Singapore); Koen Mouthaan (NUS, Singapore)
A dual-polarized L-band active antenna module and a 1x8 array with integrated thermal solutions for high-power operation are presented. A ring heatsink that surrounds the stacked patch antenna is embedded into the multilayer PCB to realize better thermal management. Two transmit/receive (T/R) modules with differential feed networks are integrated on the back side of the antenna. Digital beamforming is realized using radio frequency system-on-chip (RFSoC). In the transmit chain, a three-stage PA is employed to provide 10 W output power and around 50 dB gain to amplify the signal directly from the RFSoC. The receive chain provides around 70 dB gain to amplify weak received signal to levels that can be digitized by the RFSoC. Single active antenna modules and a 1x8 array are fabricated. The results show that good power handling and stable radiation performance can be achieved. Beam steering to +/-25 degree is achieved with the RFSoC.

12:00 Dual Polarized 4:1 Connected Array Design with a Folded Parallel Plate Waveguide Feed

Caspar M Coco Martin (Delft University of Technology, The Netherlands); Stefan Varault (THALES Defence Mission Systems, France); Isabelle LeRoy-Naneix (THALES AIRBORNE SYSTEMS, France); Hervé Legay (Thalès Alenia Space, France); Daniele Cavallo (Delft University of Technology, The Netherlands)

The experimental validation of a dual-polarized 4:1 connected slot array with a folded parallel plate waveguide (PPW) feed is presented. The array employs an artificial dielectric design resulting from a trade-off between impedance bandwidth and polarization purity. Analytical models are used for efficient design and optimization, enabling a 4:1 operational bandwidth and wide-angle scanning up to +/-60 degrees in both principal planes. A dual-polarized unit cell is implemented using printed circuit board (PCB) technology, and a 12 times 8 element array is fabricated and measured. The measured matching performance of the array is in good agreement with simulations, confirming the wideband and wide-scan capabilities of the proposed array architecture.

Friday, April 24 10:40 - 12:20

CS12b Advances in Channel Sounding and Measurements for 6G: From cm-Wave to sub-THz 2

T01 Sub-18 GHz for terrestrial networks (5G/6G) / Convened Session / Propagation
Chairs: Diego Andrés Dupleich (Technische Universität Ilmenau, Germany & Fraunhofer Institute for Integrated Circuits IIS, Germany), Wei Fan (Southeast University, China)

Room: Copenhagen

10:40 Analysis of the 5 GHz Band Air to Ground Propagation Channel Using an Unmanned Aerial Vehicle-Based Virtual Array System

Kentaro Saito and Tatsuki Sakata (Tottori University, Japan)

Recently, Unmanned Aerial Vehicles (UAVs) have been widely utilized for various industrial applications and are expected to play a key role in next-generation mobile communication systems. Since knowledge of air-to-ground (A2G) propagation channel characteristics is essential for the design and evaluation of the systems, a number of propagation measurements have been conducted. In this paper, we conducted UAV-based virtual array channel measurements in the 5 GHz band on a university campus. A key advantage of our system is that it enables the configuration of an arbitrary virtual antenna array in the air, including massive arrays with several thousand antenna elements. Particularly, the height dependencies of UAV-side channel angular characteristics were investigated. The results showed that the reflected waves were clearly observed, and their influence on the channel became significant as the UAV flight height increased, provided that it was below the surrounding building heights.

11:00 Digital-Twin-Assisted Computation of Radar Cross Section from RF Heatmaps

Camillo Gentile and Siraphop Saisa-ard (National Institute of Standards and Technology (NIST), USA); Jack Chuang (NIST, USA); Steve Blandino (National Institute of Standards and Technology, USA); Samuel Berweger (NIST, USA); Raied Caromi (National Institute of Standard and Technology, USA)

Radar cross section (RCS) is a key parameter for evaluating target scattering, with applications in automotive radar, drone detection, and integrated sensing and communication (ISAC). Classical methods obtain RCS through calibrated anechoic chamber measurements or multipath-component (MPC) extraction, but they require extensive post-processing and are limitedly scalable. Recently, we introduced a digital-twin-assisted framework that computed RCS by projecting MPCs onto segmented digital twins, establishing connection between multipath analysis and semantic scattering attribution. This work extends that concept by computing RCS directly from RF heatmaps. A digital twin, reconstructed from camera and lidar data, provides facet-level segmentation, while reference metallic spheres establish calibration through a heatmap-based matched-filtering. The resulting method eliminates MPC extraction and yields stabler RCS estimates compared to the prior MPC-based approach, using measurement at 28.5 GHz with walking human subjects. The method is further applicable to generalized ISAC scenarios where high-resolution RF heatmaps are available alongside digital-twin reconstructions

11:20 Distributed ISAC Oriented Channel Measurements in Indoor Premises with Human Body Presence

Mbissane Dieng and Raffaele D'Errico (CEA, LETI & Université Grenoble-Alpes, France)

Distributed Integrated Sensing and Communication (DISAC) approaches require detailed channel characterization involving multiple Base Stations (BSs), User Equipments (UEs), and passive objects. This paper presents a novel indoor channel measurement campaign covering both the FR1 and FR3 frequency bands. The experimental setup includes three BS locations and multiple UE positions. Both the monostatic sensing channels at the BSs and the communication channels to the UEs are recorded while a human phantom is displaced to emulate body shadowing effects. The results are analysed in terms of channel gain and power-angular-delay profiles (PADPs). Based on the multipath components extracted in the angular-delay domain, the sensing and localization capabilities are evaluated.

11:40 Analysis and Modelling of RMS Delay Spread in Indoor Environments Based on Multi-Band Channel Measurements

Sana Salous and Amar Al-Jzari (Durham University, United Kingdom (Great Britain))

The evolution towards fifth-generation (5G) and future wireless networks has created an exponential demand for radio frequency spectrum, particularly for high-capacity indoor applications. Among these demands, a critical parameter that reflects on the performance of the system is the root mean square delay spread ((RMS DS), which quantifies the time dispersive nature of the multipath channel and directly limits achievable data rates. This paper presents a comprehensive analysis and modelling of RMS delay spread based on multi-band channel measurements conducted in representative indoor environments. Using a Durham Frequency Modulated Continuous wave (FMCW) channel sounder, three cases of general indoor scenarios, including office and conference room measurements were conducted. The study analyses measurement data across a wide frequency range from 0.6 GHz to 70 GHz to investigate the dependency of RMS DS on two key factors including carrier frequency and the physical size of the environment.

12:00 Indoor near-Field Channel Measurements and Characterization in the Upper Mid-Band Using a Virtual Extremely Large Antenna Array

Shrayan Das (CWC-RT, University of Oulu); Peize Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Veikko Hovinen (University of Oulu, Finland); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain) & Queen's University Belfast, United Kingdom (Great Britain)); Pekka Kyösti (Keysight Technologies & University of Oulu, Finland)

Accurate channel models are crucial for designing and evaluating communication systems. As carrier frequencies and array apertures grow, models must account for near-field spherical wavefronts and spatial non-stationarity, departing from the conventional far-field, planar-wave geometry-based stochastic models (GBSMs) used in 3GPP. This work addresses channel characterization and modeling in the near-field via a measure- ment campaign in the upper mid-band (9.7-10.7 GHz) using a virtual uniform linear array (VULA) with 140 elements having an effective physical aperture of around 2 m. Subsequently, we adopt a recent array-domain framework to characterize near-field spatial non-stationarity by analyzing how channel parameters, such as received power, large-scale fading, and delay spread, evolve across the array aperture. We also evaluate the fidelity of these models by comparing them with our measurements.

