An Experiment and Preliminary Results for Narrow- and Wideband Land Mobile Satellite Propagation at K-band

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***Abstract*— With increasing utilization of satellite mobile services capacity shortage in respectively common frequency bands (L band) is to be expected. To enhance understanding of propagation channel characteristics at higher frequency bands (Ku/Ka band) an experiment with a mobile receiver, using narrow- and wideband test signals has been carried out. An airborne test platform has allowed to consider real satellite incidence angles. A comprehensive database has been obtained on channel behaviour and - by means of auxiliary instruments - documenting the details of four typical scenarios measured. Preliminary results indicate excellent qualitative plausibility, such as recognition of electricity poles. Ongoing quantitative analyses include comparisons to literature, e.g. specific attenuation in vegetation. Focus is a statistical analysis to set up a channel simulator predicting the propagation channel characteristics under the measured scenarios' conditions. It is planned to submit results for standardization.**

I. INTRODUCTION

The evolution of telecommunication services towards interactive and broadcast multimedia services demanding high mobility and high data rates indicates that current frequency allocations for land mobile satellite (LMS) services – communication and broadcasting - will get congested in the near future. For the analysis of higher frequency bands (Ku/Ka band) in order to increase the capacity and achievable bit rates, it is important to properly understand and characterise the propagation channel. At these frequencies, both tropospheric, such as rain dynamics, will combine together with mobile environment effects such as shadowing and multipath and affect the signal received at the vehicular terminal. Earlier measurement campaigns covered mainly shadowing effects, and the dynamics of atmospheric effects as seen by a mobile terminal and the combination of these effects has not yet been experimentally validated. Also multipath effects and frequency selective fading have been usually neglected by assuming highly directive antennas at these bands. The present activity addresses this situation.

II. THE EXPERIMENT

An experiment has been carried out to study propagation effects at K-band frequencies, with a mobile receiver, using narrow- and wideband test signals. The experiments had to realistically simulate land mobile satellite reception, thus an airborne test platform allowed to investigate the channel in azimuth and elevation dependence.

A. The Experimental Setup

The principal experiment setup uses an Elektrobit Propsound channel sounder (PS-CS) at 17.6 GHz. The sounding signal with 200 MHz bandwidth was utilized in the experiment, allowing measurements of link attenuation, and delay spread introduced by multipath. The PS-CS has been used in SISO setup. For comparison purposes a narrowband pure sine wave was also measured.

The basic concept for the experimental configuration is to let the mobile receiver move on a spot-like position so that the movement of the car would not change the measurement geometry. This requirement is fulfilled by choosing measurements routes within an area of less than 1 square-kilometre, while the transmitter was carried at a link distance of 10 km. A Hercules C130 was chosen, such aircraft is able to move on a hemisphere of 10 km radius around the spot-like position of the moving receiver. The measurement geometry thus includes full azimuth circles by the transmitter on the aircraft, and elevation steps at 20, 40 and 60 degrees seen

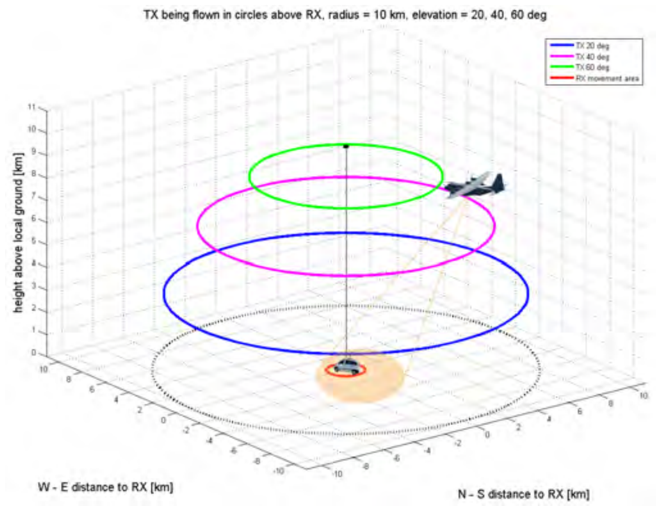

Fig. 1 measurement geometry

from the receiver, as indicated in Fig. 1.

