



Recommendation ITU-R P.681-10
(12/2017)

**Propagation data required for the design
of Earth-space land mobile
telecommunication systems**

P Series
Radiowave propagation



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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R P.681-10*

**Propagation data required for the design of Earth-space
land mobile telecommunication systems**

(Question ITU-R 207/3)

(1990-1994-1995-1997-1999-2001-2003-2009-2015-2016-2017)

Scope

This Recommendation predicts the various propagation parameters needed in planning the Earth-space land mobile-satellite service (LMSS).

The ITU Radiocommunication Assembly,

considering

- a) that for the proper planning of Earth-space land mobile systems it is necessary to have appropriate propagation data and prediction methods;
- b) that the methods of Recommendation ITU-R P.618 are recommended for the planning of Earth-space telecommunication systems;
- c) that further development of prediction methods for specific application to land mobile-satellite systems is required to give adequate accuracy in all regions of the world and for all operational conditions;
- d) that, however, methods are available which yield sufficient accuracy for many applications,

recommends

that the methods contained in Annex 1 be adopted for use in the planning of Earth-space land mobile telecommunication systems, in addition to the methods recommended in Recommendation ITU-R P.618.

Annex 1**1 Introduction**

Propagation effects in the land mobile-satellite service (LMSS) differ from those of the fixed-satellite service (FSS) primarily because of the greater importance of terrain effects. In the FSS it is generally possible to discriminate against multipath, shadowing and blockage through the use of highly directive antennas placed at unobstructed sites. Therefore, in general, the LMSS offers smaller link availability percentages than the FSS. The prime availability range of interest to system designers is usually from 80% to 99%.

* This Recommendation should be brought to the attention of Radiocommunication Study Group 4.

This Annex deals with data and models specifically needed for predicting propagation impairments in LMSS links, which include tropospheric effects, ionospheric effects, multipath, blockage and shadowing. It is based on measurements ranging from 870 MHz in the UHF band up to 20 GHz.

2 Tropospheric effects

2.1 Attenuation

Signal losses in the troposphere are caused by atmospheric gases, rain, fog and clouds. Except at low elevation angles, tropospheric attenuation is negligible at frequencies below about 1 GHz, and is generally small at frequencies up to about 10 GHz. Above 10 GHz, the attenuation can be large for significant percentages of the time on many paths. Prediction methods are available for estimating gaseous absorption (Recommendation ITU-R P.676) and rain attenuation (Recommendation ITU-R P.618). Fog and cloud attenuation is usually negligible for frequencies up to 10 GHz.

2.2 Scintillation

Irregular variations in received signal level and in angle of arrival are caused by both tropospheric turbulence and atmospheric multipath. The magnitudes of these effects increase with increasing frequency and decreasing path elevation angle, except that angle-of-arrival fluctuations caused by turbulence are independent of frequency. Antenna beamwidth also affects the magnitude of these scintillations. These effects are observed to be at a maximum in the summer season. A prediction method is given in Recommendation ITU-R P.618.

3 Ionospheric effects

Ionospheric effects on Earth-to-space paths are addressed in Recommendation ITU-R P.531. Values of ionospheric effects for frequencies in the range of 0.1 to 10 GHz are given in Tables 1 and 2 of Recommendation ITU-R P.680.

4 Shadowing

4.1 Roadside tree-shadowing model

Cumulative fade distribution measurements at 870 MHz, 1.6 GHz and 20 GHz have been used to develop the extended empirical roadside shadowing model. The extent of trees along the roadside is represented by the percentage of optical shadowing caused by roadside trees at a path elevation angle of 45° in the direction of the signal source. The model is valid when this percentage is in the range of 55% to 75%.

4.1.1 Calculation of fading due to shadowing by roadside trees

The following procedure provides estimates of roadside shadowing for frequencies between 800 MHz and 20 GHz, path elevation angles from 7° up to 60°, and percentages of distance travelled from 1% to 80%. The empirical model corresponds to an average propagation condition with the vehicle driving in lanes on both sides of the roadway (lanes close to and far from the roadside trees are included). The predicted fade distributions apply for highways and rural roads where the overall aspect of the propagation path is, for the most part, orthogonal to the lines of roadside trees and utility poles and it is assumed that the dominant cause of LMSS signal fading is tree canopy shadowing (see Recommendation ITU-R P.833).

Parameters required are the following:

f : frequency (GHz)

θ : path elevation angle to the satellite (degrees)

p : percentage of distance travelled over which fade is exceeded.

Step 1: Calculate the fade distribution at 1.5 GHz, valid for percentages of distance travelled of $20\% \geq p \geq 1\%$, at the desired path elevation angle, $60^\circ \geq \theta \geq 20^\circ$:

$$A_L(p, \theta) = -M(\theta) \ln(p) + N(\theta) \quad (1)$$

where:

$$M(\theta) = 3.44 + 0.0975 \theta - 0.002 \theta^2 \quad (2)$$

$$N(\theta) = -0.443 \theta + 34.76 \quad (3)$$

Step 2: Convert the fade distribution at 1.5 GHz, valid for $20\% \geq p \geq 1\%$, to the desired frequency, f (GHz), where $0.8 \text{ GHz} \leq f \leq 20 \text{ GHz}$:

$$A_{20}(p, \theta, f) = A_L(p, \theta) \exp \left\{ 1.5 \left[\frac{1}{\sqrt{f_{1.5}}} - \frac{1}{\sqrt{f}} \right] \right\} \quad (4)$$

Step 3: Calculate the fade distribution for percentages of distance travelled $80\% \geq p > 20\%$ for the frequency range $0.85 \text{ GHz} \leq f \leq 20 \text{ GHz}$ as:

$$\begin{aligned} A(p, \theta, f) &= A_{20}(20\%, \theta, f) \frac{1}{\ln 4} \ln \left(\frac{80}{p} \right) && \text{for } 80\% \geq p > 20\% \\ &= A_{20}(p, \theta, f) && \text{for } 20\% \geq p > 1\% \end{aligned} \quad (5)$$

Step 4: For path elevation angles in the range $20^\circ > \theta \geq 7^\circ$, the fade distribution is assumed to have the same value as at $\theta = 20^\circ$.

Figure 1 shows fades exceeded at 1.5 GHz versus elevation angles between 10° and 60° for a family of equal percentages between 1% and 50%.