Friday, April 24 10:40 - 12:20

CS3b Advanced Beam Manipulation with Metamaterial, Lenses, and Phased Arrays for 6G Communication and Sensing 2

T02 Millimetre wave and THz for terrestrial networks (5G/6G) / Convened Session / Electromagnetics
Chairs: Can Ding (University of Technology Sydney (UTS), Australia), Alessio Monti (Roma Tre University, Italy)

Room: Paris

10:40 Modeling of Hybrid Domes for Steerable Flat-Top Phased Arrays via Ray-Tracing and Physical-Optics

Hairu Wang and Mingzheng Chen (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
This paper presents a ray-tracing and physical-optics (RT-PO) model for analyzing and designing hybrid domes that enable steerable flat-top beams in phased array antennas (PAAs). The hybrid dome combines a dielectric lens (DL) and a metadome (MD), extending the PAA scanning range while reducing DL volume and broadening the MD bandwidth. The RT-PO model accurately predicts far-field radiation and determines predistorted excitations for flat-top beams at different scan angles. Using this model, a hybrid dome is designed to achieve steerable flat-top beams up to 80°, maintaining less than 1 dB directivity variation. The computed patterns agree closely with CST simulations while offering several-hundred-fold faster computation, confirming the model's effectiveness for efficient hybrid-dome-assisted flat-top and wide-angle PAA design.

11:00 Impact of Spatial Periodicity on the Scanning Performance of Transmitarray Antennas

Raul Tomas Horst (CEA-LETI, France & University of Rennes 1, France); Francesco Foglia Manzillo (CEA-LETI, France); Ronan Sauleau (Universite de Rennes, France); Antonio Clemente (CEA-Leti, France)
This work investigates the influence of periodicity on the scanning performance of transmitarray antennas and quantitatively evaluates the benefits of using smaller unit cells to reduce scan loss and extend the field of view. The scanning performance of square arrays with an edge of 10 wavelengths is first analyzed using a dedicated numerical model. Theoretical results consistently show a reduction in scan loss when the periodicity is decreased below half a wavelength, regardless of the aperture phase quantization. A scan loss reduction of 1.1 dB is observed at a scan angle of 40° using a quarter-wavelength periodicity with 3-bit phase quantization. Both the model accuracy and the improved scanning performance are validated through full-wave simulations of passive transmitarrays optimized to steer at various angles, based on specifically designed, wideband unit cells with half-wavelength and quarter-wavelength periodicities at 30 GHz.

11:20 Geometrical Optics Tools for the Design of GRIN Lens Antennas

Ilir Gashi and Stefano Maci (University of Siena, Italy); Yiannis Vardaxoglou (South China University of Technology, China); Matteo Albani (University of Siena, Italy)
This paper presents two distinct methodologies for designing inhomogeneous lens antennas: the phase tracing method (PTM) and an optimization-based Lax-Friedrichs sweeping method. The PTM employs numerical integration along wavefronts to determine refractive index distributions from prescribed ray trajectories, providing a direct design approach. In contrast, the optimization-based approach utilizes the Lax-Friedrichs sweeping method to generate multiple refractive index profiles and minimizes a cost function representing the deviation from desired field transformations. Both approaches could make use of recent advances in additive manufacturing to create practical and low cost GRIN lens antennas. We demonstrate the effectiveness of each method through the design of a telescopic and a multifocal lens, validated via full-wave simulations.

11:40 Reconfigurable Metasurface for Wide-Angle Steering of Sparse Arrays with Broadside Transparency

Stefano Vellucci (Niccolò Cusano University, Italy); Alessio Monti, Mirko Barbuto and Alessandro Toscano (Roma Tre University, Italy); Filiberto Bilotti (ROMA TRE University, Italy)
This contribution presents a reconfigurable metasurface for enhancing the beam-steering capabilities of sparse antenna arrays while preserving broadside transparency. The proposed metasurface consists of unit cells composed of three stacked ideal impedance layers, whose surface reactances are optimized to achieve two operational states: in the OFF state, an obliquely incident wave from a sparse array is steered toward a larger angle, whereas in the ON state, a normally-incident wave passes through with negligible insertion loss. The unit-cell design is based on an analytical microwave matrix model, which provides an initial guess for a multi-objective full-wave optimization accounting for inter-cell coupling and non-local effects. Full-wave results show that the metasurface effectively extends the scanning range of a sparse array from 30° to 60° without introducing grating lobes, while maintaining the broadside gain when in the ON state.

12:00 A Wide-Angle Dielectric Metalens for Directivity Enhancement of Planar Phased Arrays

Mohammad Soltani and George V. Eleftheriades (University of Toronto, Canada)
Traditionally, planar phased arrays have been deemed incompatible with lens configurations. This work presents a dielectric metalens that enhances the directivity of planar phased arrays with standard linear phasing. We employ an adjoint-based framework, formulated using integral equations, for the design process. This approach rigorously accounts for electromagnetic mutual coupling and efficiently handles large design spaces with many degrees of freedom. The resulting metalens achieves high directivity while preserving the wide-angle scanning capability and angular resolution of the underlying array.

Friday, April 24 10:40 - 12:20

CS43b Characterisation of biological tissues and tissue mimicking materials for electromagnetic medical applications 2

T06 Biomedical and health / Convened Session / Propagation
Chairs: Julian Bonello (University of Malta, Malta), Daniela M Godinho (Universidade de Lisboa, Portugal)

Room: Prague

10:40 Oil-in-Gelatin Phantom Classification by Means of Artificial Neural Networks

Simona Di Meo, Emanuele Torti, Maria Fasol, Carlotta Riboni, Roberto Gandolfi, Marco Pasian and Francesco Leporati (University of Pavia, Italy)
In this paper, the dielectric and hyperspectral properties of phantoms with varying percentages of water and oil were measured. The dielectric properties of the phantoms produced were compared with the theoretical values expected for this type of phantom, modeled using the Bruggeman formula. The hyperspectral characteristics of the phantoms, on the other hand, were used to train and subsequently test (on phantoms produced on different days) a neural network capable of classifying the analyzed tissue based on its water content. The combination of dielectric and hyperspectral information can aid decision-making processes for the classification of anomalies both during and after surgery, reducing the need for more expensive and invasive biopsies.

11:00 Tissue Dielectric Loading Effects on the Inductive Coupling of Magnetic-Resonant Implantable Sensing Systems

Icaro V Soares (University of Galway, Ireland); Muhammad Farooq (University of Galway, Ireland & Translational Medical Devices (TMD) Lab, Ireland); Marcin J. Krośny, Manavi Tejaswini, Derek T. O Keeffe, Martin O Halloran and Adnan Elahi (University of Galway, Ireland)

Magnetic-resonant implantable sensors enable minimally invasive, continuous monitoring of hemodynamic parameters, with performance critically dependent on the electromagnetic coupling to an external reader. In this work, we investigate the coupling mechanisms in such systems, highlighting the limitations of the conventional magneto-quasistatic (MQS) approximation when accounting for the dielectric properties of biological tissues. A case study of an aortic wall sensor for Abdominal Aortic Aneurysm monitoring is presented, employing both MQS and mid-field electromagnetic models within a realistic multi-layer anatomical setup. Results indicate that the optimal operating frequency for magnetic-resonant sensors lies between 13 and 30 MHz. Depending on the implant size, the transition from near-field to mid-field coupling occurs between 40 and 70 MHz, where tissue-induced phase reversal between reader and sensor coils is observed. These findings are translated into design guidelines, offering practical strategies to maximize wireless power transfer and ensure reliable sensor readout in implantable magnetic-resonant systems.

