

Characteristics of the Land Mobile Navigation Channel for Pedestrian Applications

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1 Abstract

One leading point in the choice of the signal format for the Galileo System is the multipath transmission channel. Studies concerning the signal structure (e.g. ESA Signal Design Study) [1] had clearly shown that the synchronisation performance of a specific signal strongly depends on the reflections in the environment. Especially, short delayed reflections significantly decrease the performance of the receiver. The positioning error becomes even worse if these reflections are strong and slowly varying over time, which is predominant in pedestrian applications. Although narrowband channels like GSM (COST 207) [2] or UMTS have been measured in the past, it became necessary to analyse the wideband navigation channel to minimize multipath effects in future highly accurate receivers. For these reasons we measured the channel from the satellite to a receiver in critical urban and suburban scenarios. This paper will present first preliminary statements and conclusions for typical pedestrian applications.

2 Channel measurement

The satellite was simulated by a Zeppelin NT operating at distances of up to 4000 meters from the receiver. We transmitted a special measurement signal with 10W EIRP and a bandwidth of 100 MHz. The transmitted signal had a rectangular shaped line spectrum consisting of several hundred single carriers. This guaranteed us a time resolution of 10 ns for the channel impulse response. This very high resolution is necessary for the planned wideband services of Galileo using BOC signal structures. By applying an ESPRIT ("Estimation of Signal Parameters via Rotational Invariance Techniques") based super resolution algorithm, the time resolution for the final model will be increased to 1 ns.

To achieve this high time resolution we used specially assembled rubidium clocks with an Allan variance of 10^{-11} seconds over an integration time of 1 second, as references for the measurement devices.

For the accurate positioning of the airship we spotted the ship by a camera station on the ground, seated directly under the airship (see Figure 1). The image of the camera was transmitted via a wireless radio link to a monitor in the airship for usage by the captain. During the measurement the position of the Zeppelin was kept within 30 meters.

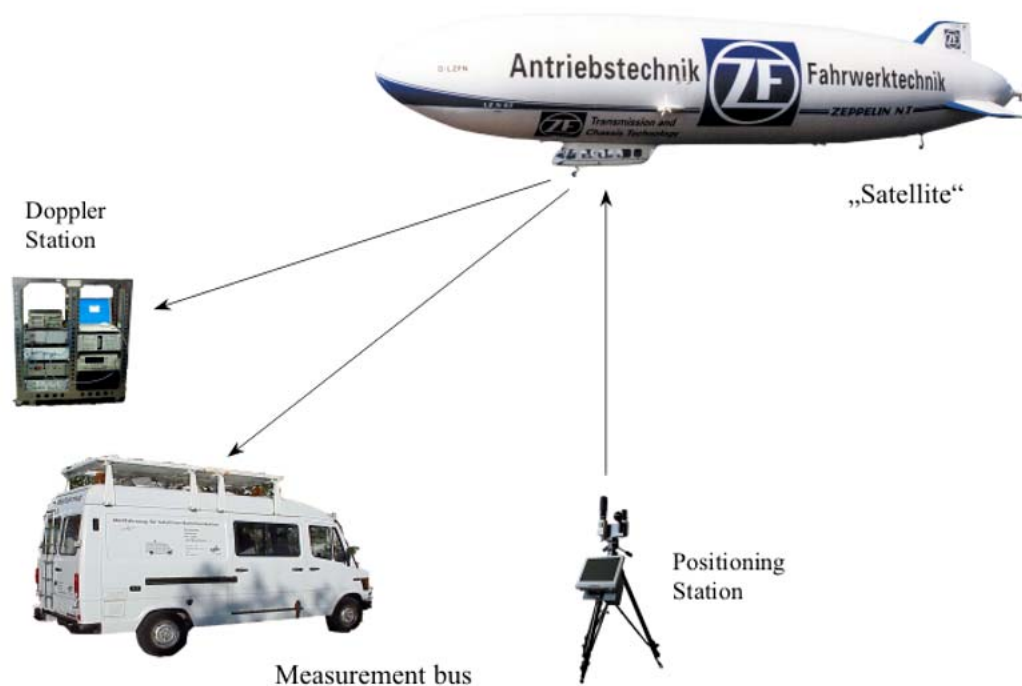


Figure 1: Measurement setup

In addition the Zeppelin transmitted a 18.8 GHz carrier whose Doppler shift was logged on a ground station in order to measure the Zeppelins movement which is in the range of the movement of a pedestrian. This data is necessary to calculate the Doppler spreads caused by the receiver and its environment only.

