



Recommendation ITU-R P.833-9
(09/2016)

Attenuation in vegetation

P Series
Radiowave propagation



Foreword

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Series of ITU-R Recommendations

(Also available online at <http://www.itu.int/publ/R-REC/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

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.833-9

Attenuation in vegetation

(Question ITU-R 202/3)

(1992-1994-1999-2001-2003-2005-2007-2012-2013-2016)

Scope

This Recommendation presents several models to enable the reader to evaluate the effect of vegetation on radiowave signals. Models are presented that are applicable to a variety of vegetation types for various path geometries suitable for calculating the attenuation of signals passing through vegetation. The Recommendation also contains measured data of vegetation fade dynamics and delay spread characteristics.

Keywords

Vegetation, attenuation, fade dynamics, delay spread, terrestrial systems, Earth-space systems

The ITU Radiocommunication Assembly,

considering

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

recommends

that the content of Annex 1 be used for evaluating attenuation through vegetation with various models addressing a frequency range from 30 MHz to 100 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 Obstruction by woodland**2.1 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:

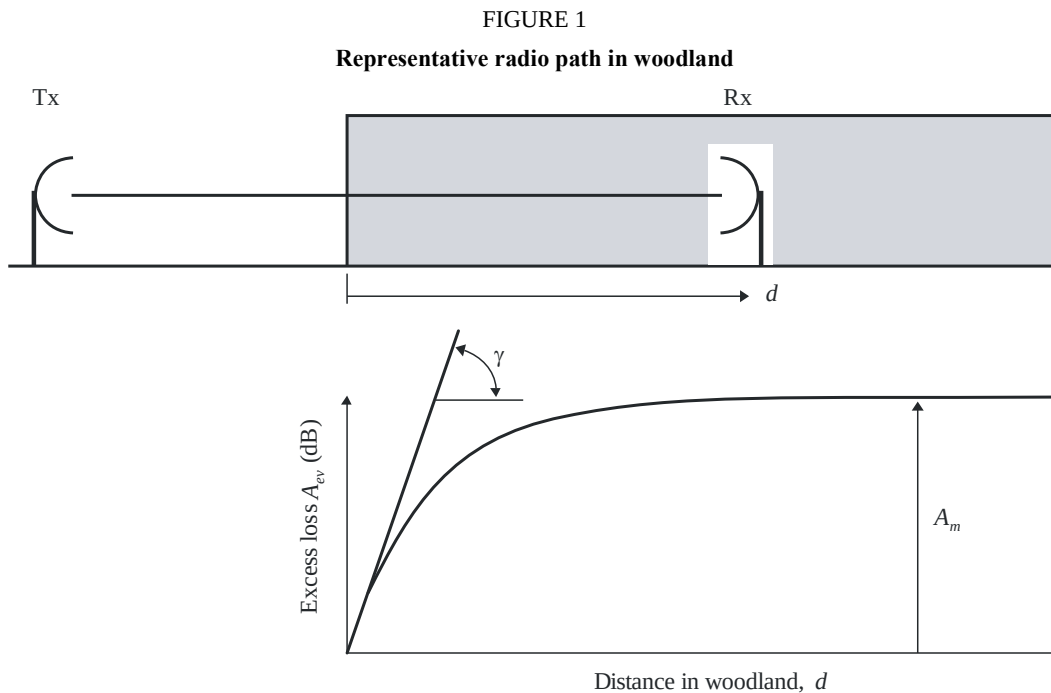
$$A_{ev} = A_m [1 - \exp (- d \gamma / A_m)] \quad (1)$$

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).