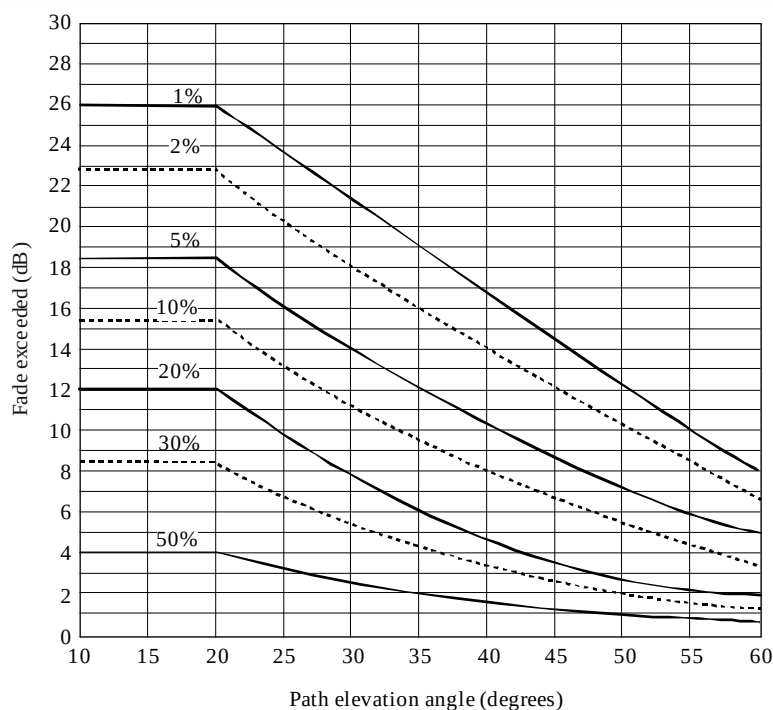
4.1.1.1 Extension to elevation angles $> 60^\circ$

The roadside shadowing model at frequencies of 1.6 GHz and 2.6 GHz can be extended to elevation angles above 60° with the following procedure:

- apply equations (1) to (5) at an elevation angle of 60° at the above frequencies;
- linearly interpolate between the value calculated for an angle of 60° and the fade values for an elevation angle of 80° provided in Table 1;
- linearly interpolate between the values in Table 1 and a value of zero at 90° .

FIGURE 1

Fading at 1.5 GHz due to roadside shadowing versus path elevation angle



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TABLE 1

Fades exceeded (dB) at 80° elevation

p (%)	Tree-shadowed	
	1.6 GHz	2.6 GHz
1	4.1	9.0
5	2.0	5.2
10	1.5	3.8
15	1.4	3.2
20	1.3	2.8
30	1.2	2.5

4.1.1.2 Application of roadside shadowing model to non-geostationary (non-GSO) and mobile-satellite systems

The prediction method above was derived for, and is applied to, LMSS geometries where the elevation angle remains constant. For non-GSO systems, where the elevation angle is varying, the link availability can be calculated in the following way:

- calculate the percentage of time for each elevation angle (or elevation angle range) under which the terminal will see the spacecraft;
- for a given propagation margin (ordinate of Fig. 1), find the percentage of unavailability for each elevation angle;
- for each elevation angle, multiply the results of step a) and b) and divide by 100, giving the percentage of unavailability of the system at this elevation;

d) add up all unavailability values obtained in step c) to arrive at the total system unavailability.

If the antenna used at the mobile terminal does not have an isotropic pattern, the antenna gain at each elevation angle has to be subtracted from the fade margin in step b) above.

In the case of multi-visibility satellite constellations employing satellite path diversity (i.e. switching to the least impaired path), an approximate calculation can be made assuming that the spacecraft with the highest elevation angle is being used.

4.1.2 Fade duration distribution model

Optimal design of LMSS receivers depends on knowledge of the statistics associated with fade durations, which can be represented in units of travelled distance (m) or (s). Fade duration measurements have given rise to the following empirical model which is valid for distance fade duration $dd \geq 0.02$ m.

$$P(FD > dd | A > A_q) = \frac{1}{2} \left(1 - \operatorname{erf} \left[\frac{\ln(dd) - \ln(\alpha)}{\sqrt{2} \sigma} \right] \right) \quad (6)$$

where $P(FD > dd | A > A_q)$ represents the probability that the distance fade duration, FD , exceeds the distance, dd (m), under the condition that the attenuation, A , exceeds A_q . The designation “erf” represents the error function, σ is the standard deviation of $\ln(dd)$, and $\ln(\alpha)$ is the mean value of $\ln(dd)$. The left-hand side of equation (6) was estimated by computing the percentage number of “duration events” that exceed dd relative to the total number of events for which $A > A_q$ in data obtained from measurements in the United States of America and Australia. The best fit regression values obtained from these measurements are $\alpha = 0.22$ and $\sigma = 1.215$.

Figure 2 contains a plot of P , expressed as a percentage, p , versus dd for a 5 dB threshold.

The model given by equation (6) is based on measurements at an elevation angle of 51° and is applicable for moderate to severe shadowing (percentage of optical shadowing between 55% and 90%). Tests at 30° and 60° have demonstrated a moderate dependence on elevation angle: the smaller the elevation angle, the larger is the fade duration for a fixed percentage. For example, the 30° fade duration showed approximately twice that for the 60° fade duration at the same percentage level.

4.1.3 Non-fade duration distribution model

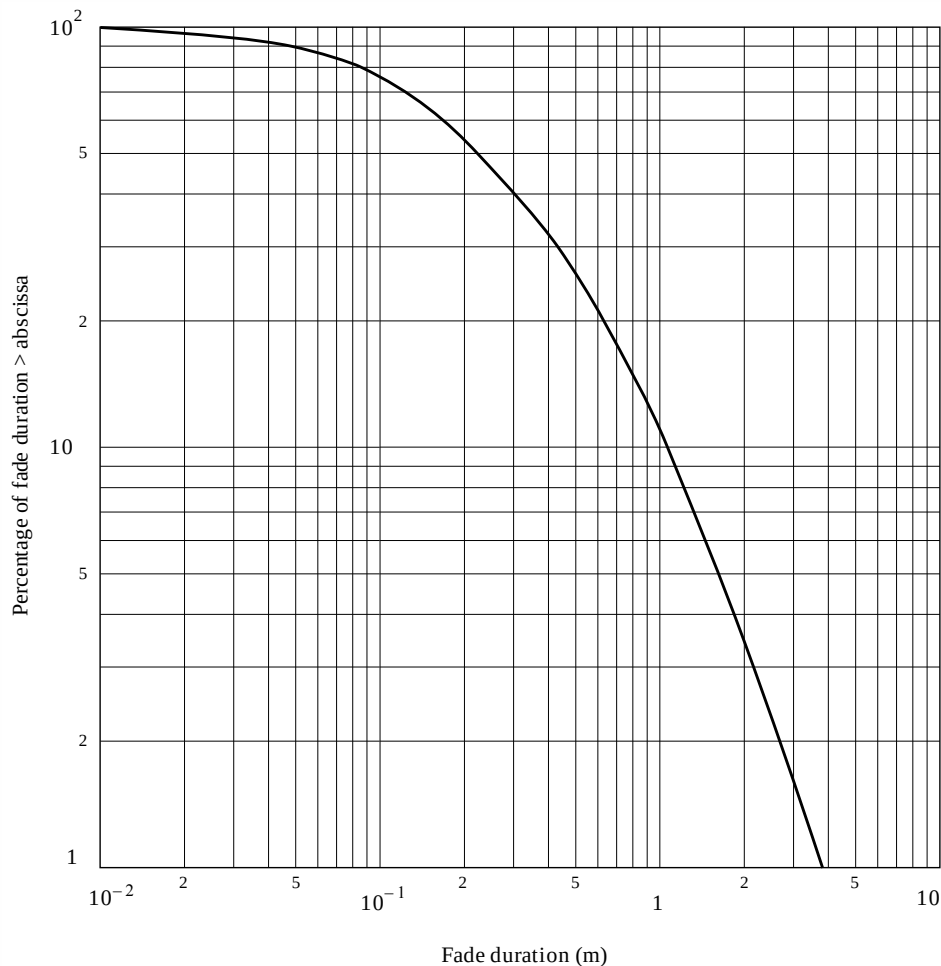
A non-fade duration event of distance duration, dd , is defined as the distance over which the fade levels are smaller than a specified fade threshold. The non-fade duration model is given by:

$$p(NFD > dd | A < A_q) = \beta (dd)^{-\gamma} \quad (7)$$

where $p(NFD > dd | A < A_q)$ is the percentage probability that a continuous non-fade distance, NFD , exceeds the distance, dd , given that the fade is smaller than the threshold, A_q . Table 2 contains the values of β and γ for roads that exhibit moderate and extreme shadowing i.e. the percentage of optical shadowing of between 55% and 75% and between 75% and 90% respectively. A 5 dB fade threshold is used for A_q .

FIGURE 2

Best fit cumulative fade distribution for roadside tree shadowing with a 5 dB threshold



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TABLE 2

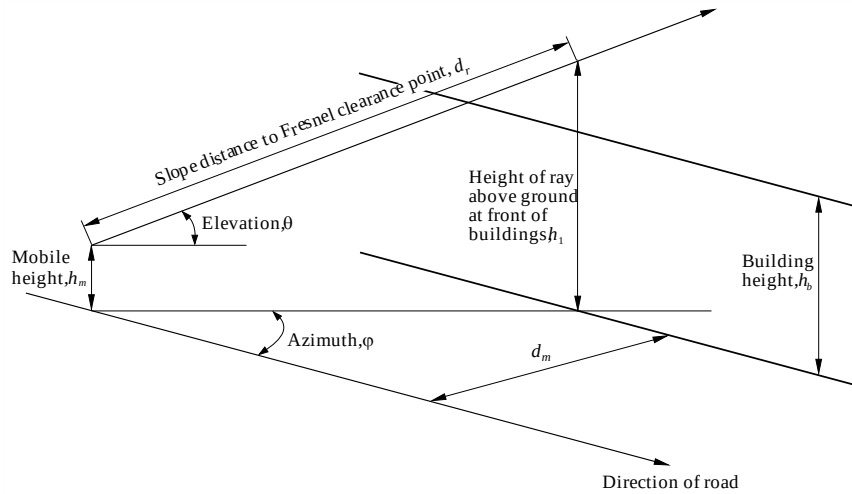
**Non-fade duration regression values for a 5 dB fade threshold
at a path elevation angle of 51°**

Shadowing level	β	γ
Moderate	20.54	0.58
Extreme	11.71	0.8371

4.2 Roadside building-shadowing model

Shadowing by roadside buildings in an urban area can be modelled by assuming a Rayleigh distribution of building heights. Figure 3 shows the geometry.

FIGURE 3
Geometry of roadside building shadowing model



P.0681-03

The percentage probability of blockage due to the buildings is given by:

$$p = 100 \exp \left[- (h_1 - h_2)^2 / 2h_b^2 \right] \quad \text{for } h_1 > h_2 \quad (8)$$

where:

$$h_1: \text{ height of the ray above ground at the building frontage, given by: } h_1 = h_m + (d_m \tan \theta / \sin \varphi) \quad (8a)$$

$$h_2: \text{ Fresnel clearance distance required above buildings, given by: } h_2 = C_f (\lambda d_r)^{0.5} \quad (8b)$$

h_b : the most common (modal) building height

h_m : height of mobile above ground

θ : elevation angle of the ray to the satellite above horizontal

φ : azimuth angle of the ray relative to street direction

d_m : distance of the mobile from the front of the buildings

d_r : slope distance from the mobile to the position along the ray vertically above building front, given by:

$$d_r = d_m / (\sin \varphi \cdot \cos \theta) \quad (8c)$$

C_f : required clearance as a fraction of the first Fresnel zone

λ : wavelength

and where h_1 , h_2 , h_b , h_m , d_m , d_r and λ are in self-consistent units, and $h_1 > h_2$.

Note that equations (8a), (8b) and (8c) are valid for $0 < \theta < 90^\circ$ and for $0 < \varphi < 180^\circ$. The actual limiting values should not be used.

Figure 4 shows examples of roadside building shadowing computed using the above expressions for:

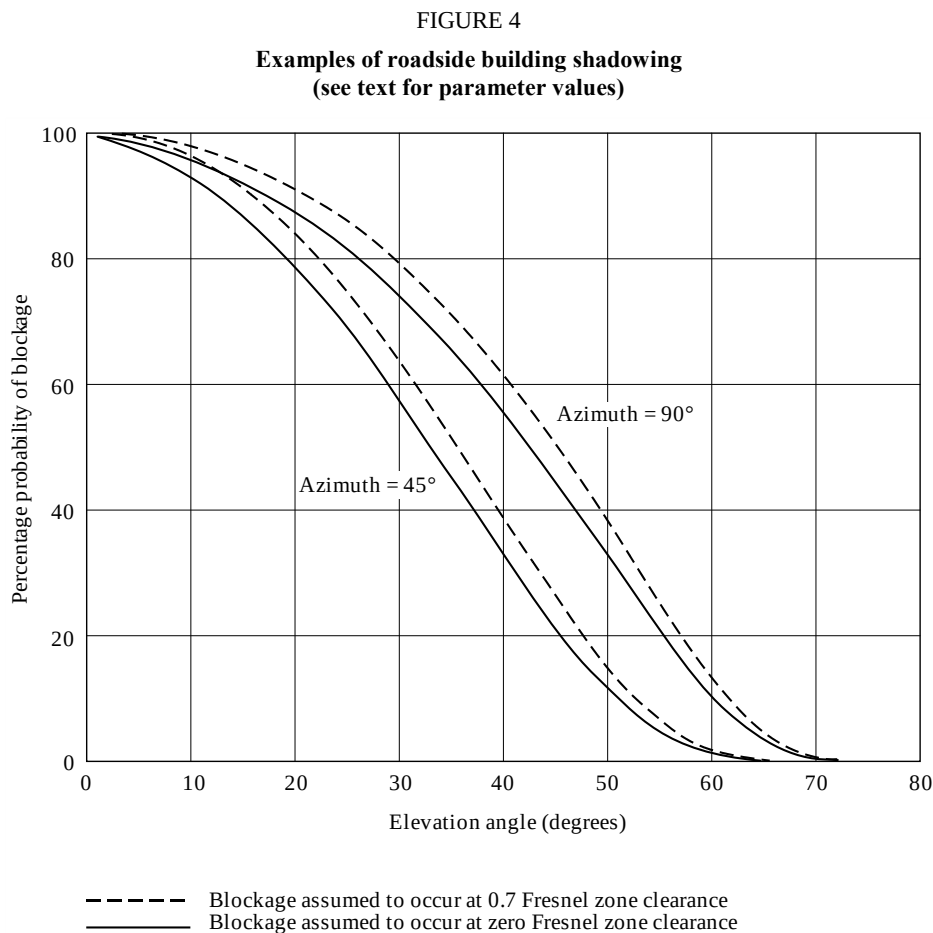
$$h_b = 15 \text{ m}$$

$$h_m = 1.5 \text{ m}$$

$$d_m = 17.5 \text{ m}$$

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Frequency = 1.6 GHz.



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In Fig. 4 the dashed lines apply when blocking is considered to exist if the ray has a clearance less than 0.7 of the first Fresnel Zone vertically above the building front. The solid lines apply when blocking is considered to exist only when there is no line-of-sight.

Although the model indicates no blockage at the highest path elevation angles, users should be aware that occasional shadowing and blockage can occur from overpasses, overhanging standards, branches, etc.

4.3 Special consideration of hand-held terminals (user blockage)

When using hand-held communication terminals, the operator's head or body in the near-field of the antenna causes the antenna pattern to change. For the case of non-low Earth orbit (non-LEO) satellite systems (GSO, high Earth orbit (HEO), ICO), the user of the hand-held terminal is expected to be cooperative, i.e. to position himself in such a way as to avoid blockage from both the head (or body) and the environment. For LEO systems this assumption cannot be made. The influence of the head (or body) can be evaluated by including the modified antenna pattern (which has to be measured) in the link availability calculation as presented in § 4.1.1.2. Assuming that the azimuth angles under which the satellite is seen are evenly distributed, an azimuth-averaged elevation pattern can be applied. The small movements of the head or hand which lead to small variations in apparent elevation angle can also be averaged.

Relating to this effect, a field experiment was performed in Japan. Figure 5a shows the geometry of a human head and an antenna in the experiment. The satellite elevation angle is 32° and the satellite signal frequency is 1.5 GHz. The antenna gain is 1 dBi and the length is 10 cm. Figure 5b shows the variation of relative signal level versus azimuth angle ϕ in Fig. 5a. It can be seen from Fig. 5b that the maximum reduction in signal level due to user blockage is about 6 dB when the equipment is in the shadow region of the human head.

The results presented in Fig. 5b are intended to be illustrative only, since the data correspond to a single elevation angle and antenna pattern, and no account is taken of potential specular reflection effects, which may play a significant role in a hand-held environment where little directivity is provided.

Propagation data related to signal entry loss for reception within buildings and vehicles, of particular interest for hand-held terminals, may be found in Recommendation ITU-R P.679.

4.4 Modelling building blockage effects using street masking functions (MKF)

Building blockage effects can also be quantified using street MKFs indicating the azimuths and elevations for which a link can or cannot be completed. Functions of this type have often been obtained by means of photogrametric studies or ray-tracing. The MKF concept can be applied to simplified scenarios to produce a limited number of MKFs and hence, making it possible to produce fast, approximate assessments of the combined availability in different multi-satellite configurations.

A given urban area could be described, as a first approximation, by an average masking angle (MKA) (degrees).

The MKA is defined as the satellite elevation for grazing incidence with building tops when the link is perpendicular to the street or in mathematical terms:

$$MKA = \arctan \left(\frac{h}{w/2} \right) \quad \text{degrees} \quad (9)$$

where:

h : average building height

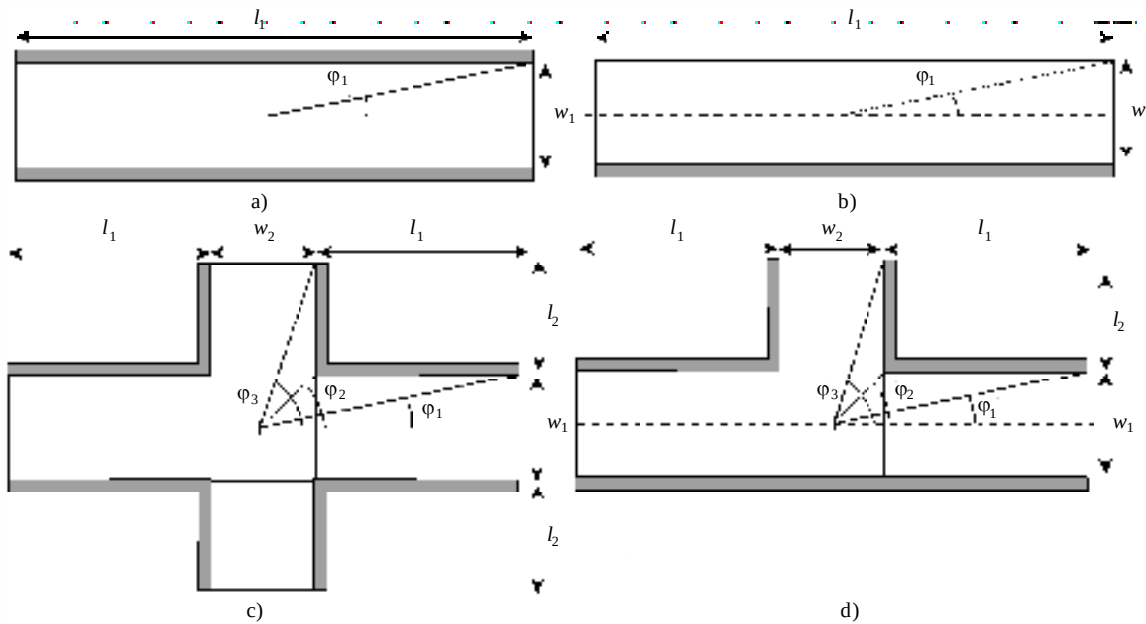
w : average street width.