For the measurements the bearer of the antenna walked on the pavement accompanied by a special measurement bus equipped with the channel sounder receiver, wheel sensors, laser gyros, audio and video system, data recording and GPS sensors. During the campaign 60 scenarios each lasting from 10 to 20 minutes were measured. For the pedestrian channel the focus was on:

- Urban channels (Large city – Munich including a shopping street)
- Suburban channels (Small city – Fürstenfeldbruck)

An antenna showing a typical navigation system receiver antenna characteristic was used throughout the measurements to guarantee realistic modelling.

3 Channel characteristics

During the measurements we covered the whole range of elevations to the “satellite” between five and ninety degrees. As an example let us have a look at some

measurement results of the urban pedestrian channel. The receiver moved along a narrow shopping street (see Figure 2) in the center of Munich. Figure 3, Figure 4 and Figure 5 show the channels impulse responses over the distance of the measured track for a satellite at elevations of 10° , 40° and 80° .



Figure 2: Measurement location in Munich

In Figure 3 we see clearly that for very low elevations many strong reflections can be seen whose delay decreases when approaching the reflecting structures. Note that in this configuration the LOS signal might already be attenuated by the receiving antenna pattern with a masking angle of about 10° . Some of these reflections appear and disappear which can be best modelled by a Markov state model, while for others a clear increasing power level is detected when approaching the reflector. There is also strong fading in the LOS path which is caused by the fact that a walking pedestrian is not carrying the receiver antenna perfectly horizontal aligned. In the last 30 meters of the measurement we moved into a side street and the zeppelin was out of view, therefore we have no LOS signal but surprisingly strong reflections. Most of the echo power is within the delay range of one chip, thus these reflected signals will directly cause an error in the receiver's DLL. Only delays larger than a chip length do not affect the propagation delay measurement of the receiver.

Compared to lower elevations, the approaching reflections become less powerful at elevations of 40° . The echo power becomes concentrated within a relative delay of 250 ns. Because the channel has a rician characteristic, there is some remaining fading in the LOS signal. Note that for the last part of the measurement the direct path becomes clearer. In Figure 5 we see that for very high elevations the zeppelin could be seen almost during the whole measurement. Even without LOS signal some very short delayed reflections indicate the line of sight distance. The reflecting structures are close to the receiver and echoes with constant delay have replaced the approaching ones.