11:20 Dielectric and Thermal Characterization of Tissue-Mimicking Phantoms for Microwave Thermal Therapies

Matteo Bruno Lodi (University of Cagliari, Italy); Simona Di Meo (University of Pavia, Italy); Andrea Melis, Gabriele Atzeni, Raffaello Possidente and Roberto Baccoli (University of Cagliari, Italy); Marco Pasian (University of Pavia, Italy); Giuseppe Mazzarella and Alessandro Fanti (University of Cagliari, Italy)

The use of microwave energy for tumor treatment has prompted extensive research, particularly in microwave hyperthermia, which offers strong clinical potential but requires rigorous quality assurance. Testing new antenna designs demands tissue-mimicking phantoms that replicate both dielectric and thermal properties of biological tissues. While several cost-effective phantom recipes exist, most emphasize dielectric characterization, neglecting thermal behavior. This study addresses that gap by presenting a comprehensive analysis of the dielectric and thermal properties of semi-solid phantoms for microwave hyperthermia experiments. Phantoms composed of oil, gelatin, water, and dishwashing liquid were formulated to emulate low-, medium-, high-density, and tumor tissues. Their dielectric properties were measured using an open-ended coaxial probe between 200 MHz and 12 GHz and validated against literature data, while thermal conductivity and specific heat were also evaluated.

11:40 Standardising Dielectric Property Measurements of Biological Tissues: An Overview on Open Ended Coaxial Probe and Measurement Guidelines

Henrique V Lopes (Universidade de Lisboa, Portugal); Amra Mehboob (University of Galway, Ireland); Alex Ramiro Masaquiza-Caiza, David O. Rodriguez-Duarte and Francesca Vipiana (Politecnico di Torino, Italy); Bilal Amin and Adnan Elahi (University of Galway, Ireland); Daniela M Godinho and Raquel C. Conceição (Universidade de Lisboa, Portugal)

The dielectric properties of biological tissues dictate the interaction of electromagnetic waves with the human body and are therefore essential for the design and optimisation of electromagnetic-based medical technologies. Several methods are available to obtain these properties; the open-ended coaxial probe method is the commonly employed. Although such measurements have been performed for more than two decades, there is no clear consensus within the community regarding the accompanying metadata. In recent years, best-practice guidelines for conducting these measurements have been proposed, yet their adoption remains limited. In this review, we revisit the existing guidelines for measuring dielectric properties of biological tissues, including recommended practices and metadata requirements. Furthermore, we propose and provide a practical, implementable table aligned with the proposed best practices, with the aim of promoting standardisation and enhancing comparability across studies.

12:00 Combined Dielectric and Thermal Characterization of Agar-Based Breast Tissue Phantoms for Hyperthermia

Staša Cvetković, Giulia Marie Montebello, Julian Bonello, Lee Farrugia, Iman Farhat and Lourdes Farrugia (University of Malta, Malta)

Given that breast cancer continues to exhibit a high global incidence rate, there is a sustained need for reliable and reproducible experimental models to advance diagnostic and therapeutic research. The aim of this work was to develop a composite breast phantom encompassing multiple tissue types and an embedded tumour for integration with microwave hyperthermia as a tumour-targeting approach. A revised formulation of biologically representative tissue-mimicking solutions was designed. This composition accurately reproduces the dielectric and thermal characteristics of human tissues, extending the phantom's applicability beyond imaging. The four tissue types include adipose/fat, skin, muscle, and tumour. Dielectric properties were measured using a vector network analyser in the range of 0.4-14 GHz. Thermal properties were indicators of whether localised heating can be achieved at the tumour site and were obtained with the TEMPOS device using the SH-3 dual-needle, which gives thermal conductivity, diffusivity, and specific heat capacity.

Friday, April 24 10:40 - 12:20

CS6 Advances in antennas for smart terminals for mobile and satellite communications and IOT

T03 Aerospace, space and non-terrestrial networks / Convened Session / Antennas
Chairs: Steven Shichang Gao (Chinese University of Hong Kong, China), Dawei Zhou (Honor Device Company Limited, China)

Room: Gothenburg

10:40 Design of End-Fire Satellite Antenna in Smartphones

Sisi Rao, Yan Wang and Feng Xu (Fudan University, China)

Direct phone-to-satellite communication is gradually becoming one of the essential communication features for modern flagship smartphones. Due to signal loss caused by the communication distance between mobile phones and satellites and the ionospheric Faraday rotation effect, the antenna for direct phone-to-satellite communication poses a significant design challenge. This paper summarizes our design for a mobile phone direct-to-satellite communication solutions.

11:00 Revisiting 2D Frequency Scanning Arrays for Low-Complexity 3D Positioning in Spacecraft and IoT Applications

Hannes Bartle and Raquel Ferrando Tarazona (Ecole Polytechnique Federale de Lausanne, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

Determining the position of a target in 3D using a radar system provides several benefits over cameras, lidar and other sensors. Applications like spacecraft rendezvous rely on reliable target detection and 3D position, irrespective of light conditions. While phased array antennas and MIMO signal processing can be combined with radar architectures to provide 3D imaging information, they require additional hardware that increases system complexity and can become costly to verify. In this work, we propose a low-cost 3D radar positioning system based on a passive 2D frequency scanning antenna and low-cost PlutoSDR hardware. We establish the performance envelope of the PlutoSDR when used as a pulse compression radar. Finally, we validate the system through a 3D drone-based radar measurement campaign, demonstrating its attractiveness as a low-complexity solution for spaceborne or IoT 3D imaging radars, as well as a low-cost radar technology demonstrator platform.

11:20 Wideband mmWave Antenna for 5G Smartphone

Preethy Sethuraman (University of Hertfordshire, United Kingdom (Great Britain)); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Yichuang Sun (University of Hertfordshire, United Kingdom (Great Britain)); Shichao Li and Dawei Zhou (Honor Device Company Limited, China)

This paper presents a compact, wideband antenna optimized for integration into 5G smartphones. Unlike conventional stacked or slot-based 5G antennas, the proposed design introduces an Edge-Loaded Parasitic patch surrounded by Yagi-Uda-inspired directors, enabling enhanced bandwidth and stable gain while maintaining a miniature footprint. The integration of a bottom-fed active patch with a precisely engineered via-wall structure ensures improved impedance matching and reduced cross-polarization. Surface current analysis confirms efficient excitation of TM modes with balanced radiation from both patches. In a 1×4 array configuration, the antenna achieves approximately 70% efficiency, supports beam steering up to +/-45 degrees, and maintains a minimum realized gain of 8 dB. The measured bandwidth of 26-42 GHz in free space corresponds to effective 24-40 GHz coverage after device integration, offering a compact and integration-resilient solution for next-generation 5G mobile terminals.

11:40 Dual Pattern s-Band Antenna for Adaptive Links Within Satellite Swarms

Vincent Laquerbe (CNES, France)

This article presents the design and characterization of a compact dual pattern S-band antenna that can radiate two different circularly polarized patterns - conical and directive - through two distinct SMA connectors and a dedicated beamforming network. Directive mode has at least 10 dBi to maximize one-to-one data rate between two aligned satellites. Conical mode has a wider radiation pattern with broadside null and favors low throughput with multiple satellites regardless of their relative location and orientation. Such antenna provides an adaptive gain and link budget for satellite communication. Antenna dimensions are 150×150×22 mm.