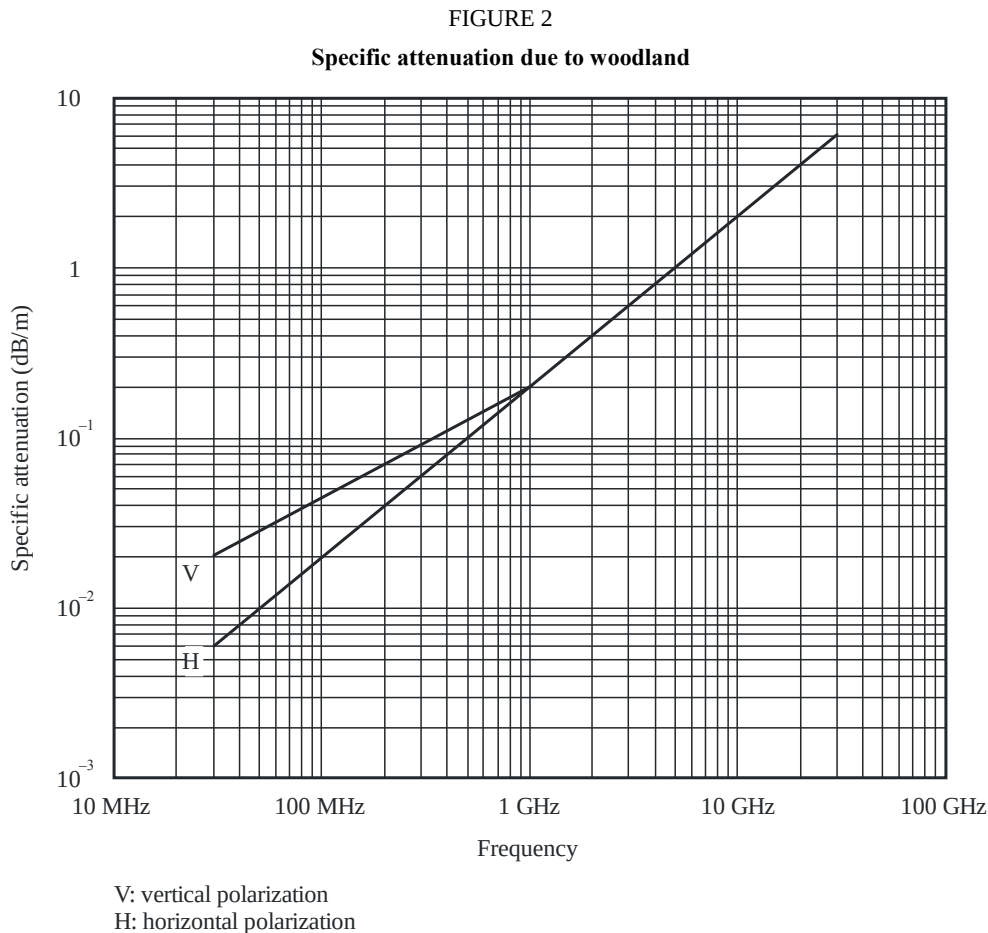
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It is important to note that excess attenuation, A_{ev} , is defined as excess to all other mechanisms, not just free space loss. Thus if the radio path geometry in Fig. 1 were such that full Fresnel clearance from the terrain did not exist, then A_{ev} 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.

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.



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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.

The maximum attenuation, A_m , 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.

Measurements in the frequency range 105-2 200 MHz carried out in mixed coniferous-deciduous vegetation (mixed forest) near St. Petersburg (Russia) on paths varying in length from a few hundred meters to 7 km with various species of trees of mean height 16 m.

These were found to agree on average with equation (1) with constants for specific and maximum attenuation as given in Table 1.

TABLE 1

Parameter	Frequency (MHz) and polarization				
Frequency, MHz	105.9 Horizontal	466.475 Slant	949.0 Slant	1852.2 Slant	2117.5 Slant
γ (dB/m)	0.04	0.12	0.17	0.30	0.34
A_m (dB)	9.4	18.0	26.5	29.0	34.1

A frequency dependence of A_m (dB) of the form:

$$A_m = A_1 f^\alpha \quad (2)$$

where f is the frequency (MHz) has been derived from various experiments:

- Measurements in the frequency range 900-1 800 MHz carried out in a park with tropical trees in Rio de Janeiro (Brazil) with a mean tree height of 15 m have yielded $A_1 = 0.18$ dB and $\alpha = 0.752$. The receiving antenna height was 2.4 m.
- Measurements in the frequency range 900-2 200 MHz carried out in a forest near Mulhouse (France) on paths varying in length from a few hundred metres to 6 km with various species of trees of mean height 15 m have yielded $A_1 = 1.15$ dB and $\alpha = 0.43$. The receiving antenna in woodland was a $\lambda/4$ monopole mounted on a vehicle at a height of 1.6 m and the transmitting antenna was a $\lambda/2$ dipole at a height of 25 m. The standard deviation of the measurements was 8.7 dB. Seasonal variations of 2 dB at 900 MHz and 8.5 dB at 2 200 MHz were observed.
- Measurements in the frequency range 105.9-2 117.5 MHz carried out in two forest-park areas with coniferous-deciduous vegetation (mixed forest) in St. Petersburg (Russia) with a tree height of 12 to 16 m and average distance between them was approximately 2 to 3 m, that corresponds to the density of 20-10 tree/100 m² have yielded $A_1 = 1.37$ dB and $\alpha = 0.42$. To receive the signal, a quarter-wave length dipole antenna at 1.5 m above the ground level was used. The distance between the receiver and the transmitter antenna was 0.4 to 7 km, and paths for measurement were chosen so as to have line-of-sight between these antennas without any obstacles but only the woodland to be measured. Different phases of the experiment were performed in similar weather conditions: dry weather, wind speed 0 to 7 m/s.
- Measurements made in southern England to a depth of 200 m through mixed coniferous-deciduous woodland gave a value for A_m of 46 dB at a frequency of 3 605 MHz. The measurements were made with directional antennas at 2 m and 10 m above ground. Multipath effects were averaged over hundreds of individual measurements made over five paths. Measurements were carried out in summer and winter, but no significant seasonal variation was seen.