As further independent reference measurements an actual Ku-band satellite signal has been used. Using an uplink station (13.98 GHz) within the experiment, a clean sine signal has been transmitted to Hellasat and broadcasted (12.73 GHz). Receive levels have been recorded directly at the uplink site and by a caravan satellite receiver installed in a van driving behind the principal vehicle.

Along with the mobile receivers, a stationary beacon receiver at 19.701 GHz has been set up in the area of Linz to measure the HotBird 6 Ka-band beacon. Fig. 2 shows on overview on these channel measurement instruments.

To support the analysis, various auxiliary data have been simultaneously recorded: the position of transmitter and receiver using GPS readings, with the aircraft attitude documented by IMU recordings. To study the environmental conditions in detail, fisheye cameras have been mounted on the roof of the measurement vans, with GPS position and time inserted into the video stream.

B. Four Measurement Scenarios

Four measurement routes were chosen, to consider typical scenarios as needed for modelling: rural, suburban, urban and railroad. The railroad scenario was substituted by a trolley-bus scenario with similar installations for electricity. All four scenarios were selected in or close to the city of Linz / Austria. The rural scenario includes open-field passages, a road through the forest, an underpass under a bridge, and also a road along family houses. The open-field passages may be used as reference for unobstructed signal reception.

The suburban scenario was located within an industrial park, characterized by a dense arrangement of flat houses and storages along the road. The urban scenario measurements took place in the very centre of Linz, with narrow street canyons made by houses of four or more floors. The trolley-bus scenario measurements were carried out on a four lane road, with vertical concrete poles in the middle and sturdy horizontal metallic beams carrying the electricity installations.

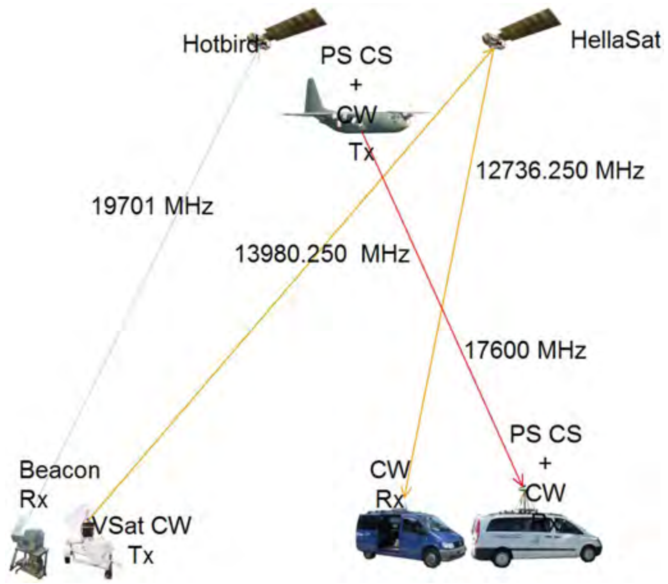

Fig. 2 Experimental configuration

III. Data Preprocessing and Validation

The wealth of data obtained requires careful preprocessing and validation to ensure reliability of subsequently derived statistics on channel characteristics. This includes:

- verification of vehicle and flight path, aircraft attitude
- application of link distance and TX antenna pattern weighting. The directive TX antenna had firmly been mounted onto the aircraft fuselage (cf. Fig. 3).
- determination of TX – RX (aircraft – vehicle) relative velocity and Doppler shift. Verification of wideband (PS-CS) data validity.
- identification of mobile route environment from fish-eye video cameras, including open-field reference passages
- identification of line-of-sight blocked / non-blocked status by means of aircraft – vehicle position and fisheye camera information
- identification of tropospheric and aircraft vs. cloud height conditions by means of aircraft position and cloud camera information, weather radar and standard meteorological sensors.

