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Wideband propagation measurements of the mobile radio channel

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1 Introduction

A detailed knowledge of the characteristics of the time-variant and frequency-selective mobile radio channel is fundamental to the development of new digital mobile communication systems and for efficient base-station engineering. Thus, propagation studies have become of increasing importance [1]. The measurement of the characteristics of the radio channel should be performed within a frequency band which is at least as large as the bandwidth of the mobile radio system. Several channel sounders having bandwidth of 5 MHz or more have been described in the literature, e.g., [2,3]. In cooperation with the Department of Communications Engineering at the University of Erlangen, Germany, two digital channel sounders, called RUSK400 and RUSK5000, with bandwidths of 400 kHz and 5.75 MHz, respectively, have been developed [4]. RUSK400 was especially designed for GSM applications [5], whereas RUSK5000 is adequate for systems with bandwidths in the MHz range (e.g., the DECT system or CDMA systems).
Channel models and estimation methods for area coverage can be derived from the measurement results. System simulations using stored channel data allow for the determination of performance limits as function of the propagation conditions [6]. The filtering of the channel data with different bandwidths by post processing can be used for the analysis of system performance as function of system bandwidth.

2 The digital real time channel sounders

The complex impulse response (IR) of the radio channel is determined with RUSK400 and RUSK5000 in real time by correlation of the received signal with a replica of a transmitted pseudo-noise sequence (PNS). All oscillators in the transmitter and receiver have to be synchronized by atomic frequency standards. The correlation is performed in the frequency domain by means of digital signal processors applying fast Fourier transform. In addition to the correlation, an equalization of the transfer function of the measurement set up and a spectral shaping with an arbitrarily chosen filter function is carried out. A cosine filter of the transfer function is favourable to interpretation and analysis of the IRs in the time domain due to the low sidelobes of its IR, whereas a rectangular filter is more appropriate for evaluations in the frequency domain because it delivers the spectral components without weighting. By using a cosine filter the transfer function of RUSK400 can be matched to the power spectrum of the GSM system [5].
The achievable dynamic range of measured IRs is limited by quantization at high input power levels and by noise at low input power levels. A further limitation of the dynamic range is given by the phase noise of the oscillators. All signal components of the IRs below levels determined by dynamic-range measurements are set to zero in off-line evaluation of the field measurements.
A special feature of RUSK5000 is the use of TV channels for signal transmission. This has the advantages that commercially available equipment can be used for the analog components of the transmitter and receiver, and that it is possible to transmit from TV base stations with high power.

The main parameters of RUSK400 and RUSK5000 are summarized in the following Table:

	RUSK400	RUSK5000
Frequency range	50...1000 MHz, 1800-MHz bands	50...800 MHz, 1800-MHz bands
Maximum bandwidth	400 kHz	5.75 MHz
Length of the PNS	127 chips	1023 chips
Duration of one chip	1.0 μs	0.1 μs
Max. length of the IRs	127 μs	102.3 μs
Max. recording rate	44 IRs/sec.	42 IRs/sec.
Max. dynamic range of the IRs	35 dB	30 dB
Sensitivity	-110 dBm	-100 dBm

Details of the measurement principle and results of RUSK400 are described in [4] and [5]. In the following, results of RUSK5000 will be discussed.

3 Analysis of measurement results

3.1 Evaluation of path loss and delay spread

Fig. 1 shows a typical result measured in an urban area at of 487.25 MHz. The measurement was carried out with a base station antenna height of 50 m above ground and a path length of approximately 600 m. Along the measurement route sections with line-of-sight (LOS) between transmitter and receiver change with shadowed regions with no line-of-sight (NLOS).