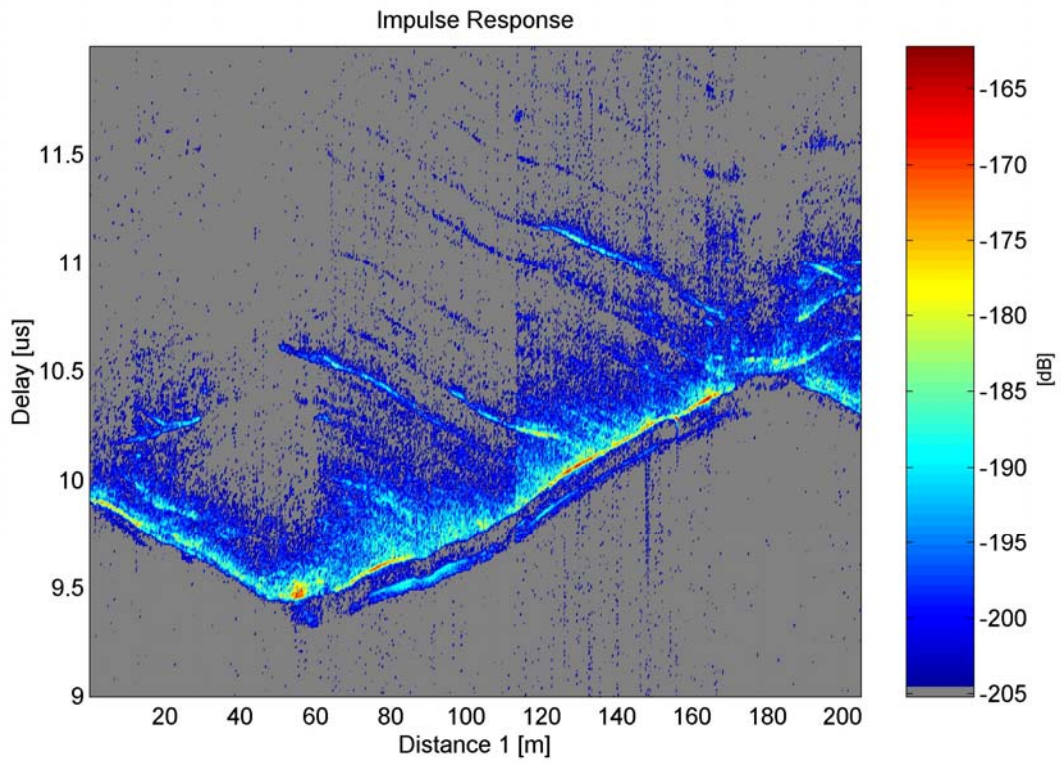


Figure 3: Urban pedestrian channel, 10° elevation

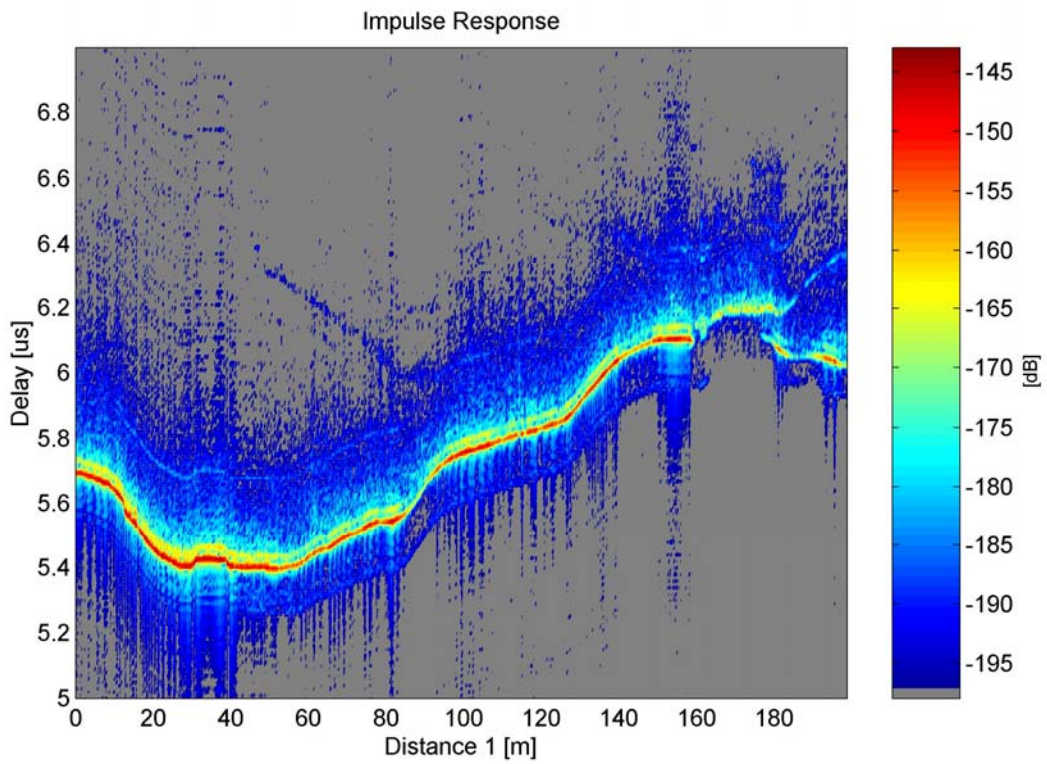


Figure 4: Urban pedestrian channel, 40° elevation

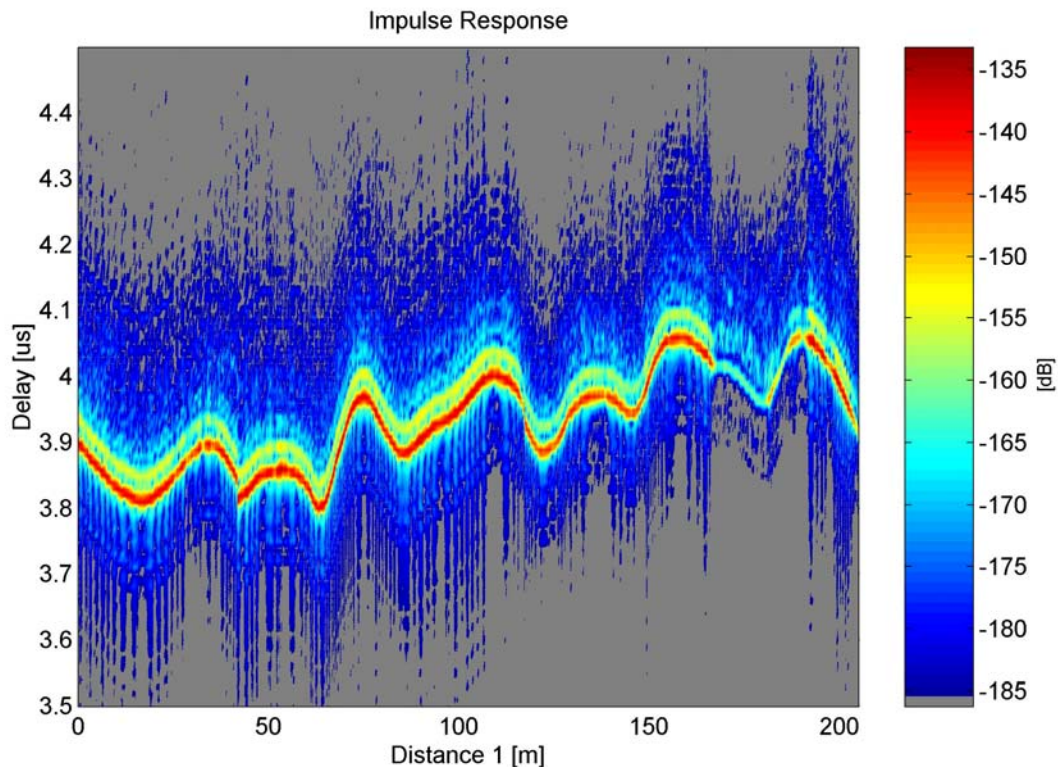


Figure 5: Urban pedestrian channel, 80° elevation

Looking into details reveals the constant delays to be related to the distance between the houses and the receiver.

Another example for the pedestrian channel was measured in Fürstentfeldbruck, a small town near Munich (see Figure 6). Again the same track was measured for elevations between 5 and 90 degrees. Figure 7 to Figure 9 show the channel for 5, 30 and 80 degrees elevation, respectively. In the first 200 seconds of the measurement the receiver moved more or less orthogonal to the Zeppelins position, therefore the absolute distance stayed nearly constant. Note that in this part the echoes keep a constant delay. But this constant delay again depends on the elevation. While there are sometimes echoes at delays of about 150 ns for low elevations, there is a strong static echo at about 40 ns at high elevations which can be seen in detail in Figure 9.

The rest of the measured track led radial to the Zeppelin position along the main road of the town and we can see the typical approaching reflectors. The very last one which could be seen during the whole second part of the measurement was the city hall which is located at the end of the road directly facing the transmitter and therefore being a strong reflector. For 80 degrees elevation the Zeppelins position was directly above the main road. Due to this fact the absolute distance decreases in the beginning and remains about the same for the second part of the measurement.

For more details on the channel measurement campaign as well as first results of the urban, suburban and rural car channel we refer to [1] and [4]. The impact of short delayed slowly varying reflections on the positioning error was simulated and is presented in [5].