Considering the complexity of such preprocessing and validation tasks, specific software tools have been developed to allow synchronous visualization and inspection of the various data streams.

IV. Preliminary Results

As first preliminary results qualitative representations of remarkable environmental situations have been generated and their plausibility verified. In the following a few samples are given:

A. Underpass under a bridge

In the rural scenario the mobile vehicle went through an underpass underneath a bridge (cf. Fig. 4). Such obstacle is clearly to be reflected in the propagation channel of the K-band signal and is thus chosen as a first plausibility check and qualitative result. Fig. 5. shows the fisheye camera picture underneath the bridge and the respective passage in the CW data stream. It is clearly visible that the bridge effects a massive blockage of the signal, reception level falls down from approx. -69 dBm to noise floor at approx. -90 dBm. The blockage lasts somewhat less than one second, corresponding well with the drive speed of some 9 m/s and the width of the

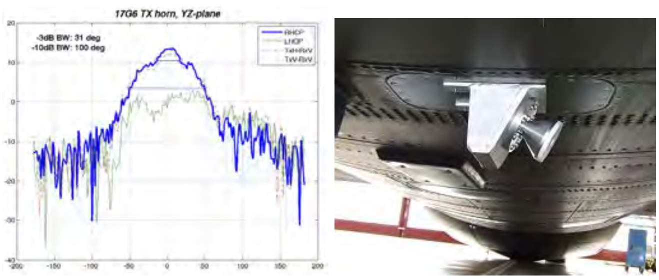

Fig. 3 TX antenna (17.6 GHz): left hand a sectional graph of the antenna pattern is shown, at right hand a view onto the antenna firmly mounted on fuselae of C139 aircarft is given..

Fig. 4: part of vehicle path in rural scenario, drive direction from NW to SE. Underpass marked in red plus 20 m before and 60 m after underpass marked in yellow. Aerial view by courtesy of the Digital geographic information system of the Upper Austrian government (http://doris.ooe.gv.at).

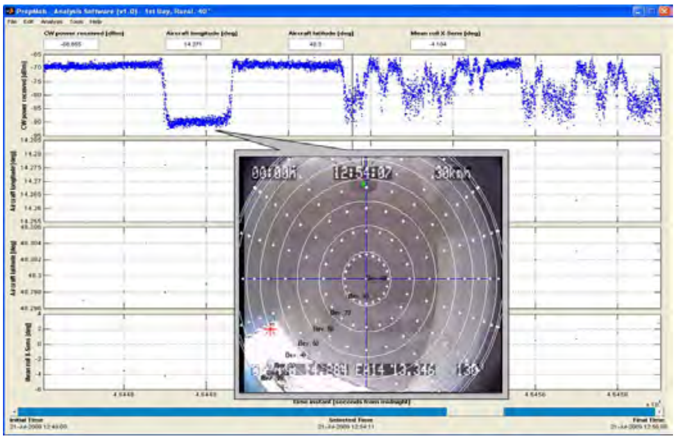

Fig. 5 the mobile vehicle goes through an underpass under a bridge (marked red in Fig. 4). CW reception level time series and a picture from fisheye camera video are given. Grid resolution is 1 second. Signal blockage within second 2 and 3 clearly visible.

bridge. Some 10 meters before and after the underpass there is unobstructed reception, also reflected in Fig. 4 and Fig. 5.

B. Fir tree forest

As seen in Fig. 4 the mobile route – direction South-East - after the underpass approaches a fir tree forest. The time series of the received K-band CW signal for the first few seconds after the underpass is plotted in Fig. 5, as well. After the underpass first an open situation of some 15 meters is recognized, after which the fir tree forest partly covers the road in the aerial view. A diversified situation of signal attenuation is to be expected. Indeed the last 4 seconds of the time series plots in Fig. 5 present a rapidly varying signal level. Pictures from the fisheye camera on the vehicle underline the reliability of and reasons for such varying attenuations. Fig. 6 shows a sample, including an azimuth / elevation grid of signal incidence angles. The current position of the aircraft and signal incidence direction is indicated by a red marker. This picture makes it visible, that shadowing for such incidence angle (elevation 40 deg) varies with motion of the vehicle.