Further, an urban scenario with a given MKA can be assumed to be made up of a combination of a small number of typical configurations (basic/constitutive scenarios), namely, street canyons (scy), street crossings (scr), T-junctions (T-j) and single walls (sw), each with a given occurrence probability (see Fig. 5). Similarly a path-mixture vector, $\vec{M}$, could be defined, stating, for a given built-up area, the probabilities of encountering each of the constitutive scenarios $\vec{M}(w_{scy}, w_{scr}, w_{T-j}, w_{sw})$, with $\sum w_i = 1$. Input data to this model, i.e., MKA, can be obtained by observation of the environment or from city maps.

...

FIGURE 5

Basic/constitutive scenarios describing a given urban area



P.0681-05

If availability probabilities are worked out for those four constitutive scenarios, the overall availability could be roughly estimated as the weighted sum of the availabilities in each scenario:

$$a_T = w_{scy} a_{scy} + w_{scr} a_{scr} + w_{T-j} a_{T-j} + w_{sw} a_{sw} \quad (10)$$

The MKFs for these four basic scenarios have been constructed by means of simple geometry assuming the user is in the middle of the scene (see Fig. 5). Considering a simple on-off, or line-of-sight – non-line-of-sight, propagation model (as in § 4.2 for the zero Fresnel zone clearance case), the MKFs of the four constitutive urban scenarios are presented in Fig. 6 where the ordinates indicate elevation angles and the abscissas azimuths or, rather, street orientations, ξ , with respect to the link. The top half-plane indicates positive azimuths and the bottom half-plane corresponds to negative azimuths. A MKF indicates the regions in the celestial hemisphere where a link can be completed (non-shaded) or not (shaded areas). The contours delimiting the “forbidden” zones in the MKFs are defined by segments and points. The most relevant ones are illustrated in Fig. 6 and given by the following equations:

$$S_A: \quad \theta = \tan^{-1} \left(h / \sqrt{\left(\frac{w}{2} \right)^2 \left(\frac{1}{\tan^2 \varphi} + 1 \right)} \right) \quad (11a)$$

$$P_A: \quad \left(\varphi_A = 90^\circ; \theta_A = \tan^{-1} \left(\frac{h}{w/2} \right) \right) \quad (11b)$$

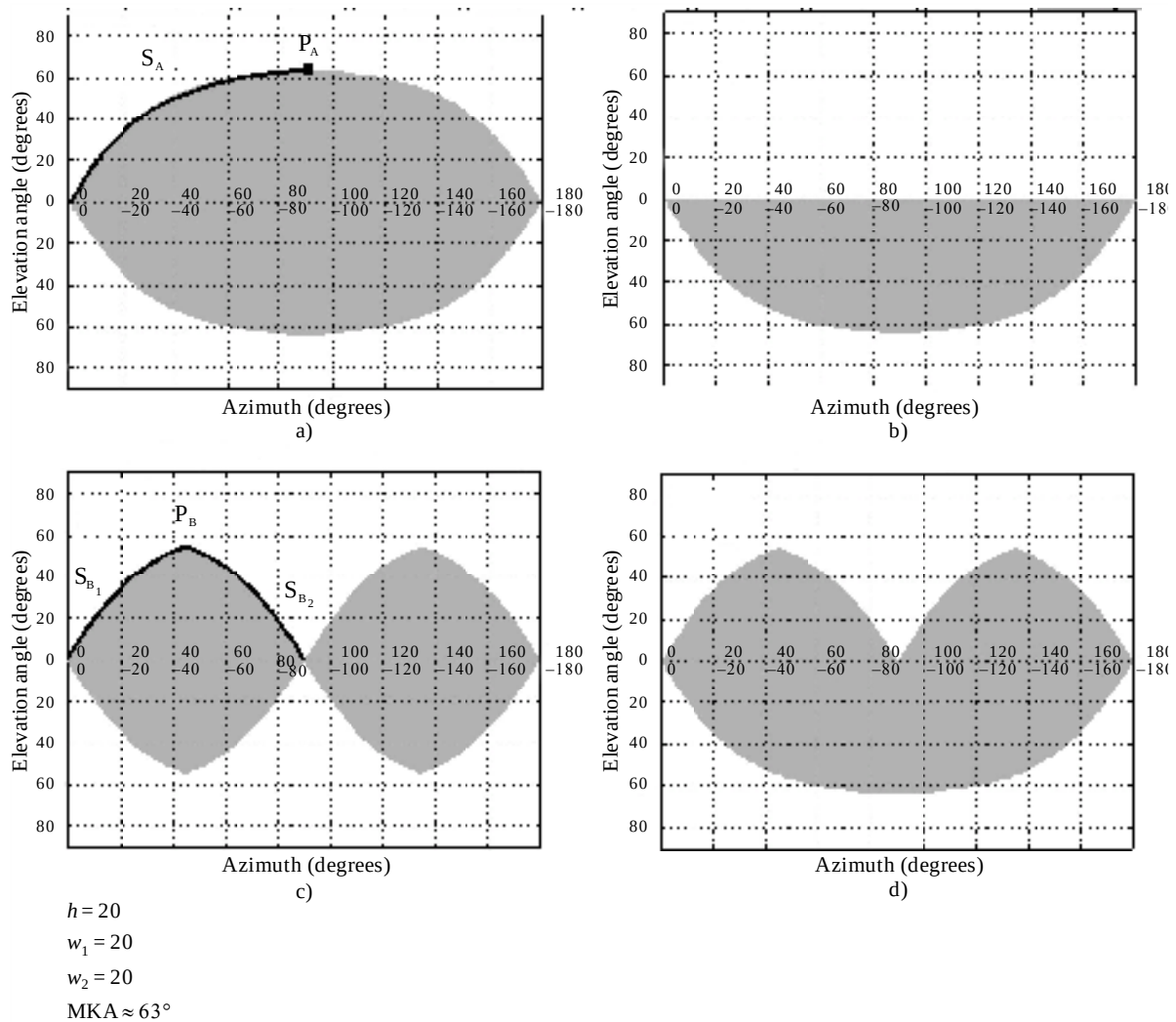
$$S_{B_1}: \quad \theta = \tan^{-1} \left(h / \sqrt{\left(\frac{w_1}{2} \right)^2 \left(\frac{1}{\tan^2 \varphi} + 1 \right)} \right) \quad (11c)$$

$$S_{B_2}: \theta = \tan^{-1} \left(h / \sqrt{\left(\frac{w_1}{2} \right)^2 \left(\frac{1}{\tan^2(90^\circ - \varphi)} + 1 \right)} \right) \quad (11d)$$

$$P_B: \left(\varphi_B = \tan^{-1} \left(\frac{w_1}{w_2} \right); \theta_2 = \tan^{-1} \left(h / \sqrt{\left(\frac{w_1}{2} \right)^2 \left(\frac{1}{\tan^2 \varphi_B} + 1 \right)} \right) \right) \quad (11e)$$

