

Wideband characterization of the LMS channel at K-band

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INTRODUCTION

The motivation behind our study is the increasing need for mobile satellite multimedia. Satellite based services working at frequency range between 1—3 GHz suffer from lack of available bandwidth due to congestion, higher frequencies in the K-band are now considered as an extension of existing services at L- and S-band. Hercules Transporter C130 aircraft was used to mimic a satellite transmitter at various elevation angles. Long link distance made it possible to include cloud layer and precipitation effects in the radio path. Utilizing the Propsound channel sounder (PSCS) and frequency conversion blocks in both ends, 200 MHz wideband measurements at the centre frequency of 17.6 GHz were carried out in Austria in the late summer of 2009. Qualitative analysis of the data has been carried out, and parameters for a Markov type model are currently being extracted.

This activity has been carried out under the ESA Contract C20871 – Propagation Effects for Mobile Multimedia Services under ARTES 5.

MEASUREMENT CAMPAIGN

The aircraft flew along equi-centred circles at various elevations carrying onboard the PSCS, a 420 W high-power tube amplifier (HPA), an uninterruptible power system and a Nitrogen source for de-moisturizing the TX waveguide. The TX antenna was mounted under the fuselage in a fixed tilt to compensate the aircraft bank angle during the circles. This ensured that the receiver van, and the RX antenna on its roof, was kept within the HPBW of the TX antenna. Fig. 1 shows the overall route planning.

Elevation angles at 20, 40 and 60 degrees were chosen to give data for an elevation dependency study. The link lengths were nominally 10 km from the preselected centre points on the ground. Deviation of the RX vehicle from the centre point of the trajectory brings a radial speed component into the radio link between the aircraft and the van. This causes a Doppler shift, and therefore the routes were carefully designed not to exceed the operational limits of the measurement system.

Four radio environments were chosen to consider typical scenarios as needed for the channel modelling. Fig. 2 gives a bird's eye view to the actual routes travelled by the measurement van. The railroad scenario was substituted by a trolley-bus scenario with similar installations for electricity. All four routes were selected in or close to the city of Linz / Austria.

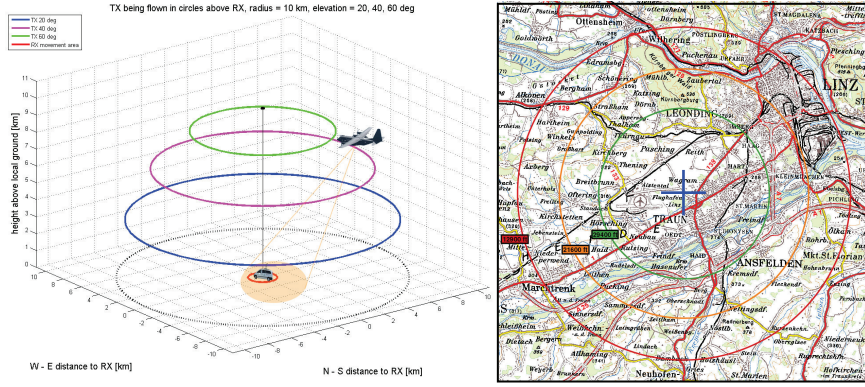


Fig. 1: Measurement configuration:
Left: Schematic view, Right: Flight plan for Rural scenario.

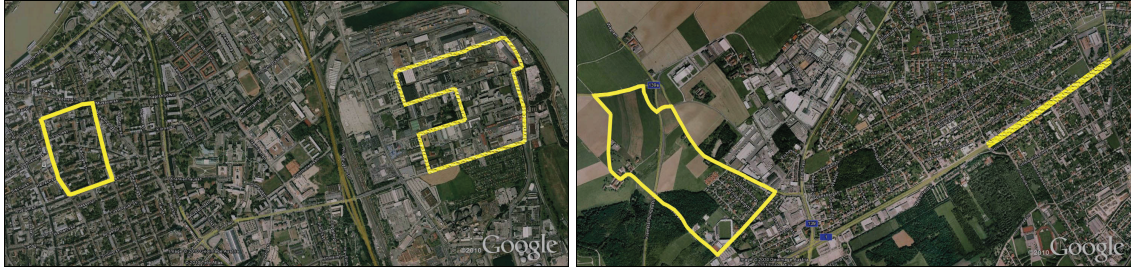


Fig. 2: Measurement routes in Linz (Scenarios from left to right):
Urban, Suburban, Rural, Railroad.

The rural scenario included open passages, a road through the forest, an underpass and a road through a residential area. 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 formed by houses of four or more storeys. The trolley-bus scenario was by a four-lane road, with vertical concrete pylons in the middle and sturdy horizontal metallic bars carrying the electricity installations above the lanes.

Fig. 3 shows how the strong signal received in an open area drops into a ‘bad state’ when the RX enters an underpass, and then fluctuates between the two states while the route is in a forested area. The large change cannot be described by a single distribution [1]. A better result is achieved with a state-oriented approach, where at least two distributions are applied to describe the good and bad signal states.

DATA ANALYSIS

In our approach we apply Rice and Rayleigh distributions for the good and bad signal states, respectively. Rice distributed signal amplitude is defined as [2]

$$p_{\text{Rice}}(r|a) = \frac{r}{\sigma^2} \exp\left[-\frac{r^2 + a^2}{2\sigma^2}\right] I_0\left(\frac{ra}{\sigma^2}\right) \quad r \geq 0, \quad (1)$$

where r is the mean signal amplitude, a is the direct path amplitude, σ^2 is the variance of the real and imaginary parts of the signal amplitude, and I_0 is the modified Bessel function of the first kind and zeroth order. With $a=0$, this becomes a Rayleigh distribution.