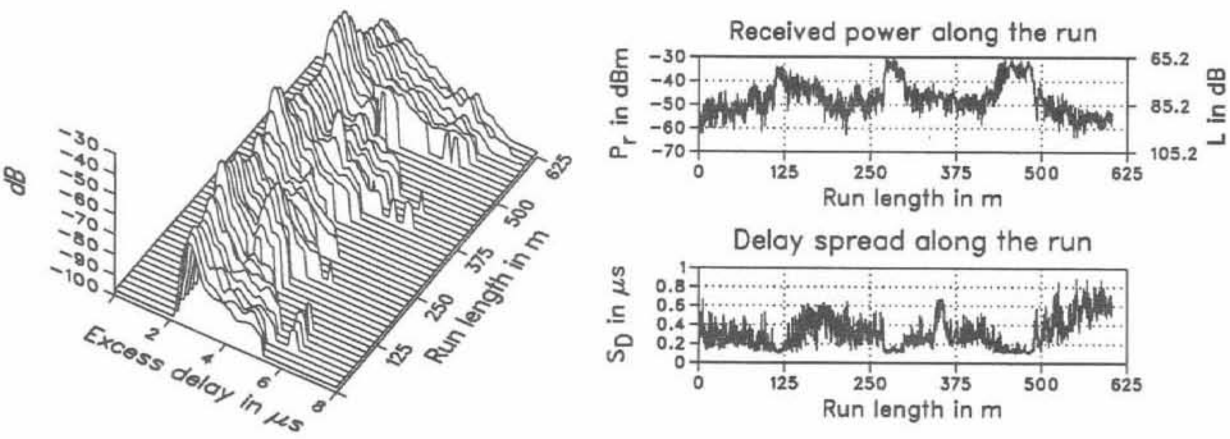

Fig. 1: Measurement result of RUSK5000 in urban area featuring line-of-sight and shadowed route sections

The three-dimensional plot depicts the shapes of the magnitude of the IRs along the run. Each curve represents an average of 30 subsequent IRs. The received power P_r as function of the location x (top right diagram) can be obtained by integrating the power density over the excess delay. The right vertical axis of the plot gives the scale for the path loss which is related to the received power by $L(x) = P_t G_t G_r / P_r(x)$, where P_t is the transmitted power, and G_t and G_r are the gains of the transmitting and receiving antennas, respectively.

The delay spread (lower right diagram) is a measure of the frequency selectivity of the radio channel. It is very sensitive against noise components having large excess delays, so that a careful noise suppression is necessary to compute reliable values of the delay spread.

In the LOS cases the received power is high and the delay spread is low, whereas in the NLOS situations the received power is 10 to 20 dB smaller, more rapidly fluctuating and associated with larger delay spread.

3.2 Doppler analysis

Fig. 2 shows an example of Doppler analysis. The delay Doppler spectrum S was computed from a measurement with a run length of about 20 m covering a shadowed section and also the sidelobe range of the transmitter antenna (antenna height 50 m).

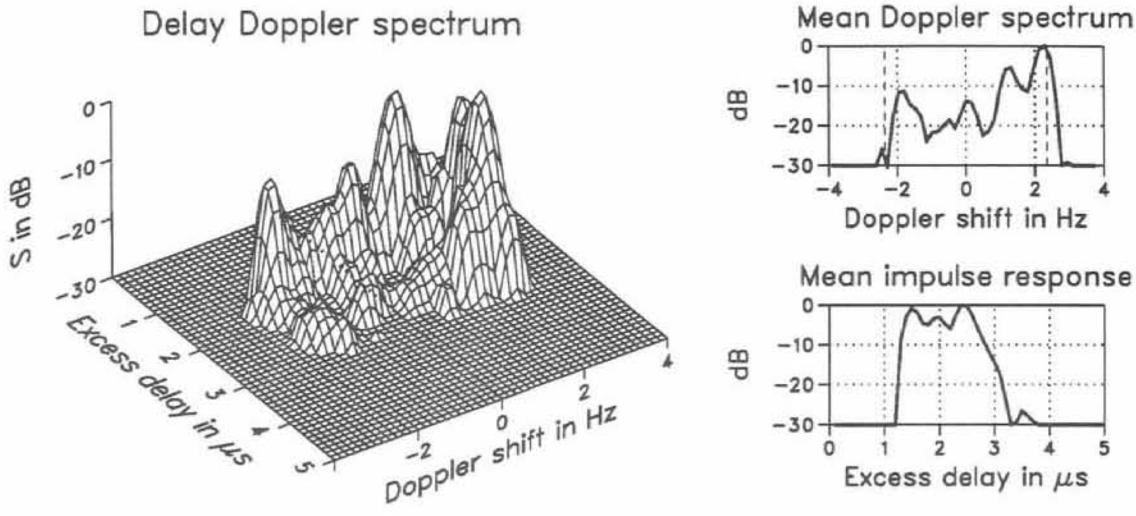

Fig. 2: Results of Doppler analysis of RUSK5000 IRs, measured along a route covering a shadowed section and the sidelobe range of the transmitter antenna

The received signal consists of a discrete number of rays which were reflected and/or diffracted at buildings and other obstructions. The measurement was carried out with a mobile speed of 1.45 m/s resulting in a maximum Doppler shift of 2.4 Hz at a radio frequency of 487.25 MHz. The mean Doppler spectrum was computed by integration over the whole excess delay range, the mean IR results from integration of the power distribution over the Doppler frequencies. From the delay Doppler spectrum the location and the reflection coefficient of scatterers can be estimated.

