

RECOMMENDATION ITU-R P.619-1*

**PROPAGATION DATA REQUIRED FOR THE EVALUATION
OF INTERFERENCE BETWEEN STATIONS IN SPACE AND THOSE
ON THE SURFACE OF THE EARTH**

(Question ITU-R 208/3)

(1986-1990-1992)

The ITU Radiocommunication Assembly,

considering

- a) that for the proper evaluation of interference between stations in space and those on the surface of the Earth, it is necessary to have appropriate propagation data that are based on both terrain and atmospheric factors;
- b) that the data available so far do not allow reliable prediction methods to be developed which would give adequate accuracy in all regions of the world;
- c) that, however, several methods are available which yield sufficient accuracy in at least some regions,

recommends

that for the evaluation of interference between stations in space and those on the surface of the Earth, administrations use the propagation and calculation methods as set out in Annex 1.

ANNEX 1

1. Introduction

Interference between terrestrial and space stations, between space stations in the same system, and between space stations not in the same system can follow many paths. These can be summarized as follows:

1.1 Interference between space stations and earth stations not in the same system

Mode B1 : a transmission from a space station of one space system causing interference to reception by an earth station of another system.

Mode B2 : a transmission from an earth station of one space system causing interference to reception by a space station of another system.

1.2 Interference between space stations and terrestrial stations

Mode C1 : a transmission from a space station causing interference to reception by a terrestrial station.

Mode C2 : a transmission from a terrestrial station causing interference to reception by a space station.

The three principal impairment mechanisms which give rise to these interference paths are those due to clear-air propagation, precipitation scatter, and differential attenuation on adjacent Earth-space paths. These mechanisms are considered below.

Ionospheric effects on Earth-space propagation are discussed in Recommendation ITU-R P.531. These effects which depend on frequency, involve scintillations (equatorial, mid-latitude, high-latitude), absorption (auroral, polar cap), variations in direction of arrival, propagation delay, frequency change and Faraday rotation.

* Radiocommunication Study Group 3 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

2. Clear-air propagation

A number of propagation impairment mechanisms can lead to variations in the path loss during conditions of essentially clear air. In general, the individual effects of these mechanisms become increasingly severe as the elevation angle of the Earth-space path decreases. Clear-air effects of interest to low-elevation angle Earth-space paths include:

- gaseous absorption,
- cloud attenuation,
- melting layer attenuation,
- tropospheric scintillations,
- low-angle fading,
- ray bending,
- antenna gain degradation,
- defocussing (or beam spreading),
- ducting,
- ground/building reflections.

Recommendation ITU-R P.452 gives prediction procedures for calculating the line-of-sight, diffraction, tropospheric scatter, and ducting layer reflection effects for terrestrial systems. Of the effects noted above, only tropospheric scintillations, low-angle fading, and ray bending give rise to varying interference levels between systems. Reflections from the ground should not occur in a well designed Earth-space system; predicting the amplitude and phase of reflections from buildings is usually only tractable through the use of deterministic models which include an accurate knowledge of the urban environment. Before establishing the varying interference levels, it is usual to calculate the basic transmission loss, L_b , along a potential interference path.

2.1 Basic transmission loss

The basic transmission loss L_b can be expressed as:

$$L_b = 92.5 + 20 \log f + 20 \log d + A_g + A_D - G_S \quad \text{dB} \quad (1)$$

where:

- f : frequency (GHz)
- d : path length (km)
- A_g : attenuation due to atmospheric gases (dB)
- A_D : attenuation (dB) due to beam spreading
- G_S : “gain” (dB) due to scintillation.

The attenuation A_g due to atmospheric gases is described in Recommendation ITU-R P.676. It is a function of the surface water vapour density ρ , the effective radius of the Earth $R_e = 10^6 (157 - \Delta N)^{-1}$ and, to a lesser extent, of the surface air temperature.

Seasonal and annual values of surface water vapour density are given in Figs. 1 to 5 of Recommendation ITU-R P.836. To a first approximation, the statistics of the temporal variations of ρ can be assumed to follow a Gaussian distribution having a standard deviation, σ , of about 0.25 times the mean value of ρ . For example, the absolute humidity likely to be exceeded for 99% of the time would be $1 - (0.25 \times 2.4) = 0.4$ times the mean value. Similarly the value exceeded for 99.99% of the time would be $1 - (0.25 \times 3.8) = 0.05$ times the mean value.