FIGURE 6

MKFs of a) a street canyon, b) a single wall, c) a street crossing and d) a T-junction



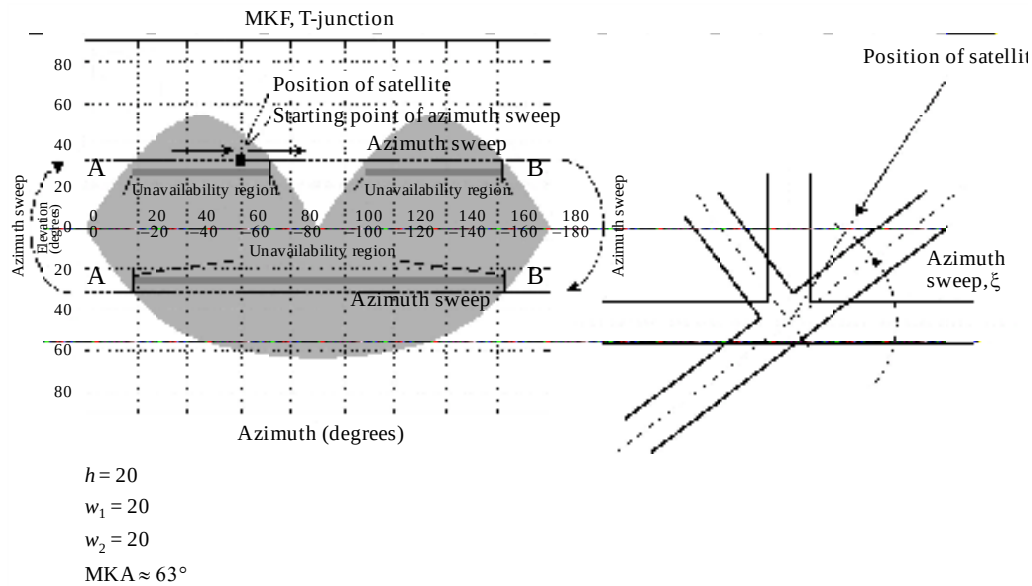
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The availability for a particular basic scenario and a given geostationary (GSO) satellite can be computed by considering all possible street orientations, ξ , with respect to the user-satellite link. In Fig. 7 the position of a GSO satellite with respect to a T-junction is indicated. For the case illustrated in the Figure all possible orientations can be described by sweeping through all points in line A-B corresponding to a constant elevation angle and all possible street orientations. The availability is the fraction of the straight line A-B in the non-shaded part of the MKF. Similarly, a non-GSO orbit

trajectory can be drawn on an MKF. The overall availability can be computed in this case by considering all possible street orientations with respect to all possible user-satellite link directions.

FIGURE 7

Calculation of the availability for a T-junction and a GSO satellite



P.0681-07

5 Multipath models for clear line-of-sight conditions

In many cases the mobile terminal has a clear line-of-sight (negligible shadowing) to the mobile satellite. Degradation to the signal can still occur under these circumstances, due to terrain-induced multipath. The mobile terminal receives a phasor summation of the direct line-of-sight signal and several multipath signals. These multipath signals may add constructively or destructively to result in signal enhancement or fade. The multipath signal characteristics depend on the scattering cross-sections of the multipath reflectors, their number, the distances to the receiving antenna, the field polarizations, and receiving antenna gain pattern.

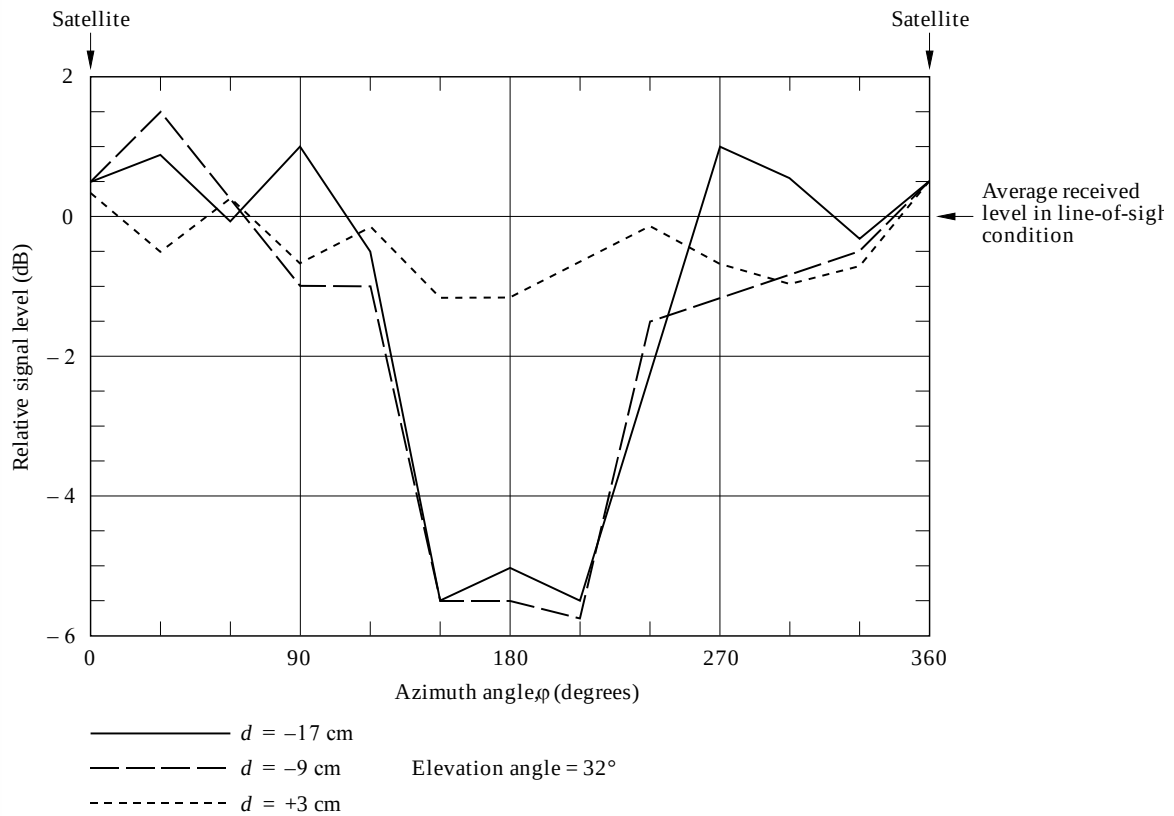
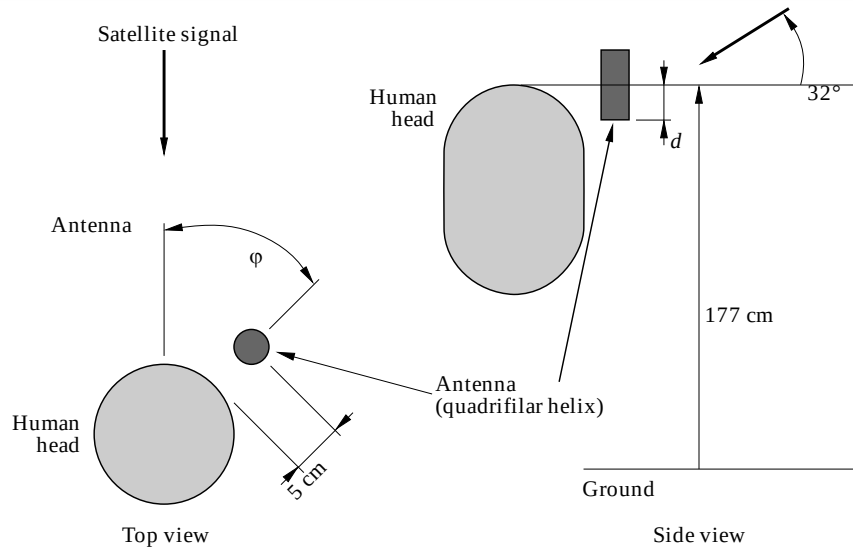
The multipath degradation models introduced in the following sections are based on measurements made using an antenna with the following characteristics:

- omnidirectional in azimuth;
- gain variation between 15° and 75° elevation less than 3 dB;
- below the horizon (negative elevation angles) the antenna gain was reduced by at least 10 dB.

FIGURE 8

a) Geometry of a human head and an antenna;

b) Fading at 1.5 GHz due to roadside shadowing versus path elevation angle



P.681-10.8

5.1 Multipath in a mountain environment

The distribution of fade depths due to multipath in mountainous terrain is modelled by:

$$p = a A^{-b} \quad (12)$$

for:

$$1\% < p < 10\%$$

where:

p : percentage of distance over which the fade is exceeded

A : fade exceeded (dB).

The curve fit parameters, a and b , are shown in Table 3 for 1.5 GHz and 870 MHz. Note that the above model is valid when the effect of shadowing is negligible.

TABLE 3
Parameters for best fit cumulative fade distribution
for multipath in mountainous terrain

Frequency (GHz)	Elevation = 30°			Elevation = 45°		
	a	b	Range (dB)	a	b	Range (dB)
0.87	34.52	1.855	2-7	31.64	2.464	2-4
1.5	33.19	1.710	2-8	39.95	2.321	2-5

Figure 9 contains curves of the cumulative fade distributions for path elevation angles of 30° and 45° at 1.5 GHz and 870 MHz.

5.2 Multipath in a roadside tree environment

Experiments conducted along tree-lined roads in the United States of America have shown that multipath fading is relatively insensitive to path elevation over the range of 30° to 60°. The measured data have given rise to the following model:

$$p = u \exp(-vA) \quad (13)$$

for:

$$1\% < p < 50\%$$

where:

p : percentage of distance over which the fade is exceeded

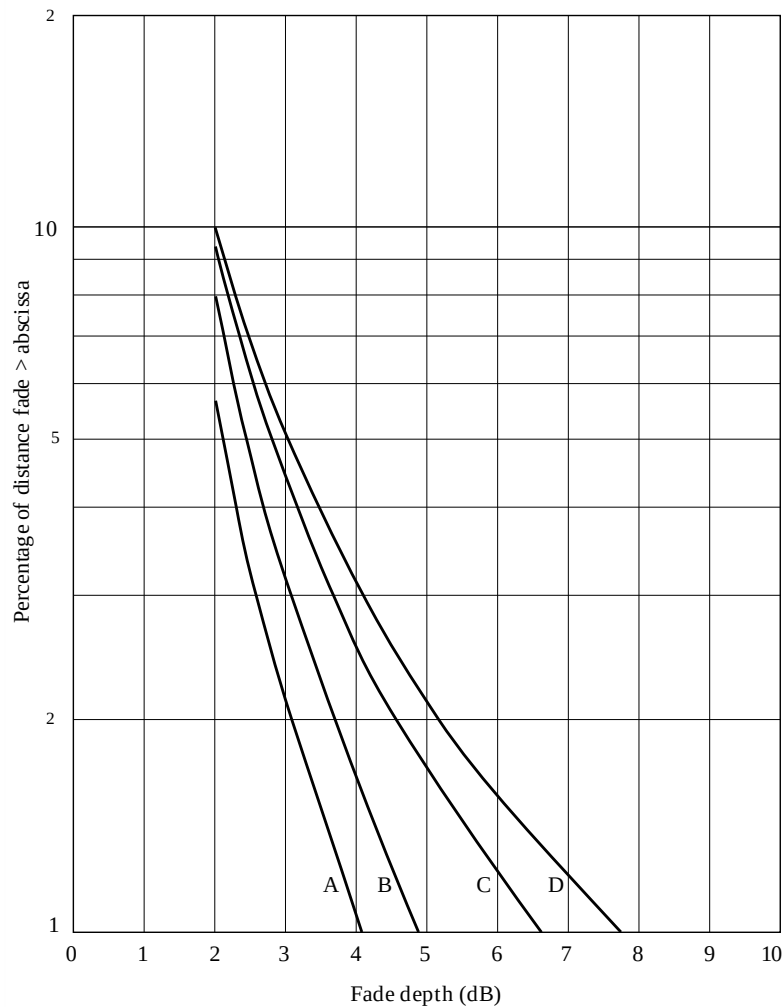
A : fade exceeded (dB).

Note that the above model assumes negligible shadowing. The curve fit parameters, u and v , are shown in Table 4.