2.2 Satellite slant paths

Representative radio path in woodland:

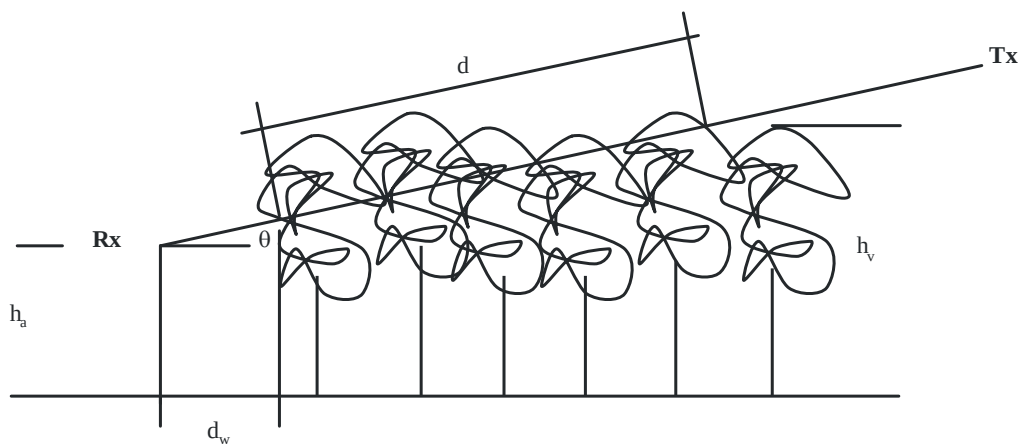
In Fig. 3, Transmitter (TX) and Receiver (RX) are outside the woodland. The relevant parameters are:

- vegetation path length, d ;
- average tree height, h_v ;
- height of the Rx antenna over ground, h_a ;

- radio path elevation, θ ;
- distance of the antenna to the roadside woodland, d_w .

FIGURE 3

Representative radio path in woodland with vegetation path length, d , average tree height, h_v , height of the Rx antenna over ground, h_a , radio path elevation, θ , and distance of the antenna to the roadside woodland, d_w



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To describe the attenuation loss, L along both, horizontal and slant foliage path propagation, the following model is proposed:

$$L(\text{dB}) = A f^B d^C (\theta + E)^G \quad (3)$$

where:

- f : frequency (MHz)
- d : vegetation depth (m)
- θ : elevation (degrees)

A, B, C, E , and G : empirical found parameters.

A fit to measurements made in pine woodland in Austria gave:

$$L(\text{dB}) = 0.25 f^{0.39} d^{0.25} \theta^{0.05} \quad (4)$$

3 Single vegetative obstruction

3.1 At or below 1 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 modelled on an approximate basis in terms of the specific attenuation and a maximum limit to the total excess loss:

$$A_{et} = d \gamma \quad (5)$$

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.

It is stressed that equation (5), 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 1 GHz

For terrestrial paths, the method based on RET described in § 3.2.1 should be applied to compute the effect of a single tree.

For slant paths, the method based on multiple scattering theory described in § 3.2.2 should be applied to compute the effect of a single tree.

