RECOMMENDATION ITU-R P.833-2

ATTENUATION IN VEGETATION

(Question ITU-R 202/3)

(1992-1994-1999)

The ITU Radiocommunication Assembly

considering

a) that attenuation in vegetation can be important in several practical applications,

recommends

1 that the content of Annex 1 be used for evaluating attenuation through vegetation between 30 MHz and 60 GHz.

ANNEX 1

1 Introduction

Attenuation in vegetation can be important in some circumstances, for both terrestrial and Earth-space systems. However, the wide range of conditions and types of foliage makes it difficult to develop a generalized prediction procedure. There is also a lack of suitably collated experimental data.

The models described in the following sections apply to particular frequency ranges and for different types of path geometry.

2 Terrestrial path with one terminal in woodland

For a terrestrial radio path where one terminal is located within woodland or similar extensive vegetation, the additional loss due to vegetation can be characterized on the basis of two parameters:

– the specific attenuation rate (dB/m) due primarily to scattering of energy out of the radio path, as would be measured over a very short path;

– the maximum total additional attenuation due to vegetation in a radio path (dB) as limited by the effect of other mechanisms including surface-wave propagation over the top of the vegetation medium and forward scatter within it.

In Fig. 1 the transmitter is outside the woodland and the receiver is a certain distance, d, within it. The excess attenuation, A_{ev}, due to the presence of the vegetation is given by:

$$A_{ev} = A_m \left[1 - \exp\left(- d \gamma / A_m \right) \right] \tag{1}$$

where:

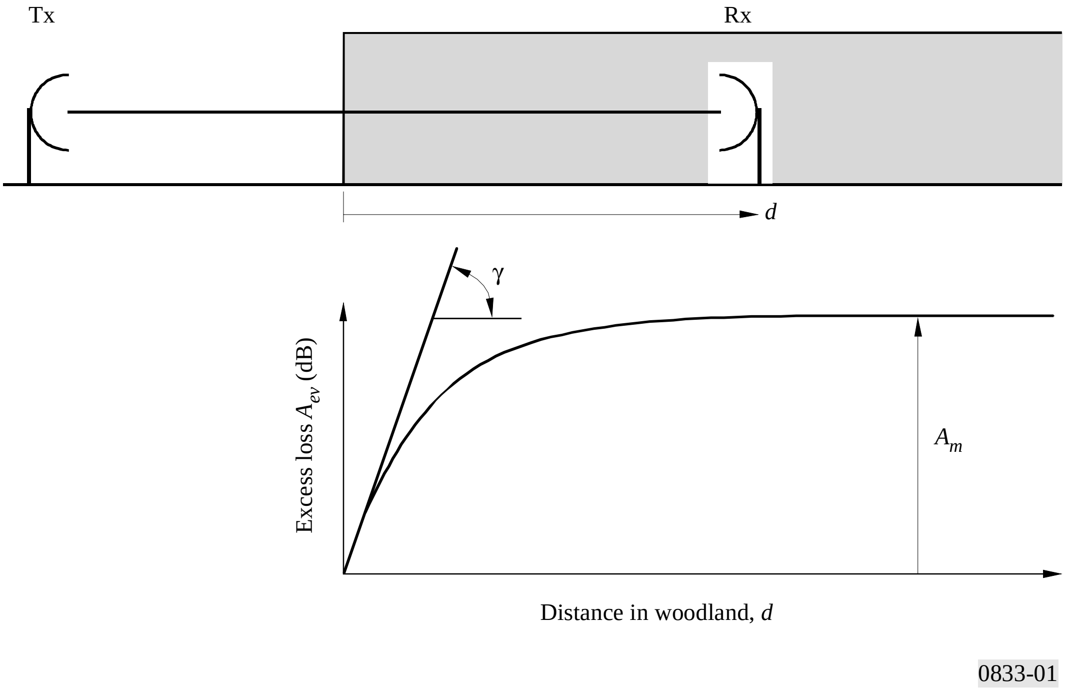
d: length of path within woodland (m)

γ: specific attenuation for very short vegetative paths (dB/m)

A_m: maximum attenuation for one terminal within a specific type and depth of vegetation (dB)

FIGURE 1

Representative radio path in woodland



It is important to note that excess attenuation, A_{ev}, is defined as excess to all other mechanisms, not just free space loss. Thus if the radio path geometry in Fig. 1 were such that full Fresnel clearance from the terrain did not exist, then A_{ev} would be the attenuation in excess of both free-space and diffraction loss. Similarly, if the frequency were high enough to make gaseous absorption significant, A_{ev} would be in excess of gaseous absorption.