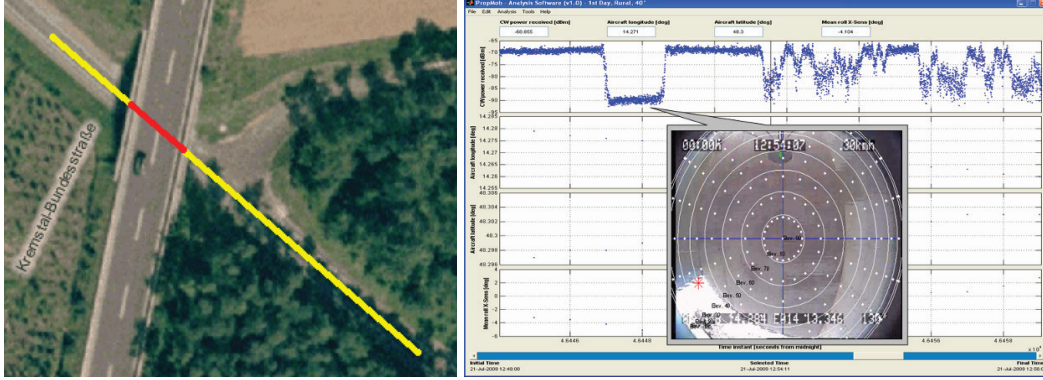


Fig. 3: Measured signal level changes in the rural scenario.

The satellite channel is modelled as a two-state Markov chain, where the channel states are determined by the Rice factor $k = a^2 / (2\sigma^2)$. For the modelling purposed, we split k into parameters $A = 20 \lg a$, representing the *direct signal power*, and $MP = 10 \lg 2\sigma^2$, which describes the normalised *diffuse multipath power* caused by the direct signal illuminating the environment in the vicinity of the mobile.

The data was analysed in two steps. In the first step, the *instantaneous power delay profiles* (PDP) $p_i(\tau)$ were averaged over $d=0.5$ meter portions of movement to yield *average PDPs* (APDP). At 17.6 GHz, distance d equals to 29.3 wavelengths, which in terms of mobile radio channel can still be considered as small-scale. As defined by (2), PDP is the squared amplitude of the input delay spread function $h_i(\tau)$ (the ‘complex impulse response’, CIR) at time instant i , cut at a given signal level to mask out the reflections from distant scatterers

$$p_i(\tau) = |h_i(\tau)|^2. \quad (2)$$

The channel state parameters A , MP and the state transition probabilities, and their dependency of elevation angle are to be extracted from the APDPs by studying the evolution of the average power delay profile over distance travelled by the RX van.

In the second step, the APDPs are fitted into an exponential decay function (a linear ramp in dB scale). The exponential decay is described by the total signal power P_0 and the delay spread τ_{rms} along the delay τ as

$$P(\tau) = \frac{P_0}{\tau_{\text{rms}}} \exp\left(-\frac{\tau}{\tau_{\text{rms}}}\right), \quad (3)$$

The delay spread τ_{rms} is calculated using definition (4) [2].

$$\tau_{\text{rms}} = \sqrt{\frac{1}{P_T} \sum_{i=1}^N \tau_i^2 P(\tau_i) - \tau_0^2}, \quad (4)$$

where $P(\tau_i)$ is the received power at delay τ_i , and P_T is the total received power. The mean excess delay τ_0 is defined by

$$\tau_0 = \frac{1}{P_T} \sum_{i=1}^N P(\tau_i) \tau_i . \quad (5)$$

Preliminary RESULTS

The mutual dependency of the channel state parameters A and MP are depicted in Fig. 4.

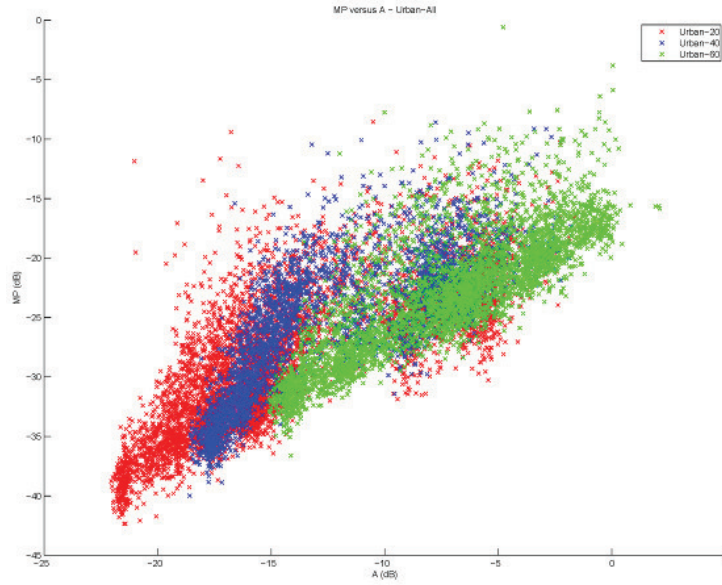


Fig. 4: Parameters for Rice distributed signal.

CONCLUSIONS

A unique radio channel measurement campaign has been carried out at 17.6 GHz to gain increased knowledge of LMS signal propagation at Ku- and Ka-band. The recorded data quality is excellent and when mapped on the real environment the signal shows plausible behaviour. Channel simulator development is currently being constructed based on these data.

REFERENCES

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- 2 Simon R. Saunders, Alejandro Aragón-Zavala, *Antennas and propagation for Wireless Communication Systems*. John Wiley & Sons Ltd, England, 2007, 524 pages.