12:00 Recent Development of Endfire Circularly Polarized Antennas for Communication Between Metal-Rimmed Mobile Phones and Satellites

Hongbin Zhu (CUHK, Hong Kong); Ning Ma (Honor, China); Dawei Zhou (Honor Device Company Limited, China); Steven Shichang Gao (Chinese University of Hong Kong, China)

This invited paper focuses on endfire circularly polarized (CP) antennas for satellite communication (satcom) mobile phones. First, this paper explains key technical challenges in different satcom scenarios. Second, a detailed review of various satcom mobile phone antennas is provided. Finally, a design example of a novel tri-band frequency-reconfigurable endfire CP antenna for metal-rimmed mobile phones is proposed. The proposed antenna consists of 1) a HP antenna integrated into clearance region and 2) a multi-mode VP patch antenna. By adjusting the states of the tuning network and the switchable pins, this antenna achieves a wide frequency-reconfigurable range, supporting operation at 1.6 GHz, 2.1 GHz, and 3.5 GHz. The proposed antenna is fabricated and measured. The measured left-hand circular polarization (LHCP) peak gains at three bands are larger than 0 dBic, with a broad half-power beamwidth (HPBW). The 3-dB axial ratio (AR) bandwidth can cover the targeted satellite communication bands.

Friday, April 24 10:40 - 12:20

M05b Recent advances in antenna measurement and over the air testing 2

T08 Fundamental research and emerging technologies/processes / / Measurements
Chairs: Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany), Matthias Hein (Technische Universität Ilmenau, Germany)

Room: Dusseldorf

10:40 Next-Generation Electromagnetic Skins for Compact Antenna Test Range Systems

Giacomo Oliveri (University of Trento, Italy & ELEDIA Research Center, Italy); Aaron A Salas-Sanchez (University of Trento, Italy); Giorgio Gottardi (ELEDIA Research Center, University of Trento, Italy); Marco Salucci (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

Compact Antenna Test Range (CATR) systems enable far-field emulation for large antennas within reduced distances, using a parabolic reflector to generate a planar wavefront in a confined Quiet Zone (QZ). However, QZ size and reflector distance are limited by geometric constraints, and maintaining high surface accuracy is costly, especially at millimeter-wave and sub-terahertz frequencies. This work proposes a novel approach using near-field focusing electromagnetic skins (EMSs) to synthesize tailored surface currents that accurately shape the field in the QZ region, enabling compact, low-cost, and potentially reconfigurable CATR implementations. Preliminary results confirm effective near-field wavefront control.

11:00 Influence of Multiprobe Array Configuration on Planar Wide Mesh Scanning Performance

Jorge Calatayud Maeso (Universidad Politecnica de Madrid, Spain); Celia Fontá Romero (Universidad Politécnica de Madrid); Fernando Rodríguez Varela (Universidad Rey Juan Carlos de Madrid, Spain); Ana Arboleya (Universidad Rey Juan Carlos, Spain); Francesco Saccardi (Microwave Vision Italy, Italy); Andrea Giacomini (Microwave Vision Italy SRL, Italy); Lars Foged (Microwave Vision Italy, Italy); Manuel Sierra Castañer (Universidad Politécnica de Madrid, Spain)

This work explores the relevance of multiprobe array design parameters in Planar Wide Mesh (PWM) grids for phase-referenced and reference-less scenarios. This analysis examines the behaviour of the optimisation metric as physical constraints are introduced across multiple multiprobe systems. An extensive comparison of the ideal and retrieved PWS has been conducted to assess the implications of multiprobe parameters in solving the inverse-source problem. This procedure has been repeated to retrieve the phase in a reference-less scenario that uses partially coherent observations in conjunction with PWM grids. Results show that, in the phase-referenced scenario, the optimisation procedure overcomes the limitations introduced by multiprobe constraints. It is concluded that the PWM grids do not constrain the optimal probe spacing. Furthermore, in reference-less scenarios, our results indicate that at least four probes are required for accurate phase retrieval. In the reference-less scenario, we find that certain probe spacing yields less accurate solutions.

11:20 Metamaterial Luneburg Lens Design and Implementation for Enhancing the Sensitivity of Quantum Rydberg Atom-Based RF Sensing

Demos Serghiou and Anton Tishchenko (University of Surrey, United Kingdom (Great Britain)); Ashwin Thelappilly Thelappilly Joy (5GIC and 6GIC, University of Surrey, United Kingdom (Great Britain)); Tim Brown (University of Surrey, United Kingdom (Great Britain)); Paul Marsh (PA Consulting, United Kingdom (Great Britain)); Ali Ali (University of Surrey, United Kingdom (Great Britain)); Paul Martin (PA Consulting, United Kingdom (Great Britain)); Gabriele Gradoni (University of Surrey, United Kingdom (Great Britain) & University of Cambridge, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

This paper presents the design and characterisation of a Luneburg metamaterial lens operating over a broad fre- quency range within the sub-6 GHz bands for the enhancement of the sensitivity of Rydberg atom-based quantum receivers. The 3D fabricated design is experimentally verified in an anechoic chamber between 3-4 GHz, showing a focal gain of approximately 20 dB. Experimental measurements, performed with a Rydberg atom-based RF receiver and the vapour cell positioned at the focal point of the Luneburg lens at 2.2 GHz and 3.5 GHz, demonstrate broadband enhancement of the EIT response and a distinct frequency splitting, confirming the increased local electric-field strength at the atomic interface. Analysis of the derivative of the measured absorption signal further reveals enhanced dispersion and a steeper EIT slope in the presence of the lens, indicative of slow-light-like behaviour and improved sensitivity.

11:40 Real-Time Radiation Pattern Measurement: Rich Scattering for Source Reconstruction

Mohammad Azadifar (EM Path, Switzerland & HEIG-VD, Switzerland); Marcos Rubinstein (University of Applied Sciences and Arts Western Switzerland, Switzerland); Mohammadreza Khalvati (HEIG-VD, Switzerland)

Conventional electromagnetic (EM) source characterization and antenna measurements rely on point-by- point field scanning in anechoic or reverberation chambers, requiring long acquisition times, expensive infrastructure, and precise mechanical systems. This paper introduces a novel methodology termed Rich Scattering for Source Reconstruction (RS-SR), which exploits the multipath diversity of arich scattering environment to reconstruct the spatio-temporal radiation characteristics of an arbitrary source without mechanical scanning or chamber isolation. Full-wave simulations and X-band experimental results demonstrate successful near- and far-field reconstruction of standard horn and patch antennas, achieving excellent agreement with simulated reference patterns. The entire measurement and reconstruction process takes less than two seconds, performed on a standard laboratory floor without absorbers. The RS-SR method offers a fast, compact, and chamber-free alternative for real-time radiation pattern measurements, with strong potential for applications in EMC testing, antenna diagnostics, and wireless system characterization.

12:00 On the Implementation of Absorber Collars for Probe Antennas Exceeding 100 GHz

Justin Geerarts (technische universiteit Eindhoven, The Netherlands); A. B. (Bart) Smolders and Ad Reniers (Eindhoven University of Technology, The Netherlands)

Throughout the years, absorber collars have been actively used in both near- and far-field measurements for their ability to reduce multiple reflections and pattern ripple. Based on the authors' experience, the use of absorber collars is often approached superficially, with insufficient consideration given to their placement and the choice of absorber. Accurate probe compensation requires consistent probe characteristics, which is challenged with inadequate absorber collar use. As frequencies exceed 100 GHz and conventional pyramidal absorbers reach their practical limits, absorber collar design must be reconsidered. While the optimal design for such collars follows from logic and electromagnetic theory, this paper validates the collar design choices through electromagnetic simulations. Multiple configurations were considered in order to ascertain the optimal collar geometry, absorber geometry and probe specific choices for absorber collars for the frequency band WR8 (90-140 GHz) and even higher.