It may also be noted that A_m is equivalent to the clutter loss often quoted for a terminal obstructed by some form of ground cover or clutter.

The value of specific attenuation due to vegetation, γ dB/m, depends on the species and density of the vegetation. Approximate values are given in Fig. 2 as a function of frequency.

The value of maximum attenuation, A_m dB, as limited by scattering from the surface wave, depends on the species and density of the vegetation, plus the antenna pattern of the terminal within the vegetation and the vertical distance between the antenna and the top of the vegetation.

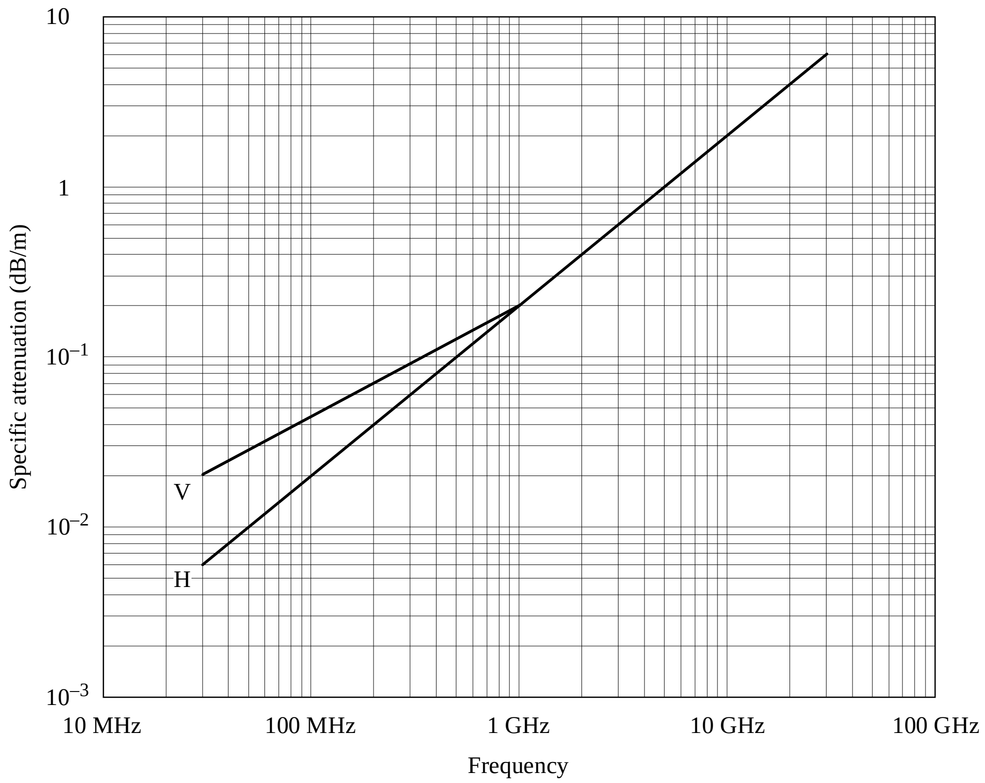
Figure 2 shows typical values for specific attenuation derived from various measurements over the frequency range 30 MHz to about 30 GHz in woodland. Below about 1 GHz there is a tendency for vertically polarized signals to experience higher attenuation than horizontally, this being thought due to scattering from tree-trunks.

It is stressed that attenuation due to vegetation varies widely due to the irregular nature of the medium and the wide range of species, densities, and water content obtained in practice. The values shown in Fig. 2 should be viewed as only typical.

At frequencies of the order of 1 GHz the specific attenuation through trees in leaf appears to be about 20% greater (dB/m) than for leafless trees. There can also be variations of attenuation due to the movement of foliage, such as due to wind.

FIGURE 2

Specific attenuation due to woodland



V: vertical polarization
H: horizontal polarization

0833-02

Measurements in the frequency range 900-1 800 MHz carried out in a park with tropical trees in Rio de Janeiro (Brazil) showed a frequency dependence of A_m:

$$A_m = 0.18\, f^{\,0.752} \tag{2}$$

where f is the frequency (MHz).

The mean tree height was 15 m and the receiving antenna height was 2.4 m.