Fig. 6: fisheye picture taken in rural scenario fir tree section (cf. Fig. 4).

C. Trolley Bus

A trolley bus scenario in terms of electromagnetic propagation is equivalent to railroad environments, which are given considerable attention (e.g. [1]), considering potential mass consumer applications. The present activity has allowed a unique possibility to measure effects of such electricity installations, where at K-band frequencies a clear representation of even thin support structures was to be expected. Fig. 7 shows a photograph taken during the measurements at the trolley bus line, with the electricity poles and bars clearly visible. The shadowing of the electricity installation is represented by deep dents in the signal strength, as is clearly seen in Fig. 8: the left hand graph represents the wideband system (PS-CS), the right hand graph stands for the CW system. The wideband received power includes the contribution by multipath components.

Fig. 7 trolley bus scenario. The posts and horizontal bars of the electrical installation are clearly visible**.**

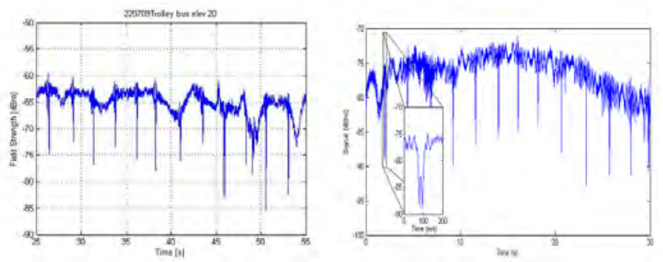

Fig. 8 RX power level at trolley bus line electricity installations. Left hand wideband signal power including multipath components, right hand CW signal power. Dents in signal power clearly visible

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V. Quantitative Analyses

Whereas the preliminary results presented herein are of qualitative nature, the ongoing quantitative analyses aim to set up a simulator predicting propagation characteristics under scenarios' categories as they have been measured. The parameters resulting from the statistics of the measurements will determine the behaviour of the simulator, with a two state Markov model being the basis [2]. The statistical analysis for parameter extraction starts with subdividing the measurement runs in portions of equal driving distance, e.g. half a meter. For each such portion the measured signal characteristics are fitted by relevant distributions and their parameters being determined. Whereas narrowband CW data stay with signal level and multipath power, the wideband measurements add an extra dimension, i.e. power delay. Power delay profiles may be characterized by their delay spread, total excess delay, their number of clusters, decay slope and the time constant for arrivals within each cluster. Within the simulator the wideband behaviour will be represented using a tapped delay line model.

For a detailed understanding of channel characteristics and accurate conditioning of the simulator, various auxiliary data will be used to provide information on subcategories of scenarios. Such categorization includes environmental and atmospheric conditions and may read e.g. as:

- rural - open field - clear sky
- rural – forest – rainclouds
- urban - narrow street canyon – clear sky
- etc.

Beyond establishing a simulator, quantitative comparisons to literature values shall be carried out. This refers e.g. to specific attenuation in vegetation as predicted by [3]. From measurement geometry the total forest attenuation may reliably be converted into specific attenuation values, directly comparable with [3].

VI. Conclusions

A unique experiment has been carried out, for an enhanced understanding of propagation mobile channel characteristics at Ku- and Ka-band frequencies. Qualitative first results do show excellent plausibility. As expected usage of such high frequencies requires careful planning. Even minor path shadowing elements like electricity poles cause strong signal degradation. Comparison of narrowband and wideband relative power levels variations are in very good agreement. The ongoing analyses aim for establishment of a simulator and comparisons to literature values. It is expected that new findings might be obtained, which then shall be submitted to standardization organisations.

VII. Acknowledgements

The flight operations for the experiment were carried out by the Austrian Airforce. Their excellent performance and cooperation is greatly acknowledged. This refers to actual execution of flights and to preparations, herein especially to equipment installation into the aircraft.

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VIII. References

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