RECOMMENDATION ITU-R P.1145

PROPAGATION DATA FOR THE TERRESTRIAL LAND MOBILE SERVICE IN THE VHF AND UHF BANDS

(Question ITU-R 203/3)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that there is a need for information on aspects of propagation likely to affect terrestrial land mobile services,

recommends

1 that the information contained in Annex 1 be taken into account in the design and planning of such services.

ANNEX 1

1 Introduction

This Recommendation provides information on various aspects of propagation which are likely to affect the terrestrial land mobile services. These aspects should be taken into account in the design and planning of such services.

2 Depolarization phenomena

In the land mobile environment some or all of the transmitted energy may be scattered out of the original polarization due to diffraction and reflection of the radiowave. It is convenient to take this depolarization effect into consideration by using a cross-polarization discrimination (XPD) factor, as defined in Recommendation ITU-R P.310.

XPD measurements at 900 MHz show that:

– XPD depends little on distance;

– the average XPD in urban and residential areas ranges from 5 to 8 dB, and is over 10 dB in open areas;

– the average correlation between vertical and horizontal polarization is 0.

XPD increases with decreasing frequency, to about 18 dB at 35 MHz.

XPD is log-normally distributed with a standard deviation somewhat dependent on the frequency. The average value of the difference between the 10% and 90% values (in the frequency range 30 to 1 000 MHz) is about 15 dB. Whether the original polarization is vertical or horizontal has been observed to make only a slight difference in this respect.

Two types of time variation of the depolarization effect have been found. The first is a slow variation resulting from the changing electrical properties of the ground with weather conditions. This effect is most pronounced at lower frequencies. The second is due to the motion of trees which gives a depolarization fading phenomenon amounting to several decibels in amplitude at quite moderate wind velocities.

3 Losses due to terrain cover

These losses are likely to be of great importance for the land mobile service. They will depend on the category of the terrain, the extent of vegetation, and on the location, density and height of buildings. These aspects are dealt with in Recommendations ITU-R P.1058, ITU-R P.833 and ITU-R P.1146.

4 Dependence of field strength on time, location and nature of terrain

The received field strength will vary with time, with location (in a small area of, say, 200 m × 200 m) and with the nature of the terrain.

The large scale influences of the terrain are taken into account in the more precise prediction procedures which utilize the diffraction theory.

The standard deviation of location variability, σ_L, is 8 dB at VHF and 10 dB at UHF in rural areas.

The standard deviation of time variability, σ_t, is given in Table 1.

TABLE 1

Standard deviation σ_t

Band		σ_t (dB)			
	d (km)	50	100	150	175
VHF	Land and sea	3	7	9	11
UHF	Land	2	5	7	
	Sea	9	14	20	

The overall standard deviation is given by:

$$\sigma = \sqrt{\sigma_L^2 + \sigma_t^2} \qquad (1)$$

5 Multipath propagation

In radio systems with low antenna heights, the direct signal between the transmitter and the receiver is very often accompanied by a number of echoes from objects that reflect or scatter the radiowaves. Distant reflectors and scatterers give rise to persistent echoes with relatively long time delays. On the other hand the effect of reflections from nearby objects is to create a large number of signals with random amplitudes, phases, angles of arrival, and short time delays. In the case of mobile radio, this multipath geometry changes with time as the mobile traverses its route. Whilst the macroscopic multipath structure is changing slowly, the changes in the local scattering conditions can be very fast. This latter effect manifests itself as fast fading or Doppler shifting in the radio channel. The amplitudes of the direct signal and the echoes may undergo rapid fluctuations thereby altering the impulse response of the channel at a rate proportional to the speed of the mobile (and/or the scatters). Therefore, a receiver has to be able to cope with the distortion arising from echoes in the channel as well as the rapid changes in the nature of this distortion. Such characteristics of the mobile radio channel are described by the "power delay profiles" and the "Doppler spectra" which are obtained from wideband channel sounding measurements.

Signals transmitted to and from moving vehicles in urban or forested environments exhibit extreme variations in amplitude due to multiple scattering. Fades of 30 dB or more below the mean level are common. The instantaneous field strength when measured over distances of a few tens of wavelengths is approximately Rayleigh-distributed. The mean values of these small sector distributions vary widely from area to area, depending on height, density and distribution of hills, trees, buildings and other structures.

Multipath propagation characteristics are a major factor in controlling the quality of digital mobile communications. Physically, multipath propagation characteristics imply multipath number, amplitude, path-length difference (delay), and arrival angle. These can be characterized by the transfer function of the propagation path (amplitude-frequency characteristics), and the correlation bandwidth.

A time-varying linear channel can be characterized by a linear transversal filter. The output of this filter contains a sum of delayed, attenuated and Doppler shifted versions of the input signal. The channel is then represented by the "delay-Doppler-spread function", sometimes referred to as the scattering function. This function represents the multipath phenomenon in the three dimensions of excess delay, Doppler frequency and power density. This formulation is particularly suitable for realizing a hardware simulator in the form of a dynamic transversal filter.

The appropriate parameters for the statistical description of multipath effects are given below:

These parameters can be computed either from instantaneous power delay profiles or from profiles averaged over a run of a few wavelengths.

The "average delay" is the power weighted-average of the excess delays measured and is given by the first moment of the impulse response.

The "delay spread" is the power weighted standard deviation of the excess delays and is given by the second moment of the impulse response. It provides a measure of the variability of the mean delay.

The "delay window" is the length of the middle portion of the power profile containing a certain percentage of the total energy found in that impulse response.

The "delay interval" is defined as the length of the impulse response between two values of excess delay which mark the first time the amplitude of the impulse response exceeds a given threshold, and the last time it falls below it.