3 Single vegetative obstruction

3.1 At or below 3 GHz

Equation (1) does not apply for a radio path obstructed by a single vegetative obstruction where both terminals are outside the vegetative medium, such as a path passing through the canopy of a single tree. At VHF and UHF, where the specific attenuation has relatively low values, and particularly where the vegetative part of the radio path is relatively short, this situation can be modelling on an approximate basis in terms of the specific attenuation and a maximum limit to the total excess loss:

$$A_{et} = d\ \gamma \tag{3}$$

where:

d: length of path within the tree canopy (m)

γ: specific attenuation for very short vegetative paths (dB/m)

and $A_{et} \leq$ lowest excess attenuation for other paths (dB)

The restriction of a maximum value for A_{et} is necessary since, if the specific attenuation is sufficiently high, a lower-loss path will exist around the vegetation. An approximate value for the minimum attenuation for other paths can be calculated as though the tree canopy were a thin finite-width diffraction screen using the method of Recommendation ITU-R P.526, § 4.2.

It is stressed that equation (3), with the accompanying maximum limit on A_{et}, is only an approximation. In general it will tend to overestimate the excess loss due to the vegetation. It is thus most useful for an approximate evaluation of additional loss when planning a wanted service. If used for an unwanted signal it may significantly underestimate the resulting interference.

3.2 Above 3 GHz

Attenuation through vegetation is important for broadband wireless access systems. These systems are typically based on a star network, with a well positioned hub (or base station) serving many individual users with rooftop antennas. In many cases, signals will be obscured by vegetation close to the user antenna. For simplicity, the hub antenna will be referred to as the transmitter and the user antenna as the receiver.

The model only considers propagation through vegetation. The attenuation experienced will be the minimum of the level determined from the following model and the signal diffracted around the vegetation which may be estimated using Recommendation ITU-R P.526, § 4.2.

An empirical model of propagation through vegetation has been developed for frequencies above 3 GHz. The model gives the attenuation through vegetation as a function of vegetation depth, taking into account the dual slope nature of the measured attenuation versus depth curves.

The model was derived from a database of measured data over a range of frequencies 9.6-57.6 GHz, but also takes into account the site geometry in terms of the extent of illumination of the vegetation, defined by the illumination width, W. The attenuation for a vegetation depth, d (m), is given by:

$$A = \frac{R_\infty}{f^a W^b} d + \frac{k}{W^c}\left(1 - \exp\left(-\frac{(R_0 - R_\infty) W^c}{k} d\right)\right) \tag{4}$$

where f is the signal frequency (GHz) and a, b, c, k, R_0 and R_∞ are constants as given in Table 1.

TABLE 1

Constant values for equation (4)

Constant parameter	In leaf	Out of leaf
a	0.7	0.64
b	0.81	0.43
c	0.37	0.97
k	68.8	114.7
R_0	16.7	6.59
R_∞	8.77	3.89

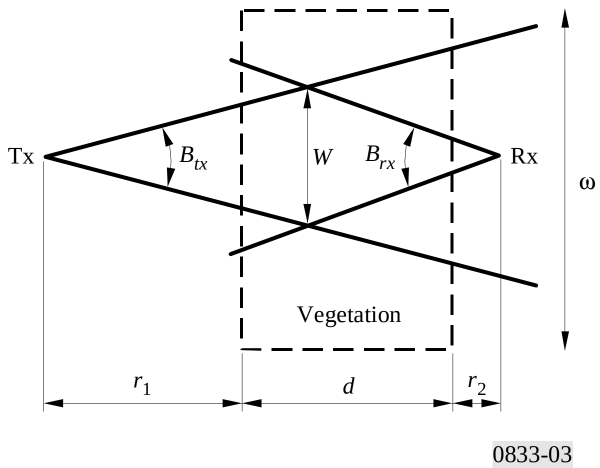
In order to account for the site geometry, one must consider the extent of illumination of the vegetation. This may be characterized by the illumination width, W, as shown in Fig. 3. W is the maximum horizontal dimension within the vegetation common to both transmitter and receiver beamwidths. As this model is an empirical fit to measured data, it should only be applied within the following bounds for W:

$$1 \text{ m} < W < 50 \text{ m}$$

The vertical dimension is not currently modelled. It is assumed that the vegetation fills the vertical dimension of the receiver antenna.

FIGURE 3

Vegetation path geometry



B_{tx} and B_{rx} are the 3 dB beamwidths of the transmitter antenna and the receiver antenna, respectively, ω is the physical width of the vegetation, d is the depth of vegetation and r_1 and r_2 are the distances to the vegetation from the transmitter and receiver, respectively. It is assumed that the receiver is closest to the vegetation.