ΔN is the mean decrease (lapse) of the radio refractivity over a 1 km thick layer based at the surface. World maps of the monthly mean values of ΔN are given in Figs. 3 to 6 of Recommendation ITU-R P.453.

The scintillation gain, G_S , is a function of frequency, earth-station antenna diameter, elevation angle, and local climate and can be calculated from the predicted intensity of tropospheric scintillation.

Application of the prediction methods of Recommendation ITU-R P.530 indicates that in a few regions of the world the combined effects of severe clear-air flat fading and multipath fading on the wanted signal (at fade depths of about 25 dB) can be at least as significant at about 23 GHz as rain attenuation even on paths as short as 10 km. These regions are locations in which ducts are prevalent but which also have mild rain climates (i.e., warm or arctic desert areas). Most other regions subject to the prevalence of ducts are humid regions also subject to severe rain attenuation which would dominate the outage of the wanted signal for margins of about 25 dB. In the United Kingdom, East Anglia is one area at temperate latitudes within which multipath fading of the wanted signal, at the 25 dB level, is known to occur for the same percentage of time as rain attenuation on a 10 km path.

2.2 Tropospheric scintillation

A prediction method for tropospheric scintillation applicable down to elevation angles of about 4° is given in Recommendation ITU-R P.618. This procedure allows the calculation of both the scintillation intensity and the cumulative distribution of effective fading. Tropospheric scintillation also produces signal enhancements which will lead to transmission loss values less than those of free space. Significant levels of tropospheric scintillation can exist for percentage times well above 1% of a year. On very low elevation angle paths, small-scale changes in the refractive index coupled with a wave-like movement of the atmosphere can give rise to severe low-angle fading.

2.3 Low-angle fading

For elevation angles below 5° and for small percentage times, substantial signal enhancements and fading can occur. Measurements at 7 GHz have indicated up to 6 dB enhancements of the signal at elevation angles of between 1° and 2° , while on a 3.3° elevation angle path, enhancements of up to 8 dB and fading down to 16 dB were measured in essentially clear-air conditions. No recommended model exists as yet to predict these levels of low-angle fading.

2.4 Ray bending

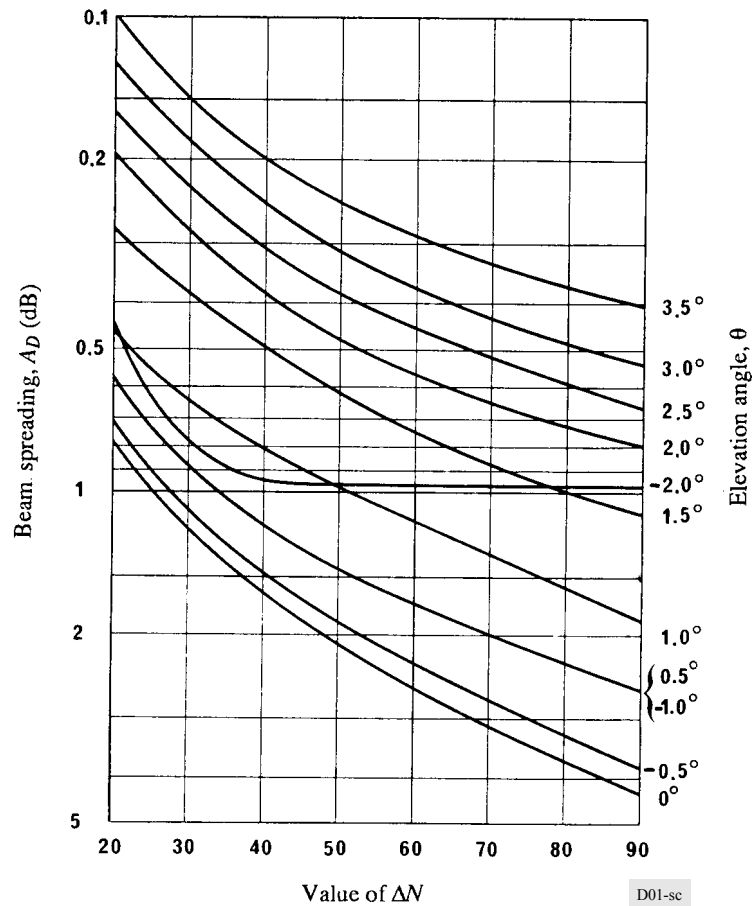
Ray bending is caused by variations in the refractive index along the path. Such variations are usually only significant in a vertical direction, since the lower atmosphere at any given altitude tends to be fairly stratified. The main beam of an antenna is not infinitely thin and so the upper and lower edges of the beam will undergo different amounts of ray bending due to their different elevation angle paths through the lower atmosphere. The differential ray bending will therefore lead to beam spreading. Beam spreading in a vertical plane is given in Fig. 1.