3.3 Statistics of the received power levels for different bandwidths

Fading statistics of received power at different bandwidths can be evaluated by off-line filtering of the stored complex IRs. Fig. 3 depicts the cumulative distributions of the power levels for bandwidths of 5 MHz, 500 kHz and 50 kHz in a Rayleigh grid. The same data were used as in Fig. 2. The distribution of the power levels is significantly different between bandwidths of 5 MHz and 500 kHz, whereas the statistics are very similar for 500 kHz and 50 kHz. This is due to the fact that the length of the IRs is about 2 μs (see Fig. 2). Therefore, for bandwidths below 500 kHz the time resolution is too small to seperate different propagation paths.

4 Conclusions

Two wideband channel sounders for real-time measurement of IRs of the mobile radio channel have been presented. Post processing of stored channel data allows for noise

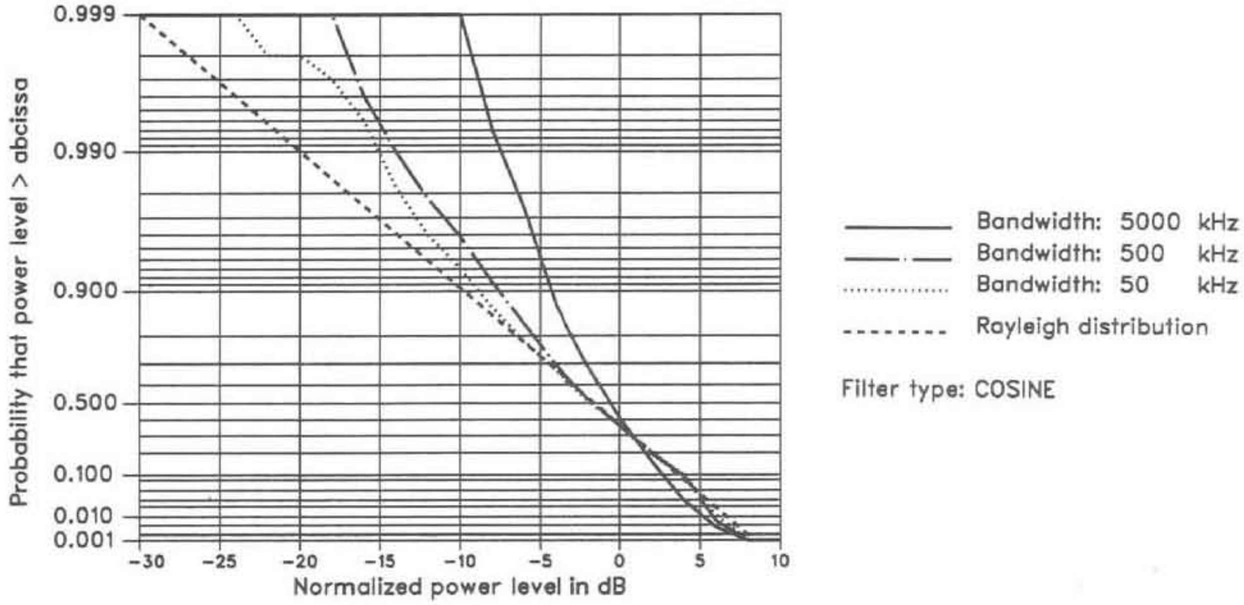

Fig. 3: Cumulative distribution of power levels for different bandwidths

reduction and the extraction of system relevant channel parameters. By Doppler analysis of the complex IRs the location and reflection coefficient of scatterers in the terrain can be estimated. This is the base for development and verification of new three-dimensional propagation models. Channel sounders which measure only the magnitude of the IRs, as for instance described in [2], do not have these capabilities. The set-up presented in [3] allows the measurement of complex IRs, but with a maximum length of 25.6 μs. The systems RUSK400 and RUSK5000, however, are capable of measuring much longer delays (see Table above). Hence, echos from scatteres at large distances can be identified. The fading statistics as function of the system bandwidth demonstrate the potential of "multipath diversity" for wideband systems.

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