Friday, April 24 10:40 - 12:20

P02b AI techniques for radio propagation assessment 2

T07 Electromagnetic modelling and simulation tools / / Propagation
Chairs: Miyuki Hirose (Kyushu Institute of Technology, Japan), Vasilii Semkin (New York University Abu Dhabi, United Arab Emirates)

Room: London

10:40 A Multi-City Generalization Study of a Generative Model for Radio Propagation Prediction

Satoshi Iwasaki, Kenshi Horihata and Yukiko Kishiki (Kozo Keikaku Engineering Inc., Japan); Miyuki Hirose (Kyushu Institute of Technology, Japan)

This study explores a generative modeling approach for radio propagation prediction using Conditional Generative Adversarial Networks (cGANs). Our previous work demonstrated that cGANs can reproduce propagation characteristics from environmental features such as building height and transmitter-receiver distance. In this study, we improve the model architecture and training framework while extending the dataset to include six cities with diverse propagation environments. Ray-tracing simulations were used to generate datasets reflecting various building densities and heights. The proposed model was then evaluated for its generalization capability to unseen cities. Results show that the enhanced cGAN-based model achieves higher generalization performance, reducing the root-mean-square error (RMSE) from 11 dB (single-city model) to approximately 7-9 dB. These results confirm the effectiveness of the proposed multi-city generative approach as a data-driven method for propagation prediction.

11:00 Landmine Detection and Discrimination by GPR-Data-Driven Models

John Rangel (National University of Colombia, Colombia); Cesar Pedraza (Universidad Nacional de Colombia, Colombia); Felix Vega (Technology Innovation Institute, United Arab Emirates); David O. Rodriguez-Duarte (Politecnico di Torino, Italy)

This paper presents an approach to improve target-to-clutter discrimination in data acquired using Ground Penetrating Radar (GPR). The proposed methodology integrates semantic segmentation with classifiers to robustly detect and classify hyperbolic signatures of buried targets, with emphasis on Improvised Explosive Devices (IEDs). Two Convolutional Neural Networks (CNNs) architectures, U-Net and SegNet, are employed for segmentation purposes, while classification tasks use Random Forest (RF) and Support Vector Machine (SVM) algorithms. The effectiveness of the proposed method is validated using an experimentally constructed dataset through a comprehensive measurement campaign that includes a diverse range of objects, such as surrogate IEDs.

11:20 Fast MoM-Based Solvers for Cavity-Backed Reflectarrays and RIS Design

Dijun Lin (Ericsson AB, Sweden & Chalmers University of Technology, Sweden); Lars Manholm (Ericsson Research, Sweden); Rob Maaskant (CHALMERS, Sweden)

This paper presents a fast electromagnetic field data generation framework based on the Method of Moments (MoM) combined with a Domain Decomposition Method and Woodbury identity-based iterative updates. The approach enables rapid recomputation of reflectarray and reconfigurable intelligent surface (RIS) configurations without the need for full matrix reassembly. A Jacobi-type preconditioner is also introduced to accelerate convergence of the Generalized Minimal Residual Method solver for large-scale problems. The proposed techniques significantly reduce computation time, achieving up to 249x speed-up compared to conventional MoM formulations for single single element change, while preserving accuracy. Validation on a 5x5 cavity-backed reflectarray demonstrates that the framework efficiently supports localized element updates and is well suited for large-scale dataset generation in deep learning applications. The method provides a scalable foundation for intelligent design and optimization of reflectarray and RIS architectures.

11:40 Topology-Guided Point Sampling for Indoor Propagation Prediction Using Quantum Circuit-Based Learning

Miyuki Hirose (Kyushu Institute of Technology, Japan)
This paper presents a topology-guided framework for efficient indoor propagation prediction using point cloud data. Two complementary approaches are investigated: (1) a classical deep-learning model employing topology-guided sampling with PointNet, and (2) a quantum-classical hybrid model utilizing correlation-based extraction with Variational Quantum Circuits (VQC). The classical model leverages geometric and topological cues-such as reflectors, obstructions, and Fresnel zones-to enhance propagation-aware feature selection, achieving a root mean square error (RMSE) of 1.66 dB across ten diverse indoor environments. The quantum-classical model applies a topologically compressed representation to eight quantum-encoded features, maintaining comparable accuracy, RMSE of 2.13 dB, while achieving a 90% reduction in memory usage and faster inference. These results demonstrate that topology-guided geometric sampling effectively bridges the gap between spatial structure and radio propagation, and that quantum feature encoding enables efficient, scalable prediction for next-generation wireless systems.

12:00 Advancing EM Imaging Through Multiphysics and AI: Recent Advances and Future Trends

Marco Salucci, Samantha Lusa and Luca Tosi (ELEDIA Research Center, Italy); Xinyao Chen (National University of Defense Technology, China); Andrea Massa (University of Trento, Italy)
This work discusses recent advances in electromagnetic (EM) imaging enabled by Artificial Intelligence (AI) and multiphysics (MP) strategies. In particular, it provides an overview of the System-by-Design (SbD) framework, which leverages AI paradigms such as global optimization and machine learning to enable the computationally-efficient solution of fully non-linear inverse scattering problems (ISPs). Moreover, it presents how MP schemes can enhance the reconstruction accuracy by exploiting the complementary information provided by different sensing modalities, such as microwaves and ultrasounds. Finally, future research directions are outlined, and an industrial EM imaging application is presented as an illustrative example.

Friday, April 24 10:40 - 12:20

P09b RIS modelling and design for smart propagation environments 2

T07 Electromagnetic modelling and simulation tools / / Propagation
Chairs: Anikó Német (University of Glasgow, United Kingdom (Great Britain)), Enrico M Vitucci (University of Bologna, Italy)

Room: Madrid

10:40 A Power-Balance Model for Quantized mm-Wave RIS: Concept and Experimental Assessment

Elena Bernardi, Nicolò Cenni and Silvi Kodra (University of Bologna, Italy); Settimio Pavoncello (ARPA Lazio, Italy); Luca Chiaraviglio (University of Rome Tor Vergata, Italy); Marina Barbiroli (University of Bologna, Italy & DEI, Italy); Enrico M Vitucci and Vittorio Degli-Esposti (University of Bologna, Italy)
Reconfigurable Intelligent Surfaces (RIS) are emerging as low-cost, energy-efficient solutions to control wireless propagation. Practical RIS reconfigurability is achieved through phase quantization, e.g. using 1-bit PIN diodes, which may lead to anomalous reradiation modes, limiting the signal coverage enhancement towards the intended direction. Such quantization modes should be taken into account to tune realistic RIS models through proper, physically sound parameters. The goal of this work is to design and evaluate a power balance model for reflective RIS, explicitly accounting for both quantization-induced and parasitic reradiation modes alongside desired reradiated power. We parametrize the model by performing signal measurements in a realistic scenario, using a 1-bit RIS operating at mm-Wave frequencies. The proposed approach analyses how phase quantization redistributes power across modes and provide a framework for realistic RIS modeling.