The "correlation bandwidth" is defined as the frequency for which the autocorrelation function of the transfer function falls below a given threshold.

The "total energy", P_m, of the impulse response is:

$$P_m = \int_{t_0}^{t_3} P(t) \; \mathrm{d}t \tag{2}$$

where:

$P(t)$: power density of the impulse response

t: excess delay

t_0: instant when $P(t)$ exceeds the cut-off level for the first time

t_3: instant when $P(t)$ exceeds the cut-off level for the last time.

The "average delay", T_D, is given by the first moment of the impulse response

$$T_D = \frac{1}{P_m} \int_{t_{LOS}}^{t_3} (t - t_{LOS}) \; P(t) \; \mathrm{d}t \tag{3}$$

where t_{LOS} is the delay of the line of sight (LOS) path. The impulse response cannot commence earlier than t_{LOS}, it may, however start at ($t_0 \geq t_{LOS}$).

The "delay spread", S, is defined by the square root of the second central moment:

$$S = \sqrt{\frac{1}{P_m} \int_{t_0}^{t_3} t^2 \; P(t) \; \mathrm{d}t - \left[\frac{1}{P_m} \int_{t_0}^{t_3} t \; P(t) \; \mathrm{d}t \right]^2} \tag{4}$$

The "delay window", W_q, is the length of the middle portion of the impulse response containing a certain percentage q of the total energy:

$$W_q = (t_2 - t_1) \tag{5}$$

whereby the boundaries t_1 and t_2 are defined by:

$$\int_{t_1}^{t_2} P(t) \; \mathrm{d}t = q \int_{t_0}^{t_3} P(t) \; \mathrm{d}t = q \; P_m \tag{6}$$

and the energy outside of the window is split into two equal parts $(1 - q/2) \, P_m$.

The "delay interval", I_{th}, is defined as the time difference between the instant t_4 when the amplitude of the impulse response first exceeds a given threshold P_{th}, and the instant t_5 when it falls below that threshold for the last time:

$$I_{th} = (t_5 - t_4) \tag{7}$$

The Fourier transform of the power density of the impulse response provides the autocorrelation $C(f)$ of the transfer function:

$$C(f) = \int_{t_0}^{t_3} P(t) \; \exp(-\mathrm{j} \, 2 \, \pi \, f \, t) \; \mathrm{d}t \tag{8}$$

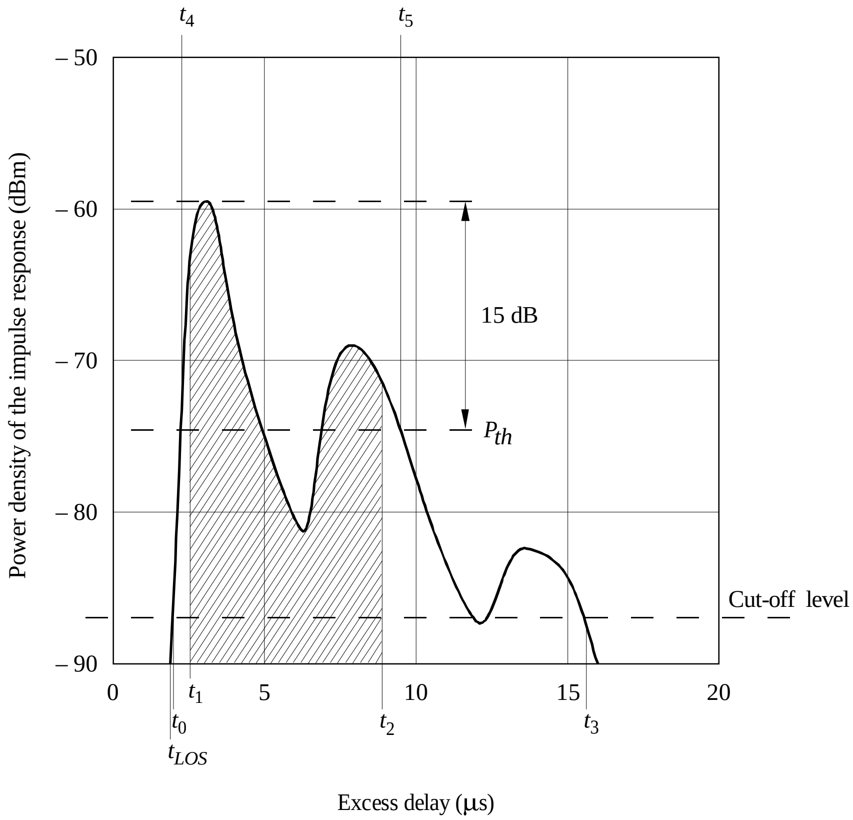
The "correlation bandwidth" B_x is defined as the frequency for which $|C(f)|$ equals x% of $C(f = 0)$.

Delay windows for 50, 75 and 90% energy, delay intervals for thresholds of 9, 12 and 15 dB below the peak and correlation bandwidth for 50% and 90% of correlation are recommended for analysis of data. It is worth noting that the effects of noise and spurious signals in the system (from RF to data processing) can be very significant. Therefore, it is important to determine the noise and/or spurious threshold of the systems accurately and to allow a safety margin on top of that. A safety margin of 3 dB is recommended, and in order to ensure the integrity of results, it is recommended that a minimum peak-to-spurious ratio of, for example, 15 dB (excluding the 3 dB safety margin) is used as an "acceptance criterion" before an impulse response is included in the statistics.

An example of the use of some of these terms is given in Fig. 1.

FIGURE 1

Example of an averaged delay power profile



The delay window, W_{90}, containing 90% of the received energy, is marked by hatching. The delay interval, I_{15}, containing the signal above the level "15 dB below the peak value", lies within t_4 and t_5

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