Figure 9

FIGURE 9

Best fit cumulative fade distributions for multipath fading in mountainous terrain



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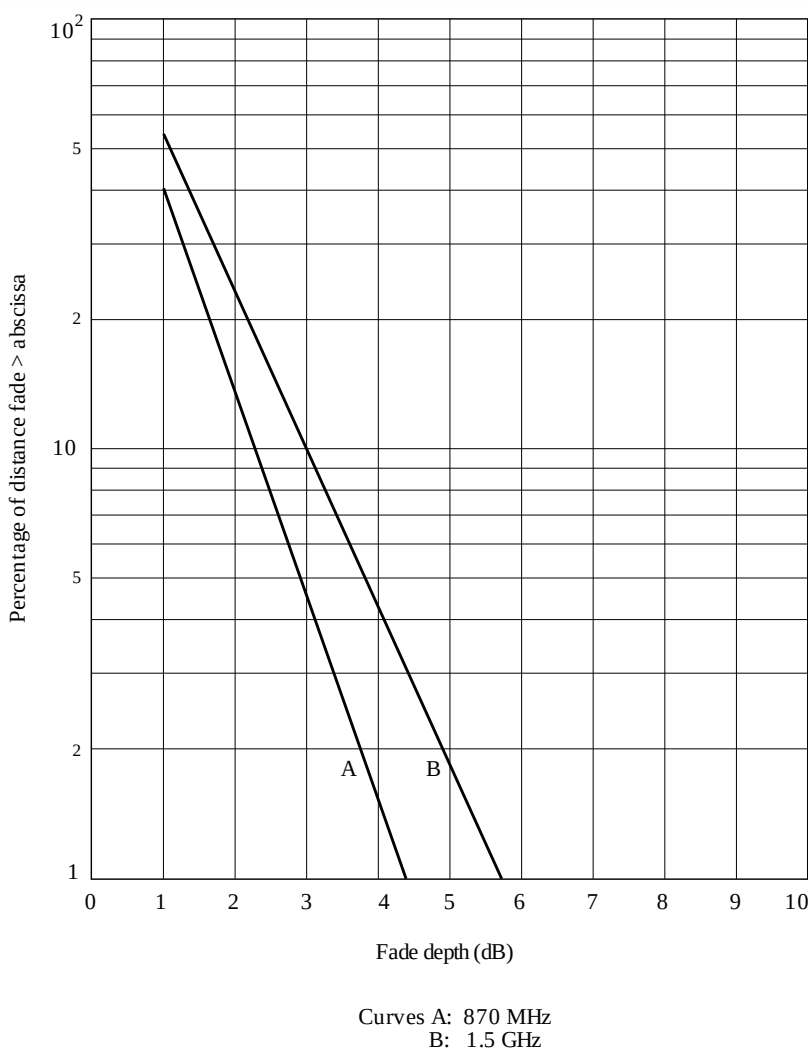
TABLE 4

Parameters for best exponential fit cumulative fade distributions
for multipath for tree-lined roads

Frequency (GHz)	u	v	Fade range (dB)
0.870	125.6	1.116	1-4.5
1.5	127.7	0.8573	1-6

Figure 10 contains curves of the cumulative fade distributions for 1.5 GHz and 870 MHz. Enhanced fading due to multipath can occur at lower elevation angles (5° to 30°) where forward scattering from relatively smooth rolling terrain can be received from larger distances.

FIGURE 10
Best fit cumulative fade distributions for multipath fading on tree-lined roads



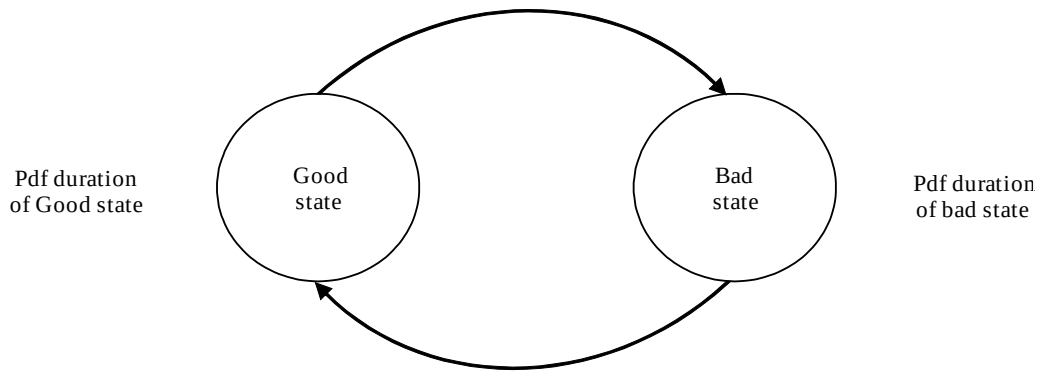
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6 Statistical model for mixed propagation conditions

In §§ 4.1 and 5, models for specific conditions, that is, roadside shadowing conditions and clear line-of-sight conditions in a mountain environment and a roadside tree environment are given. In actual LMSS propagation environments such as rural, wooded, urban and suburban areas, a mixture of different propagation conditions can occur. The cumulative distribution function (CDF) of signal levels in such mixed conditions can be calculated based on the following enhanced 2-state model which is composed of a GOOD state, including slightly shadowed conditions, and a BAD state, including more severe shadowed conditions (referred as “statistical model” hereafter). Based on the same analytical assumptions, time/space series of the power signal level complex envelope can be stochastically generated (referred as “generative model” hereafter). Sections 6.1 and 6.2 provide step-by-step methods to implement respectively the statistical and the generative models. Both models are valid for narrow-band LMSS where the frequency response of the channel affects in the same way all the frequencies within the bandwidth of the signal (frequency non-selective channels).

The long-term variations in the received signal may be described by a semi-Markov chain including the two distinct states, GOOD and BAD (see Fig. 11). The duration of each state is considered to be log-normally distributed. The signal in the Good and Bad states follows a Loo distribution. The Loo distribution considers that the received signal is the sum of two components: the direct path signal and the diffuse multipath. The average direct path amplitude is considered to be normally distributed and the diffuse multipath component follows a Rayleigh distribution. The standard deviation of the direct path amplitude and the multipath power are linearly connected to the average direct path amplitude.

FIGURE 11
2-State Semi-Markov chain approach



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For the stochastic synthesis of the channel complex envelope, a fixed correlation length for the direct path amplitude should be considered and a fixed Doppler spectrum should be considered for the diffuse multipath component. Between two successive events (belonging necessarily to different states), a given transition length must be considered where the diffuse multipath component power increases/decreases linearly. These transitions should be neglected for the statistical prediction of the channel complex envelope.

The main characteristics of the model are:

- 1) The model assumes two states: Good and Bad not necessarily matching with line-of-sight and non-line-of-sight condition.
- 2) The duration of each state is characterized by a lognormal distribution:

$$p_{lognormal}(x) = \frac{1}{\sigma_i x \sqrt{\pi}} \exp \left[-\frac{(\ln x - \mu_i)^2}{2\sigma_i^2} \right] \quad (14)$$

where:

$i = G$ for Good states

$i = B$ for Bad states

μ_G and σ_G : mean and standard deviation for Good state

μ_B and σ_B : mean and standard deviation for Bad state

- 3) The fading within each state is described by a Loo distribution, where the Loo triplet parameters are not fixed:

$$\text{Fading} \sim \text{Loo}(M_{Ai}, \Sigma_{Ai}, MP_i),$$