W is the maximum effective coupling width between the transmitter and receiver antennas that lies within the vegetation medium (i.e. that given at the largest measured vegetation depth), defined by:

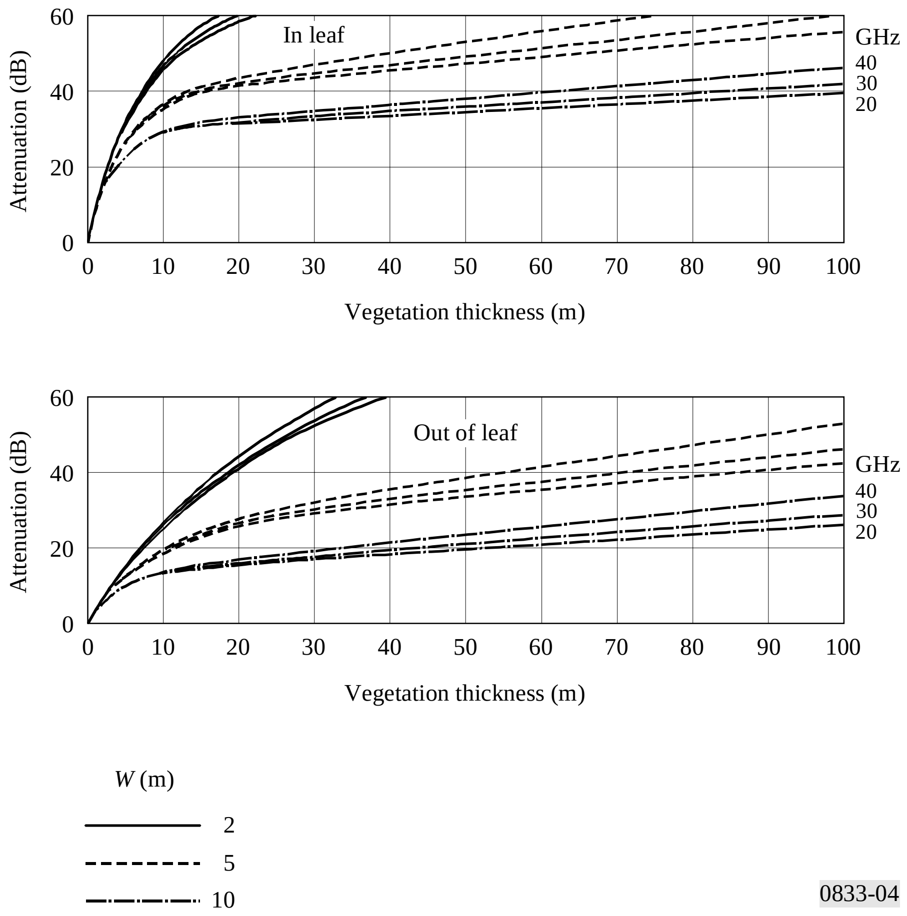
$$W = \min \begin{bmatrix} \dfrac{(r_1 + d + r_2)\ \tan(B_{tx})\ \tan(B_{rx})}{\tan(B_{tx}) + \tan(B_{rx})} \\ (r_1 + d)\tan(B_{tx}) \\ (d + r_2)\tan(B_{rx}) \\ \omega \end{bmatrix} \tag{5}$$

In practice $r_1 >> r_2$ and the beamwidth of the receiver, B_{rx}, is expected to be only a few degrees. Under these conditions the parts of equation (5) containing r_2 will not normally be required.

Figure 4 shows an example of the model for three cases of vegetation width W and three frequencies 20, 30 and 40 GHz for vegetation in and out of leaf. This model for the attenuation due to vegetation as a function of depth through the vegetation can be incorporated into deterministic models (such as ray-based tools using a 3D database of the local building and tree locations) to give a more realistic prediction of the extent of coverage for a given transmitter location.

FIGURE 4

Modelled vegetation attenuation at 20, 30 and 40 GHz for the parameters shown inTable 1



4 Depolarization

Previous measurements at 38 GHz suggest that depolarization through vegetation may well be large, i.e. the transmitted cross-polar signal may be of a similar order to the co-polar signal through the vegetation. However, for the larger vegetation depths required for this to occur, the attenuation would be so high that both the co-polar and cross-polar components would be below the dynamic range of the receiver.