11:00 Hybrid Physics-Informed Neural Network for Channel Estimation in RIS-Enabled mmWave Channels

Lazaros Alexios Iliadis (Aristotle University of Thessaloniki, Greece); Stavros Koulouridis (University of Patras, Greece); Sotirios Sotiroudis and Zaharias D. Zaharis (Aristotle University of Thessaloniki, Greece); Christos Christodoulou (The University of New Mexico, USA); Sotirios Goudos (Aristotle University of Thessaloniki, Greece)
Reconfigurable intelligent surface (RIS)-enabled millimeter wave (mmWave) communication requires accurate channel estimation for optimal beamforming and phase control. Model-based methods face high computational complexity, while traditional data-driven approaches fail to exploit the underlying physical structure. This work applies a hybrid physics-informed neural network (PINN) which utilizes physics-based preprocessing as augmented input features while maintaining direct end-to-end learning of the cascaded channel matrix. We concatenate raw observations with physics-motivated transformations obtained through combining RIS phase matrices, leveraging both data patterns and electromagnetic principles. The proposed DL architecture consists of four fully-connected layers with layer normalization and dropout for robust generalization. Extensive simulations on RIS-enabled mmWave SIMO system demonstrate that the hybrid PINN achieves a satisfactory normalized mean square error (NMSE), outperforming least squares, multilayer perceptron, and model-based unfolding networks (UNF). Furthermore, the proposed method exhibits computational efficiency and low inference time, making it suitable for real-time deployment in next-generation wireless systems.

11:20 Dynamic Reflection Phase Optimization for RIS-Empowered Vehicular Communication Systems

Liang Dai and Ziwei Zhang (Chang'an University, China); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Jiangwei Liao (University of Hertfordshire, United Kingdom (Great Britain)); Ke Guan (Beijing Jiaotong University, China); George C. Alexandropoulos (University of Athens & University of Illinois Chicago, Greece)
This paper proposes a dynamic reflection phase optimization method for vehicular communications empowered by a reconfigurable intelligent surface (RIS). The RIS phase configuration is formulated as a nonconvex optimization problem aimed at maximizing the received signal-to-noise ratio (SNR), which is solved using a block coordinate descent (BCD) algorithm. Real-time phase optimization enhances the SNR and reduces the Doppler effect. Compared with conventional optimization and static phase configuration methods, the proposed algorithm achieves improved performance with reduced computational complexity, making it suitable for real-time vehicular applications. Simulation results demonstrate that the proposed method improves channel capacity and reduces the impact of Doppler shifts. Furthermore, the influence of RIS scale and deployment location is analyzed, providing practical insights for RIS deployment in vehicular communication systems.

11:40 Smart Electromagnetic Skin-Assisted Wireless Sensing: Design and Evaluation from 27.5 to 60 GHz

Sanaz Kianoush (National Research Council of Italy (CNR), Italy); Roberto Nebuloni (Ieiit - Cnr, Italy); Federico Francesco Luigi Mariani and Davide Scazzoli (Politecnico di Milano, Italy); Carlotta Sabato (Polito, Italy); Michele Beccaria (Télécom SudParis, Polytechnique de Paris, France & DET- Politecnico di Torino, Italy); Stefano Savazzi (Consiglio Nazionale delle Ricerche, Italy); Paola Pirinoli (Politecnico di Torino, Italy); Maurizio Magarini (Politecnico di Milano, Italy)

Improving sensing performance in the 27.5 to 60 GHz frequency range remains challenging in integrated sensing and communication (ISAC) systems due to complex propagation conditions and signal variability. Smart reconfigurable environments, which allow control over the channel's propagation characteristics, offer a promising approach to enhance sensing accuracy. This paper emphasizes the key role of engineered surfaces in indoor environments with existing wireless infrastructure at 27.5-60 GHz, demonstrating their importance for practical passive localization in ISAC systems. Ray tracing simulations are performed to evaluate the power delay profile (PDP) and assess the influence of engineered surfaces on signal propagation in the presence of a human body. To achieve more intelligent and controllable coverage, smart electromagnetic surfaces (SESs) are designed and characterized at these frequencies. Future works, will focus on the integration of SESs tailored to specific frequency ranges into ray tracing to further validate and prototype practical ISAC scenarios.

12:00 Design Trade-Offs in RIS-Assisted Adaptive Reflection via Low-Complexity 2D AoA Estimation

Stefano Lioce (Centre Inria d'Université Côte d'Azur, France); Antonello Florio and Gianfranco Avitabile (Politecnico di Bari, Italy); Damien Saucez (Inria, France); Walid Dabbous (Inria, Université Côte d'Azur, France)

Accurate user localization is essential for next-generation wireless networks, enabling precise beamforming and efficient resource allocation. Reconfigurable Intelligent Surfaces (RISs) are key to enhancing coverage, spectral efficiency, and spatial resolution, where localization enables the dynamic focus of the reflected beam. However, existing RIS-assisted techniques often involve high computational and hardware costs. This paper introduces a low-complexity adaptive reflection algorithm based on 2D angle of arrival (AoA) estimation through phase interferometry. The algorithm dynamically adjusts RIS phase profiles according to estimated azimuth and elevation angles to preserve reflection accuracy while minimizing overhead. A simulation campaign assessed the impact of three key parameters: (i) receiver ADC resolution, (ii) RIS phase quantization, and (iii) surface size. Results show that higher ADC resolution, finer phase quantization, and larger RIS arrays improve performance, with ADC resolution having the dominant influence. Notably, high-resolution ADC offers limited benefit with coarse RIS quantization.

Friday, April 24 10:40 - 12:20

SW9b Efficient Wireless Power Transfer for Sustainable Smart Environment Sensors

/ / Antennas

Room: Firenze

Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain)
George Shaker (University of Waterloo, Canada)
Will Whittow (Loughborough University, England)
Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)
Mahmoud Wagih (University of Glasgow, Scotland)
Spyros Daskalakis (Green IoT Solutions Ltd, Scotland)
Manos Tentzeris (Georgia Tech, USA)

This workshop addresses self-powered sensors for smart environments to solve the strong sustainability problem of standard wireless sensors, which, as expected by the European Innovation Council-European Union, will require 80 million batteries to be changed daily by 2040. Challenges and opportunities of the different microwave wireless power transfer (WPT) subsystems (antennas, harvesting circuits, wireless sensing, and energy management) will be discussed with novel solutions towards making them suitable for various sensor systems, such as environmental monitoring and smart homes/cities. It will feature perspectives from both academia and industry, complemented by insights from the IEEE AP-S Environment Technical Committee.

Workshop outline: The workshop will combine technical presentations, each followed by interactive discussions. Then, a panel with all speakers to foster collaboration within the community working on these domains.

08:30 - 08:40 Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain) George Shaker (University of Waterloo, Canada) Welcome and Workshop Scope Insights from the IEEE AP-S Environment Technical Committee.
08:40 - 09:05 George Shaker (University of Waterloo, Canada) Fluid-Activated Matter: Toward Battery-Free Intelligence and Universal Connectivity
09:05 - 09:30 Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain) Compact Liquid Dielectric Antennas for Wireless Power Transfer
09:30 - 09:55 Will Whittow (Loughborough University, England) 3D printed RF devices and optically transparent antennas and metasurfaces
09:55 - 10:10 Panel with all speakers Discussion / Q&A
10:40 - 11:05 Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain) Miniaturized Microwave Wireless Power Transfer Systems
11:05 - 11:30 Mahmoud Wagih (University of Glasgow, Scotland) Making RF Wireless Power Sustainable? From Quantifying Impact to Circular Electronics
11:30 - 11:55 Spyros Daskalakis (Green IoT Solutions Ltd, Scotland) Manos Tentzeris (Georgia Tech, USA) Green IoT Solutions and Global Environmental Responsibility
11:55 - 12:10 Panel with all speakers Discussion / Q&A
12:10 - 12:20 Chairs Wrap-Up and Outlook

