MEASUREMENT OF TOPOGRAPHIC INFLUENCE ON MOBILE SATELLITE DATA LINKS

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1. Introduction

In the European area three slighly different systems for mobile low rate digital data transmission via geostationary satellites are in the preparatory or operational state. The PRODAT (ESA), the STANDARD-C (INMARSAT), and the LOCSTAR system. All of them work in the L-Band, only LOCSTAR uses the S-Band for the mobile receiving channel.

The elevation angles of geostationary satellites are relatively low for European users. Such, mountains, hills, buildings and particularly trees have a preponderant influence on the propagation path and determine the link quality. This paper deals with measurements of data reception with respect to the land mobile environment.

2. Test vehicle

A 2.5 tons van (Volkswagen Bus) was equipped with a set-up for simultaneous measurement of received power, data bit error rate, speed and direction. An operator documented the inclination of obstacles in direction to the satellite, using the on-board compass and an audio tape recorder.

The antenna was a Quadrifilar Helical type, mounted on top of the van. The 1.5 GHz RF signal was preamplified (GaAs, NF=1dB) and then split into a power measurement chain and a data chain. The power chain consisted of a synthesized down-converter (MD-614, R&S SMS and doubler), a selective voltmeter (R&S ESH-2) with 500 Hz bandwidth, and a digital voltmeter (Solartron 7055). In the data chain a commercially available Std-C receiver (Thrane&Thrane) with a RS-232 output of the Viterbi decoded data stream has been used. A desktop computer (hp 9816) preprocessed the Std-C and all other data and stored it as a compressed code on disk. Furtheron, all necessary information for the operator was presented on-line on screen. The power supply with car batteries and DC/AC converter enabled a continuous five-hour operation time.

Since the satellite EIRP per channel depends on the satellite load, the Std-C channel of the employed satellite had to be monitored at a fixed station in order to check the validity of the mobile measurement results.

3. Results

With the MARECS-B2 satellite, the signal level at the vehicle antenna output port is in between -21 dBμV and -25 dBμV in the morning, while the noise floor referring to this port is -39 dBμV. This relatively low signal-to-noise ratio (S/N) leads to fluctuations of the actual signal level of roughly ± 1 dB up to ± 2 dB (rms). When the vehicle is in motion, the fluctuations gather up approximately 1 dB due to multipath. This is true even in a flat and undisturbed environment.

Fig.1 shows examples of the signal level, measured with the test vehicle at a speed of 50 km/h and different environments during 150 s periods. In order to discern the slowly changing environmental influence from the

noise, the signal level was integrated using a 1 s window.
The diagram B was measured in a very low build-up area and it shows only short interruptions of the signal path at 10 s, 55 s, 70 s and 85 s, caused by single trees and, furtheron, interruptions caused by a few houses between 115 s and 150 s. The statistical investigation of this period results in the probability density function (PDF), also shown in Fig.1. As the satellite was in sight most of the time, the PDF (B) in this low build-up area is Rice distributed. In the case of the motion-less vehicle (A) the PDF is a Gauß function, since now the fluctuations are mainly caused by thermal noise. The receiving level is in a 5 dB interval (standing car: 2.5 dB) for 80 % of the time and the 50 % level is 4 dB below that of the standing vehicle (-21 dBμV).