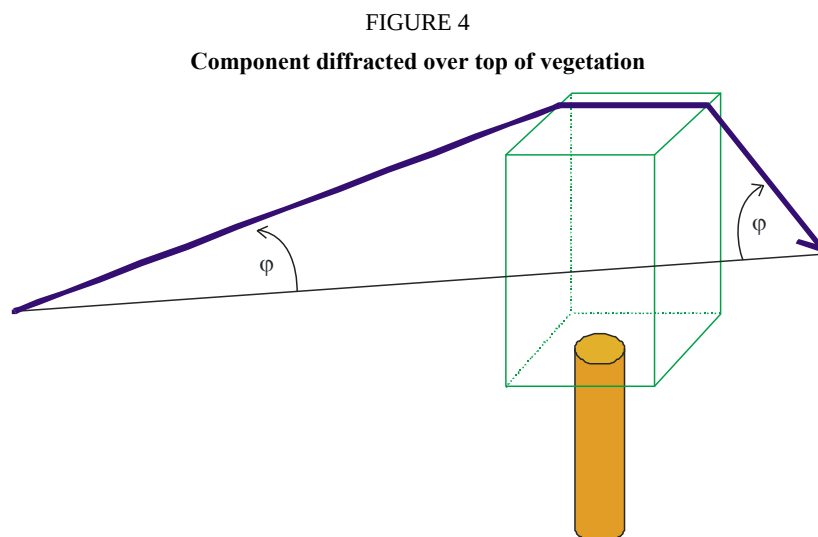
3.2.1 Terrestrial path

In order to estimate the total field, the diffracted, ground reflected and through-vegetation scattering components are first calculated and then combined.

The diffracted components consist of those over the top of the vegetation and those around the sides of the vegetation. These components and the ground reflected component are calculated using ITU-R Recommendations. The through or scattered component is calculated using a model based upon the theory of radiative energy transfer (RET).

3.2.1.1 Calculation of the top diffracted component

The diffraction loss, L_{top} , experienced by the signal path diffracted over the vegetation, may be treated as double isolated knife-edge diffraction for the geometry defined in Fig. 4.



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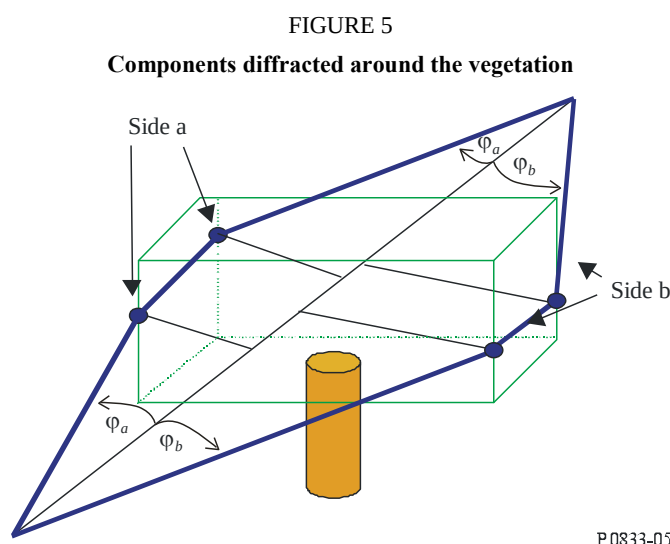
This is calculated as follows:

$$L_{top} = L_{top_diff} + G_{Tx}(\varphi) + G_{Rx}(\varphi) \quad (6)$$

where $G_{Tx}(\varphi)$ and $G_{Rx}(\varphi)$ are the losses due to angles of the diffracted wave leaving the transmit antenna and coming into the receive antenna, respectively. L_{top_diff} is the total diffraction loss as calculated using the method of Recommendation ITU-R P.526 for double isolated edges.

3.2.1.2 Calculation of the side diffracted component

The diffraction loss, L_{sidea} and L_{sideb} , experienced by the signal diffracted around the vegetation, may again be treated as double isolated knife-edge diffraction, for the geometry defined in Fig. 5.



The losses are calculated using equations (7) and (8).

$$L_{sidea} = L_{diff_sidea} + G_{Tx}(\varphi_a) + G_{Rx}(\varphi_a) \quad (7)$$

and

$$L_{sideb} = L_{diff_sideb} + G_{Tx}(\varphi_b) + G_{Rx}(\varphi_b) \quad (8)$$

where $G_{Tx}(\varphi_{a,b})$ and $G_{Rx}(\varphi_{a,b})$ are the losses due to angles of the diffracted wave leaving the transmit antenna and coming into the receive antenna, for sides a and b, respectively. L_{diff_sidea} and L_{diff_sideb} are the total diffraction loss around each side found using the method of Recommendation ITU-R P.526 for double isolated edges.

3.2.1.3 Calculation of the ground reflected component

It is assumed that the path is sufficiently short that the ground reflected wave may be modelled by the geometry shown in Fig. 6.