BIOGRAPHIES: Dr. Kerlos Atia Abdalmalak (Organizer) is an assistant professor at Universidad Carlos III de Madrid, Spain. He has authored 1 book chapter and 80+ reviewed papers. Participated in 21 R&D and industrial projects (total fund +3.2 M€) where he led two of them. Co-organizer of European School of Antennas (ESoA) fundamental-of-the-Antenna course in 2025. Fellowship, MDPI Symmetry Travel-Award, IEEE/AESS Young Professionals Travel Grant, and Fulbright short-stay for young doctors.
Prof. George Shaker (Co-organizer) is the lab director of the Wireless Sensors and Devices Laboratory at the University of Waterloo, where he is an adjunct associate professor with +200 peer-reviewed publications and +35 patents/patent applications. He has +20 years industrial experience with many commercial products available from startups and multinationals includes Apple, Amazon, Google, and Blackberry. He is currently an IEEE AP-S Distinguished Industry Speaker and IEEE Sensors Council Distinguished Lecturer. Received multiple awards, including IEEE/AP-S Best Paper Award, IEEE/AP-S Honorable Mention Best Paper Award (4 times), IEEE/MTT-S Graduate Fellowship, IEEE Sensors most-popular-paper award, NASA Tech-Briefs-HM Award, and Nature-Communications-Engineering Top25-downloaded-papers.
Prof. Will Whittow FIET, AFWES, SFHEA, SMIEEE (WW) is Professor of Radiofrequency Materials and leads the Wireless Communications Research Group at Loughborough University. He is a named PI/CI on grants totalling > £17m: 3D Metamaterials (SYMETA) (PI, EP/N010493/1), Anisotropic metasurfaces (ANISAT) (PI, EP/S030301/1); and Transparent metasurfaces (PI, EP/W037734/1). He has > 350 peer-reviewed publications (~ 130 journal papers) (> 6,500 citations, h-index = 41): including metasurfaces; dielectric lenses, and dielectric characterisation. He is an IEEE Distinguished Lecturer in Additively Manufactured RF Devices. WW won the inaugural Women's Engineering Society (WES) Men As Allies Award (2017) for outreach.

Prof. Daniel Segovia-Vargas is a full Professor at Universidad Carlos III de Madrid, Spain and the Chair of the Radiofrequency, Electromagnetics, Microwaves and Antennas Group (GREMA) and a former head of Telecommunications Engineering. Has authored or co-authored more than 350 publications in scientific journals and international conferences. His areas of research include antennas, active antennas, metamaterials, energy harvesting, and THz technologies. He was a Treasurer of the European Microwave Conference2018 and EuCAP2022, the Chairperson of URSI2011. He has organized several international workshops and chaired courses in European School of Antennas since 2013. He has chaired more than 90 R&D projects.
Dr. Mahmoud Wagih is a reader at the University of Glasgow, leading the Green RF-Enabled Electronics Lab, holds a UKIC Fellowship from the Royal Academy of Engineering, and is the Founder of RX Watt Ltd. His interests cover RF-enabled sustainable systems for energy harvesting, sensing, and wearable applications. He has published 130 journal and conference publications and 3 patents and has been principal/co-investigator on over £15M research projects. He is an IEEE Distinguished Microwave Lecturer, received 20+ awards, including multiple IEEE Best Paper, EurAAP Per-Simon Kildal, 2 URSI Young Scientist Award, and was listed in Forbes 30 Under 30 in 2024.
Dr. Spyros Daskalakis is co-founder of Green IoT Solutions Ltd (UK) and Assistant Professor at Heriot-Watt University, UK, specializing in radio electronics for sensors and wireless communications. His research focuses on environmental sensing, batteryless sensors, RF energy harvesting, ambient backscatter communications, ultra-low-power embedded systems, and agricultural IoT applications, with over 8 years dedicated to design, integration, fabrication, and testing of hardware for wireless sensing devices and RF applications. He serves as Associate Vice President of Conferences for IEEE Council on RFID (2025-2027) and vice chair of Subcommittee 17, WiSNet-Wireless Sensors for IoT Applications, Radio and Wireless Week 2026 (RWW2026).

ABSTRACTS: Fluid-Activated Matter: Toward Battery-Free Intelligence and Universal Connectivity: As billions of sensors blanket our built environment, battery dependency emerges as an unsustainable paradigm, burdening ecosystems with toxic waste, costly replacements, and recycling complexities. Batteries further introduce fire hazards in thermally dense AI data centers and detectable thermal signatures compromising military concealment. We present a self-powered water leak detection platform harvesting hydroelectric energy for perpetual, maintenance-free operation. Remarkably, this harvested energy powers wireless radios from short-range to satellite connectivity over Low Earth Orbit constellations. This battery-free architecture unlocks transformative applications across residential towers, industrial facilities, military installations, and smart city grids, envisioning a future of resilient, self-sustaining, planet-scale monitoring.
Compact Liquid Dielectric Antennas for Wireless Power Transfer: This presentation addresses self-powered sensors to solve the strong sustainability problem of standard wireless sensors, which, as expected by the European Innovation Council-European Union, will require 80 million batteries to be changed daily by 2040. The focus will be directed to antennas working at lower frequencies (<1GHz) for far-field Microwave wireless power transfer (WPT) systems. Novel solutions for compact high-gain designs will be discussed, such as constructing high-permittivity liquids to be injected into 3-D-printed shells, along with a WPT demo based on these liquid solutions. This provides sufficient power over larger distances, required for various applications such as environmental monitoring, smart homes/cities, and industry.
3D printed RF devices and optically transparent antennas and metasurfaces: 3D printing not only allows control of the external shape, the local relative permittivity can be tailored to precise specifications by controlling the internal geometry and hence varying the ratio of air and filament. The local relative permittivity can then be graded in all three axes for extra degrees of freedom. This can be exploited to create flat grade index lenses as well as hybrid lenses. By using specialist printers and careful control of the settings, filaments with relative permittivities up to 15 can be printed. The talk will demonstrate how these RF materials can be used to create artificial dielectrics, filters, metamaterials, and bespoke antennas. The talk will also cover the challenges of measuring dielectric properties. A current ongoing project is exploring optically transparent conductors to fabricate antennas and metasurfaces.
Miniaturized Microwave Wireless Power Transfer Systems: The development of miniaturized wireless power transfer (WPT) has recently attracted huge interest, especially for implantable antennas. Thus, a miniaturized dual-band implantable antenna, combining meandered line and spiral techniques to achieve wide impedance bandwidths, is proposed. Furthermore, the proposed WPT system achieves a power transfer efficiency (PTE) of 1.15% by improving the coupling between the receiving (Rx) and transmitting (Tx) antennas using magnetic-based designs, thereby reducing human tissue losses. Finally, the measured results obtained inside minced pork show a high degree of agreement with the expected performance, validating the system's performance in realistic biological environments.
Making RF Wireless Power Sustainable? From Quantifying Impact to Circular Electronics: RF power delivery to rectennas could enable battery-free devices, but its environmental impacts are not clearly understood. This talk will review the sustainability of different RF power delivery scenarios and more broadly the underpinning components' sustainability, through Life Cycle Assessment (LCA). Efficiency improvement approaches and also associated antenna-IC co-design will be discussed. Finally, fabrication processes and materials for zero-waste and fully recyclable antennas and RF power harvesting frontends will be introduced.
Green IoT Solutions and Global Environmental Responsibility: Batteries are one of the biggest barriers to large-scale wireless sensor deployment, they need replacing, they fail, and they create waste. This talk presents work from Heriot-Watt University, Green IoT Solutions Ltd, and Georgia Tech on sensors that run without batteries, harvesting energy from ambient RF and solar sources. We cover the underlying RF energy harvesting and backscatter communication techniques, as well as real-world deployments in precision agriculture and environmental monitoring. The goal is simple: sensors that just work, indefinitely, with no maintenance, and a smaller environmental footprint to match the "green" in Green IoT.