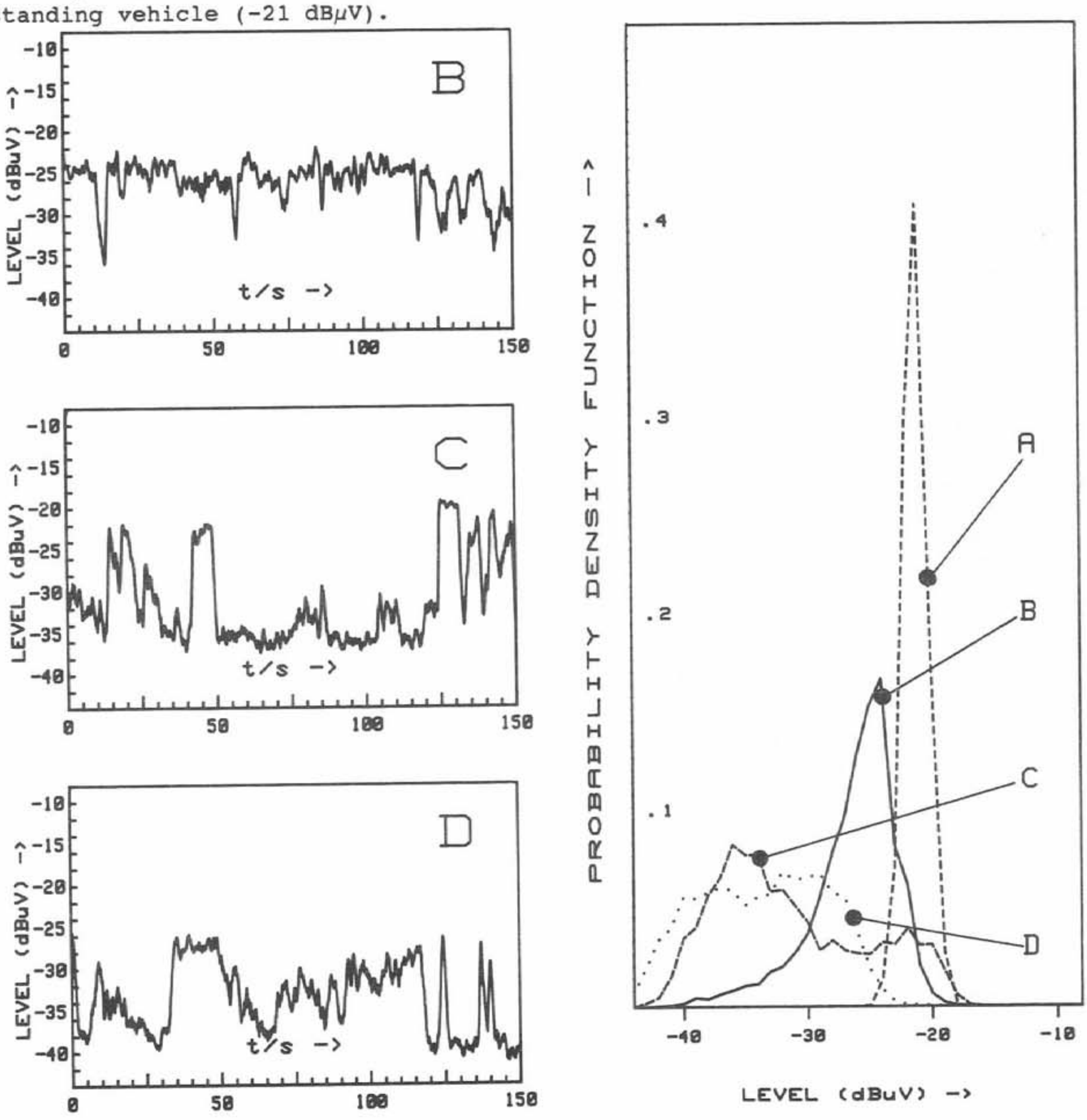

Fig.1: RF signal level and PDF for standing vehicle (A), very low build-up area (B), forrest (C), and suburban area (D)

Diagram C shows the influence of trees and buildings: During the first 10 s the density of trees is increasing. Between 12 s and 25 s there is a clearing with a single higher tree. At 40 s there is an absolutely free clearing lasting for 10 s. Between 50 s and 125 s the street leads through a forrest with trees very close to the road. At 125 s the road leaves the forrest and passes the first houses of a small village (130 s to 150 s), which block the signal path again. From this example it can be seen, that communication with the satellite is impossible, while the vehicle is driving through forrests with high trees close to the road. Exeptions are roads orientated into the satellite's position. The PDF for this example (C) has two maximum values (-36 dBμV and -22 dBμV, respectively) and cannot be compared with the usual PDFs of propagation paths. Nevertheless, the origin of this function is obvious, since there are rougly two different situations: propagation path undisturbed (clearing) or propagation path blocked (trees). As the second situation prevails, the PDF at lower levels is higher than at the second maximum. The 50 % level is found to be more than 10 dB below that of the standing vehicle, while the 80 % interval is spread over more than 17 dB.

