

RECOMMENDATION ITU-R P.1623-1

Prediction method of fade dynamics on Earth-space paths

(Question ITU-R 201/3)

(2003-2005)

The ITU Radiocommunication Assembly,

considering

- a) that for a variety of radiocommunication services, design objectives have to be met that require information on the dynamics of outage events;
- b) that for the evaluation of parameters associated with the risk of failure to provide a certain quality and reliability of service, the probability of occurrence of fades of a certain duration must be known;
- c) that for the evaluation of internal parameters inside a fade mitigation technique (FMT) control loop (used to improve the quality and reliability of service), the probability of occurrence of fade slope corresponding to a given attenuation threshold must be known;
- d) that there is a need to provide engineering information for the calculation of fade duration, interfade duration and fade slope statistics,

recommends

- 1 that the methods described in Annex 1 § 2.2 be used for the calculation of the statistics of fade duration due to the combined effects of attenuation (gases, clouds and rain) and scintillation on Earth-space paths;
- 2 that the methods described in Annex 1 § 3.2 be used for the calculation of the statistics of fade slope due to attenuation on Earth-space paths.

Annex 1**1 Introduction**

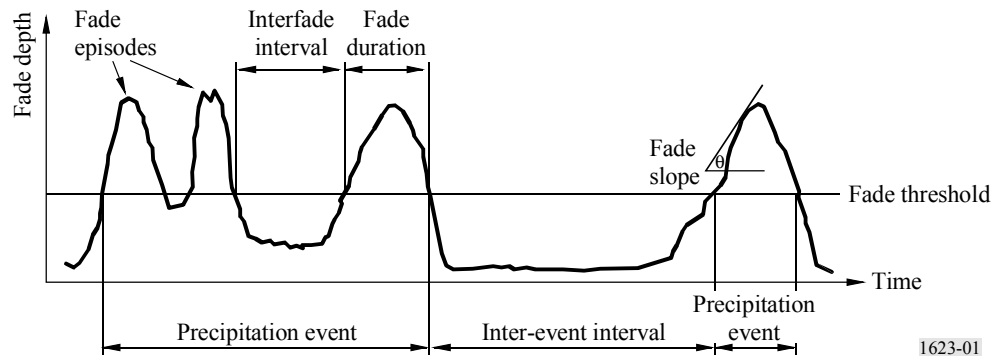
In the design of a variety of telecommunication systems, the dynamic characteristics of fading due to atmospheric propagation are of concern to optimize system capacity and meet quality and reliability criteria. Examples are fixed networks that include a space segment and systems that apply fade mitigation or resource sharing techniques.

Several temporal scales can be defined, and it is useful to have information on fade slope, fade duration and interfade duration statistics for a given attenuation level (Fig. 1).

Fade duration is defined as the time interval between two crossings above the same attenuation threshold whereas interfade duration is defined as the time interval between two crossings below the same attenuation threshold. Fade slope is defined as the rate of change of attenuation with time.

FIGURE 1

Features characterizing the dynamics of fade events



Of particular interest in the context of availability criteria is the distinction between fades of shorter and longer duration than 10 s. Knowledge of the distribution of fade duration as a function of fade depth is also a prerequisite for the application of risk concepts in the provision of telecommunication services.

In addition, information about the expected fade slope is essential to assess the required minimum tracking rate of a fade mitigation system.

2 Fade and interfade duration

2.1 Requirements for fade duration information

Fade duration is an important parameter to be taken into account in system design for several reasons:

- system outage and unavailability: fade duration statistics provide information on number and duration of outages and system unavailability due to propagation on a given link and service;
- sharing of the system resource: it is important from the operator's point-of-view to have an insight into the statistical duration of an event in order to assign the resource for other users;
- FMT: fade duration is of concern to define statistical duration for the system to stay in a compensation configuration before coming back to its nominal mode;
- system coding and modulation: fade duration is a key element in the process of choosing forward error correction codes and best modulation schemes; for satellite communication systems, the propagation channel does not produce independent errors but blocks of errors. Fade duration impacts directly on the choice of the coding scheme (size of the coding word in block codes, interleaving in concatenated codes, etc.).

2.2 Fade duration prediction method

Fade duration can be described by two different cumulative distribution functions:

- 1 $P(d > D | a > A)$, the probability of occurrence of fades of duration d longer than D (s), given that the attenuation a is greater than A (dB). This probability can be estimated from the ratio of the number of fades of duration longer than D to the total number of fades observed, given that the threshold A is exceeded.

- 2 $F(d > D|a > A)$, the cumulative exceedance probability, or, equivalently, the total fraction (between 0 and 1) of fade time due to fades of duration d longer than D (s), given that the attenuation a is greater than A (dB). This probability can be estimated from the ratio of the total fading time due to fades of duration longer than D given that the threshold A is exceeded, to the total exceedance time of the threshold.

For a given reference period, the number of fades of duration longer than D is estimated by multiplying the probability of occurrence $P(d > D|a > A)$ by the total number of fades exceeding the threshold, $N_{tot}(A)$. Likewise, an estimate of the total exceedance time due to fade events of duration longer than D is obtained by multiplying the fraction of time $F(d > D|a > A)$ by the total time that the threshold is exceeded, $T_{tot}(A)$.

The two-segment model presented here consists of a log-normal distribution function for long fades and a power-law function for short fades. The boundary between short and long fades is given by the threshold duration D_t calculated in the model. The power-law model is valid for fade durations longer than 1 s. Fades of shorter duration do not contribute significantly to total outage time.

The following provides estimates of the parameters required for the model and finally defines the two-segment model for both distribution functions, i.e. the occurrence probability P and the exceedance probability (or fraction of time) F .

The model is expected to be valid for durations longer than 1 s.

The following parameters are required as input to the model:

f : frequency (GHz): 10-50 GHz

ϕ : elevation angle (degrees): 5-60°

A : attenuation threshold (dB).

The step-by-step calculation of the fade duration distribution is as follows:

Step 1: Calculate the mean duration D_0 of the log-normal distribution of the fraction of fading time due to fades of long duration, given that the attenuation is greater than A , as:

$$D_0 = 80 \phi^{-0.4} f^{1.4} A^{-0.39} \quad \text{s} \quad (1)$$

Step 2: Calculate the standard deviation σ of the lognormal distribution of the fraction of fading time due to fades of long duration as:

$$\sigma = 1.85 f^{-0.05} A^{-0.027} \quad (2)$$

Step 3: Calculate the exponent γ of the power-law distribution of the fraction of fading time due to fades of short duration as:

$$\gamma = 0.055 f^{0.65} A^{-0.003} \quad (3)$$

Step 4: Calculate the boundary between short and long fade durations, D_t , as:

$$D_t = D_0 e^{p_1 \sigma^2 + p_2 \sigma - 0.39} \quad \text{s} \quad (4)$$

where:

$$p_1 = 0.885\gamma - 0.814 \quad (5)$$

$$p_2 = -1.05\gamma^2 + 2.23\gamma - 1.61 \quad (6)$$