Friday, April 24 10:40 - 12:20

SW1b AMTA Workshop: Toward Improved Standardization of RCS Measurements.

/ / Measurements

Room: The Hague

Lars Jacob Foged, MVG, Italy,
Peter Collins, Resonant Sciences, USA,
Brian Fischer, Resonant Sciences, USA,
Christer Larsson, Lund University, Sweden,
Paul J DeGroot, Boeing, USA,
Amedeo Capozzoli, University of Naples, Italy
Ivan Lahaie, Retired, USA

In this AMTA-supported workshop, we aim to provide an overview and facilitate discussion on widely accepted practices for conducting and reporting monostatic and bistatic radar cross-section (RCS) measurements in both near-field (NF) and far-field (FF) configurations. Topics will include calibration procedures, measurement configurations, data transformation techniques, and uncertainty evaluation, key elements in ensuring repeatable and traceable results across different facilities. By engaging experts from academia, industry, and government, this effort seeks to harmonize best practices, strengthen the foundation for global RCS measurement standardization, and provide valuable input to the update and review of IEEE Std 1502-2020 "Recommended Practice for Radar Cross-Section Test Procedures".

Workshop Outline: The workshop will feature a series of invited presentations, each addressing a key aspect of radar cross section (RCS) measurements, with particular emphasis on topics relevant to upcoming revisions of the IEEE 1502 standard. Confirmed speakers include Pete Collins, Brian Fisher (Resonance Science, USA), and Ivan LaHaie (retired, USA), with additional contributions from Lars Foged (MVG, Italy) and Paul DeGroot (Boeing, USA) in support of the ongoing standardization effort. The program will cover complementary subjects spanning measurement methodologies, signal processing, error mitigation, and standardization insights. The workshop format is designed to encourage active discussion and knowledge exchange among leading experts from both industry and academia.

BIOGRAPHIES: Lars Foged received his M.S. degree in Electrical Engineering from the California Institute of Technology (Caltech), USA, in 1990. He is currently Vice President of Research and Development at the Microwave Vision Group (MVG). He has held several leadership positions within the IEEE Antennas and Propagation Society (AP-S), including Chair of the Industry Initiatives Committee (IIC) and current Chair of the Antenna Standards Committee (ASC). In 2023, he received the IEEE AP-S Industrial Innovation Award. He served as Vice-Chair of the European Conference on Antennas and Propagation (EuCAP) in both 2011 and 2022, and is course organizer, and board member of the European School of Antennas (ESoA). He served as President of the Antenna Measurement Techniques Association (AMTA) in 2023 and is AMTA Fellow and Distinguished Achievement Award recipient. He is the author of two books and numerous scientific papers on antennas and measurement techniques. His work has earned multiple distinctions, including Best Technical Paper Awards at AMTA (2013) and EuCAP (2021).
Paul De Groot is a Technical Fellow at The Boeing Company and an Antenna Measurement Techniques Association (AMTA) Edmond S. Gillespie Fellow with expertise in RADAR Cross Section (RCS) and Antenna measurements and frequency spectrum management. For over 35 years, Paul has engineered complex systems and lead teams to conduct RCS and antenna measurements at both the Boeing Enterprise and national levels. Paul was AMTA Vice President while serving on the AMTA Board of Directors and is a member of IEEE, IEEE Antennas and Propagation Standards Committee and chairing the review of RCS standard IEEE Std 1502-2020.
Ivan J. LaHaie received his BS degree from Michigan State University in 1976 and his MS and Ph. D. degrees from the University of Michigan in 1977 and 1981, respectively, all in electrical engineering. He joined the Environmental Research Institute of Michigan (ERIM) in 1980 and worked there for 30 years during its various incarnations as ERIM International, Veridian Systems, and General Dynamics Advanced Information Systems. He joined Integrity Applications Incorporated (later Centauri and KBR) in 2010 as a Senior Principal Scientist and Technical Fellow until his retirement in 2021. Dr. LaHaie is an internationally-recognized authority in the development of techniques for RCS measurement error mitigation, near field-to-far field RCS transformations, and RCS uncertainty analysis. Dr. LaHaie is an IEEE life fellow and an AMTA fellow. In 1991, he received the IEEE Aerospace and Electronic Systems Society Radar Systems Panel Award, given annually to the nation's leading radar engineer under 40 years of age, for his contributions to synthetic aperture systems and electromagnetic modeling. He received the AMTA Distinguished Achievement award in 2004 for his pioneering work in the development of automated radar signature imaging technology, RCS measurement technology and standards, the design and evaluation of electromagnetic interference and error source mitigation techniques, and for his contributions to the field of radar signature target support interaction modeling
Brian E. Fischer is a Chief Engineer at Resonant Sciences in Dayton, Ohio. His research interests have focused on the development of electromagnetic optimization methods, signal processing, measurements, predictions, and associated uncertainty. Applications are in areas of synthetic aperture radar, antenna direction finding, and near-field measurements supporting a variety of US Government sponsors. His current technical focus is in the areas of high-speed electronic sensing and signal exploitation using adaptive antenna methods and generalized near-field RCS transformation. Dr. Fischer is a Distinguished Achievement Award recipient and Fellow of the Antenna Measurement Techniques Association (AMTA), and served as AMTA President in 2012. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), and served as Associate Editor for the Measurements Corner in the IEEE Antennas and Propagation Society Magazine from 2007-2019. He is a retired US Air Force officer. Dr. Fischer received the BSEE from Michigan Technological University in 1988, the MSEE from the Air Force Institute of Technology in 1992, and the Ph.D. in Signal Processing from the University of Michigan in 2005.
Peter J. Collins is currently a senior staff engineer with Resonant Sciences (RS), Dayton, Ohio. He is a Fellow of the Antenna Measurement Techniques Association (AMTA), Senior Member of the IEEE, and a member of the Eta Kappa Nu and Tau Beta Pi honor societies. With over 35 years of government subject matter expert experience, Dr. Collins has served in many positions throughout the Department of Defense (DoD). Highlights include a term as commander of the National RCS Test Facility (NRTF), where he led a diverse team of government and contractor scientists, engineers, and technicians to ensure testing and upgrades at the Air Force's premiere outdoor static RCS range. Upon retirement from active duty, Dr. Collins joined the Air Force Institute of Technology (AFIT) where he served as Professor of Electrical Engineering. In addition to advising over 50 graduate students, Dr. Collins was the Low Observables (LO) Curriculum Chair responsible for ensuring AFIT's LO program met the needs of the Air Force and broader DoD. While at AFIT, Dr. Collins received the 2013 Secretary of the Air Force Harold Brown Award for survivability technology development including efforts to develop low-frequency noise radar-enabled RCS measurement systems and a patented low clutter bistatic measurement concept for indoor RCS measurement. In addition to his academic service, Dr. Collins served the National RCS Measurement Facility Certification Program as an Executive Committee Member for five years, pushing for balance in QA best practices and test cost. His long association with the certification program includes time as an RCS range reviewer for the Air Force Research Laboratory's Advanced Compact Range, the AFRL Mobile Diagnostic Radar and Dynamic Measurement System, and Boeing management of the UK Ministry of Defense's Range and Dynamics Measurement System at the Ministry's SAF II Compact Range and the Tejon Outdoor Far-field Range.

Monday, April 20 12:40 - 13:10

CC **Closing Ceremony**

Room: Main Auditorium/Dublin