3. Precipitation scatter

Interference can be caused when energy from one system is scattered by precipitation and enters the antenna beam of another system. This situation is only of significance when the main beams of the two systems intersect within that portion of the atmosphere in which hydrometeors can exist. Under these conditions, a common volume can be set up in which hydrometeors are present for appreciable periods and enhanced levels of unwanted signals may result. While such interference can be significant, it is usually not severe enough to be system-limiting and, by a judicious selection of path geometries to prevent the likelihood of common volumes occurring, can usually be avoided altogether.

The procedure for calculating precipitation scatter is given in Recommendation ITU-R P.452.

FIGURE 1
Beam spreading of near-horizontal radio waves



An important problem in this context is possible interference from a solar power satellite. Using available data on likely harmonic content, it can be shown that – even at the 4th harmonic – the interfering signal, at a distance of 50 km from the rain cell, can be comparable with the level of the received signal in the fixed-satellite service. At the fundamental frequency, however, direct radiation from the side lobes of the power satellite to the terrestrial station will probably exceed the signal due to precipitation scatter.

4. Differential attenuation on adjacent paths

4.1 Rain effects

If two space stations operating at the same frequency are separated from one another by a small angle, situations can arise when rain attenuation on the path from a space station reduces the signal sufficiently to allow interference from a neighbouring space station into the receiving earth station.

In this case it is essential to consider the joint effects of the rain attenuation of A_c of the wanted signal and the rain attenuation of A_i of the interfering signal.

For interference calculations, the conditional distributions of $\Delta A = A_c - A_i$ and A_c must be used. As a basis for generating total exceedance statistics for various regions, in which the single path attenuation statistics are different, ΔA statistics exceeded for 1% of the time have been calculated under the condition: $0.5 \text{ dB} < A_c < A_m$, where A_m is the maximum allowed attenuation of the wanted signal. The empirical formula:

$$\Delta A(1\%) = 0.036 (0.45 f + \operatorname{cosec} \theta) \cdot [\log_e (\varphi + 1) \cdot \log_e (A_m + 1)]^{1.15} \quad \text{dB} \quad (2)$$

where:

f : frequency (GHz): $11 \leq f \leq 30$ GHz

θ : earth-station elevation angle (degrees): $5^\circ \leq \theta \leq 30^\circ$

φ : angular separation (degrees) of the two paths in the azimuth direction: $0^\circ \leq \varphi \leq 10^\circ$

was found to give a good fit to the data in the parameter ranges noted.

In order to determine the percentage of time that a particular value of ΔA is exceeded for a given value of A_m , the 1% figure must be multiplied by the probability that $0.5 \text{ dB} < A_c < A_m$. The latter can be obtained from a measured or predicted cumulative distribution for a single path (see Recommendation ITU-R P.618).

Equation (2) has yet to be tested over a larger range of frequencies and elevation angles. Nevertheless, results obtained over a relatively large azimuth separation (31.5°) appear to be in general agreement with the predictions of equation (2). On this basis, differential rain attenuation along separate Earth-space paths is not considered to be a likely cause of unacceptable interference.

4.2 Scintillation effects

Height diversity measurements at an elevation angle of 3.3° and a frequency of 11.198 GHz showed that a separation of 15.1 m resulted in essentially uncorrelated scintillation at the two antennas. This implies that two separate Earth-space paths need only have an elevation angle difference of the order of 0.1° at an elevation angle of 3.3° to be uncorrelated in terms of scintillation. Closely spaced satellites, and even some which are co-located, could therefore be subjected to essentially uncorrelated scintillation and care should be taken in evaluating the potential interference between such systems, particularly when up-link power control is to be implemented.
