

RECOMMENDATION ITU-R PN.840-1

ATTENUATION DUE TO CLOUDS AND FOG

(Question ITU-R 201/3)

(1992-1994)

The ITU Radiocommunication Assembly,

considering

- a) that there is a need to give guidance to engineers in the design of Earth-space telecommunication systems for frequencies higher than 10 GHz;
- b) that attenuation due to clouds may be a factor of importance especially for microwave systems well above 10 GHz or low-availability systems;
- c) that even if no global prediction of cloud attenuation exists due to the lack of extensive cloud measurements the basic phenomena are well understood,

recommends

- 1. that the curves and prediction models given in Annex 1 should be used for the calculation of attenuation due to clouds and fog.

ANNEX 1

1. Introduction

For clouds or fog consisting entirely of small droplets, generally less than 0.01 cm, the Rayleigh approximation is valid and it is possible to express the attenuation in terms of the total water content per unit volume. Thus the specific attenuation within a cloud or fog can be written as:

$$\gamma_c = K_I M \quad \text{dB/km} \quad (1)$$

where:

- γ_c : specific attenuation (dB/km) within the cloud
- K_I : specific attenuation coefficient (dB/km)/(g/m³)
- M : liquid water content of the cloud or fog (g/m³).

At frequencies of the order of 100 GHz and above, attenuation due to fog may be significant. The liquid water content of fog is typically about 0.05 g/m³ for medium fog (visibility of the order of 300 m) and 0.5 g/m³ for thick fog (visibility of the order of 50 m).

2. Specific attenuation coefficient

A mathematical model based on Rayleigh scattering, which uses a double-Debye model for the dielectric permittivity $\epsilon(f)$ of water, can be used to calculate the value of K_I for frequencies up to 1 000 GHz:

$$K_I = \frac{0.819f}{\epsilon''(1 + \eta^2)} \quad \text{dB/km/g/m}^3 \quad (2)$$

where f is the frequency, in GHz, and:

$$\eta = \frac{2 + \epsilon'}{\epsilon''} \quad (3)$$

The complex dielectric permittivity of water is given by:

$$\varepsilon''(f) = \frac{f(\varepsilon_0 - \varepsilon_1)}{f_p \left[1 + (f/f_p)^2 \right]} + \frac{f(\varepsilon_1 - \varepsilon_2)}{f_s \left[1 + (f/f_s)^2 \right]} \quad (4)$$

$$\varepsilon'(f) = \frac{\varepsilon_0 - \varepsilon_1}{\left[1 + (f/f_p)^2 \right]} + \frac{\varepsilon_1 - \varepsilon_2}{\left[1 + (f/f_s)^2 \right]} + \varepsilon_2 \quad (5)$$

where:

$$\varepsilon_0 = 77.6 + 103.3 (\theta - 1) \quad (6)$$

$$\varepsilon_1 = 5.48 \quad (7)$$

$$\varepsilon_2 = 3.51 \quad (8)$$

$$\theta = 300 / T \quad (9)$$

with T : temperature (K).

The principal and secondary relaxation frequencies are:

$$f_p = 20.09 - 142 (\theta - 1) + 294 (\theta - 1)^2 \quad \text{GHz} \quad (10)$$

$$f_s = 590 - 1500 (\theta - 1) \quad \text{GHz} \quad (11)$$

Figure 1 shows the values of K_I at frequencies from 5 to 200 GHz and temperatures between -8°C and 20°C . For cloud attenuations, the curve corresponding to 0°C should be used.

FIGURE 1
Specific attenuation by water droplets at various temperatures as function of frequency