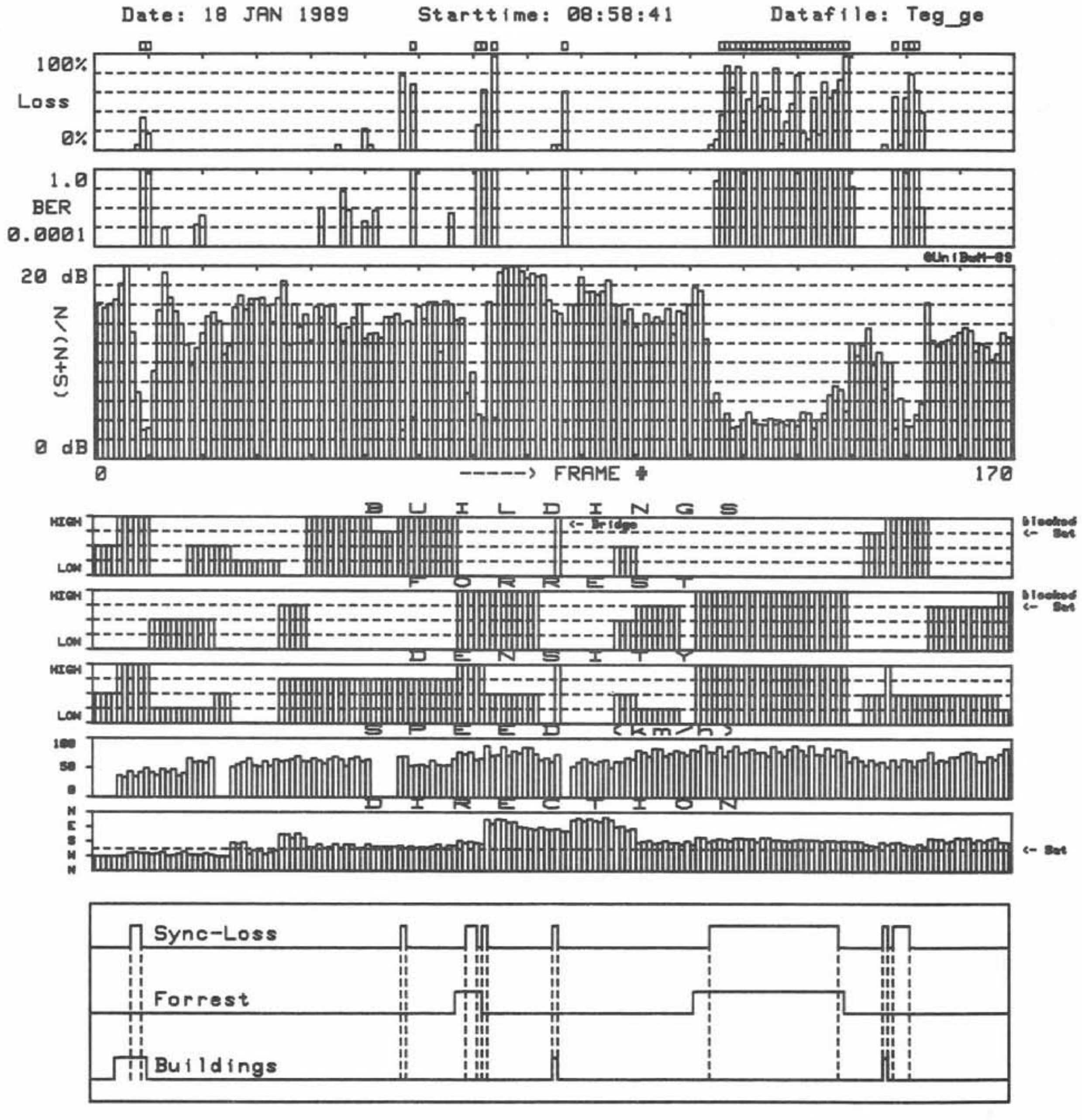

Fig.2: Complete data set of a test drive with changing environmental conditions

Diagram D finally shows a typical situation in a medium build-up suburban area. Only between 35 s and 50 s, the propagation path is clear. During this time the buildings were more than 20 m apart the road. In the remaining parts of the diagram, the inclination of the buildings from the vehicle is strongly correlated with the received signal level. Between 115 s and 150 s the street was transvers to the propagation path and at 125 s and 140 s cross streets were passed, the second of which was devided by trees. Also this fact can be found at the level diagram.

Fig.2 shows the complete result of another test drive, lasting approximately 24 minutes . All data blocks are referred to the 8.4 s duration of the Std-C frames. The diagramm on top marks the frames with lost sychronisation. The second diagram from top gives the percentage of measurements per frame below a 3 dB S/N, to detect short interrupts, and the third diagram shows the measured bit-error rate (BER) per frame. The fourth diagram gives the mean S/N per frame which can be calculated from the received level (as in Fig.1). The next three diagrams are operator inputs: the inclination of buildings and trees, and their density. Each dotted line in the inclination diagrams represents a step of 8° in elevation. Such, for inclinations higher than three lines (24°) and with high density, the propagation path is blocked. The following two diagrams are vehicle informations, i.e. speed and direction. In the lowest diagram there are three traces to document the correlation between obstacles and reception: The upper trace gives the synchronisation loss, the second trace the blocking caused by trees (Forrest high & Density high) and the third trace the blocking caused by buildings (Buildings high & Density high). It shows, that almost every sync-loss is caused by an obstacle. The blocking from trees can be quite severe, as it can last very long. Whenever the propagation path is blocked, but the synchonisation still works, the BER is very high.

4.Conclusion

Satellite communication from and to mobiles offers a great number of useful applications. However, in countries in the very north or very south the blocking of the propagation path, caused by the terrain, by trees, and by buildings will lead to interruptions of the data flow. This is demonstrated with some typical examples, using the Std-C system.

References: G.Kroppen, Messungen der Empfangsbedingungen für die mobile Satellitenkommunikation, Diplomathesis, University of the Bundeswehr, Munich, Dec.1987