Figure 6: Measurement location in Fürstentfeldbruck

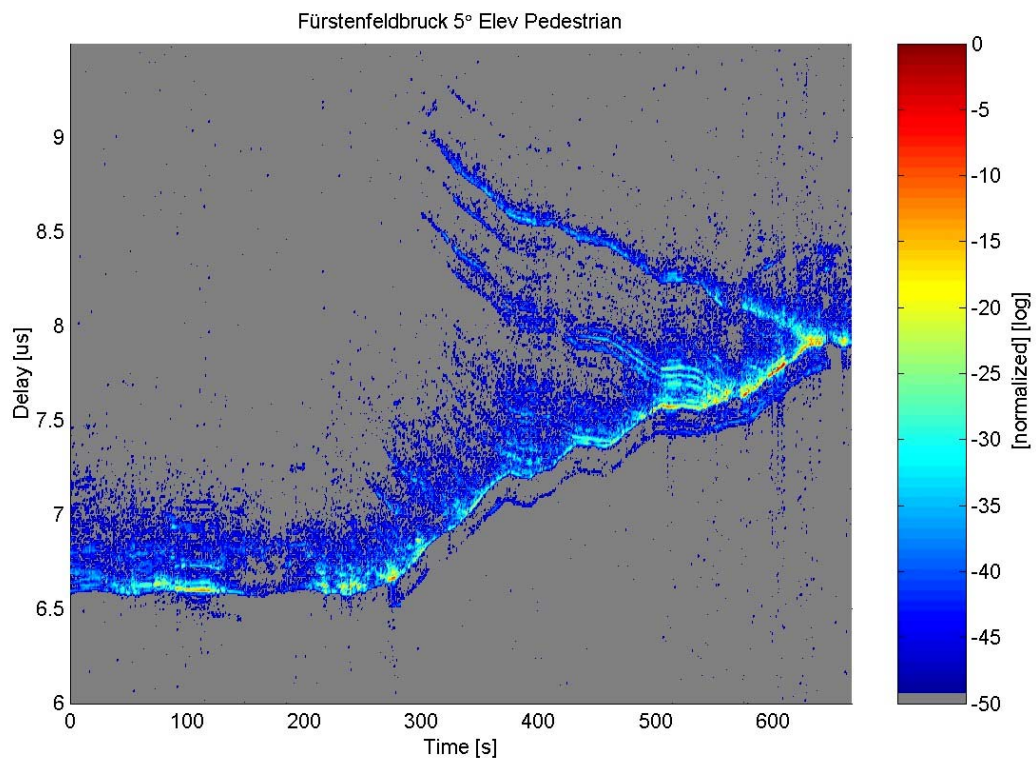


Figure 7: Suburban pedestrian channel, 5° elevation

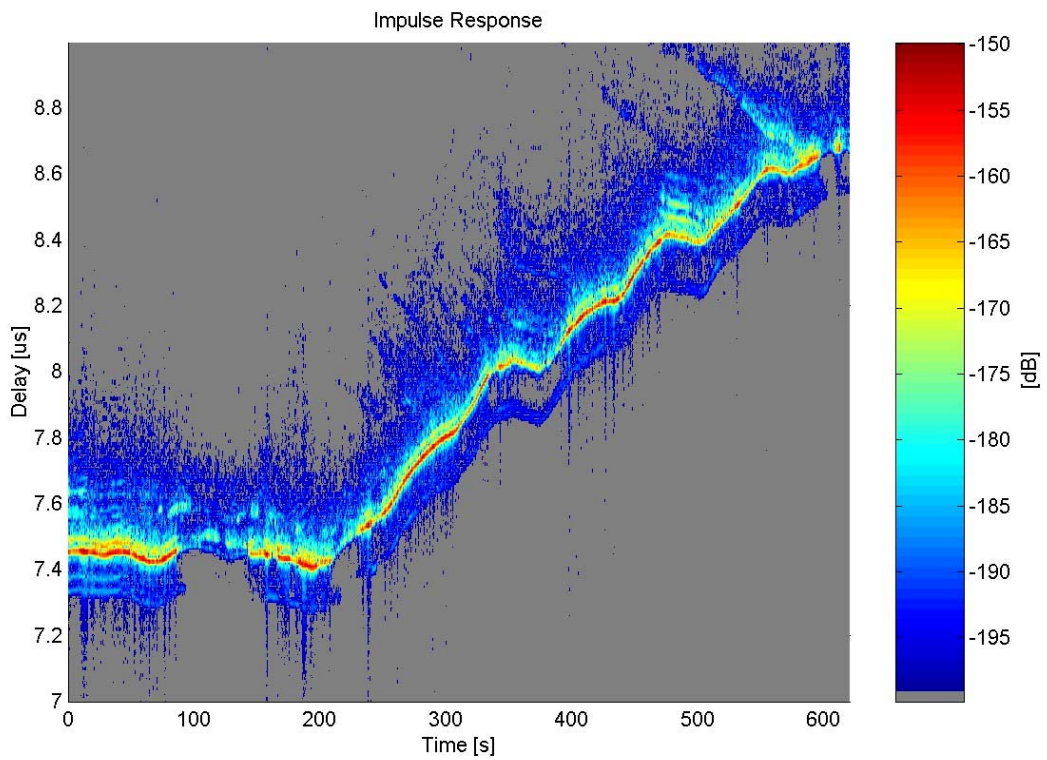


Figure 8: Suburban pedestrian channel, 30° elevation

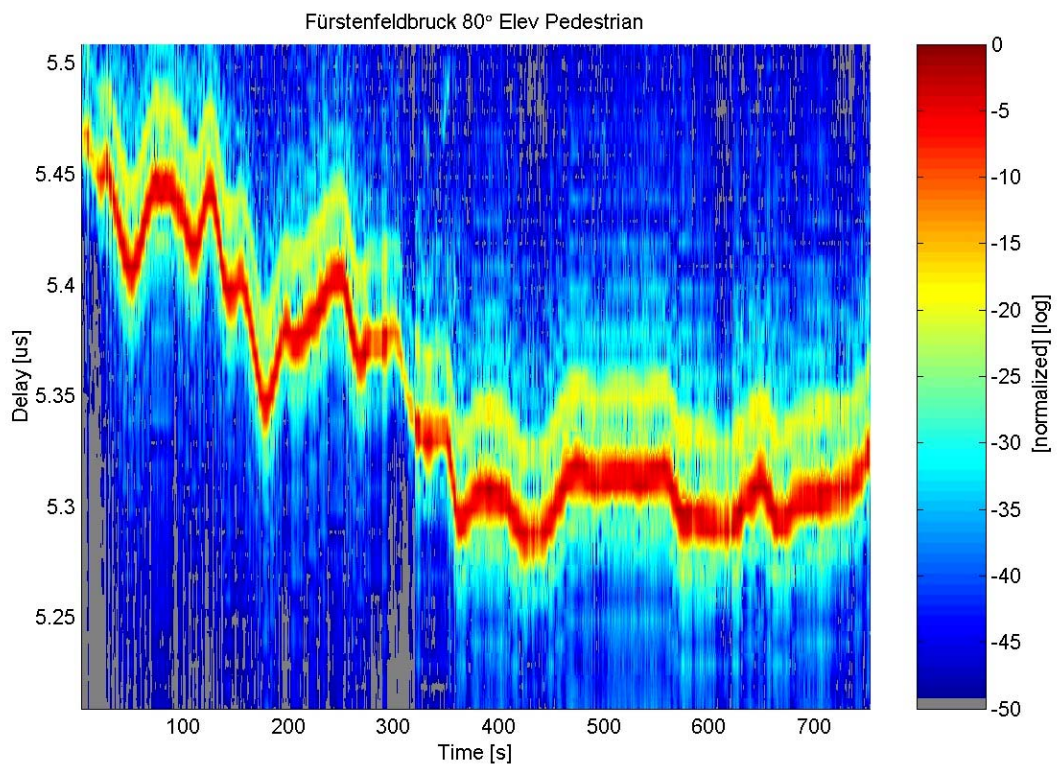


Figure 9: Suburban pedestrian channel, 80° elevation

4 Conclusion

A high time resolution satellite navigation channel measurement campaign was performed to investigate critical multipath scenarios. There is a very high probability of strong short delayed echoes causing very large positioning errors. Especially slow varying echoes in pedestrian application lead to errors of several tenth of meters. A clear elevation dependency of constant delayed and “approaching” reflections characterizes the power delay profiles of the measured channels.

References

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- [2] COST 207 WG1: "Proposal on channel transfer functions to be used in GSM tests 1986", Technical report, CEPT Paris, 1986.
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