RECOMMENDATION ITU-R P.525-2[[1]](#footnote-1)\*

CALCULATION OF FREE-SPACE ATTENUATION

(1978-1982-1994)

Rec. ITU-R P.525-2

The ITU Radiocommunication Assembly,

considering

a) that free-space propagation is a fundamental reference for radio-engineering,

recommends

**1.** that the methods in Annex 1 be used for the calculation of attenuation in free space.

ANNEX 1

# 1. Introduction

As free-space propagation is often used as a reference in other texts, this Annex presents relevant formulae.

# 2. Basic formulae for telecommunication links

Free-space propagation may be calculated in two different ways, each of which is adapted to a particular type of service.

## 2.1 Point-to-area links

If there is a transmitter serving several randomly-distributed receivers (broadcasting, mobile service), the field is calculated at a point located at some appropriate distance from the transmitter by the expression:

 (1)

where:

*e* : r.m.s. field strength (V/m) (see Note 1)

*p* : equivalent isotropically radiated power (e.i.r.p.) of the transmitter in the direction of the point in question (W) (see Note 2)

*d*: distance from the transmitter to the point in question (m).

Equation (1) is often replaced by equation (2) which uses practical units:

 (2)

For antennas operating in free-space conditions the cymomotive force may be obtained by multiplying together*e* and *d* in equation (1). Its dimension is volts.

*Note 1* – If the wave is elliptically polarized and not linear, and if the electric field components along two orthogonal axes are expressed by *ex* and *ey*, the left-hand term of equation (1) should be replaced by . *ex* and *ey* can be deduced only if the axial ratio is known. *e* should be replaced by *e* in the case of circular polarization.

*Note 2* – In the case of antennas located at ground level and operating on relatively low frequencies with vertical polarization, radiation is generally considered only in the upper half-space. This should be taken into account in determining the e.i.r.p. (see Recommendation ITU‑R PN.368).

## 2.2 Point-to-point links

With a point-to-point link it is preferable to calculate the free-space attenuation between isotropic antennas, also known as the free-space basic transmission loss (symbols: *Lbf* or *A*0), as follows:

mmmmmmdB (3)

where:

*Lbf* : free-space basic transmission loss (dB)

*d*: distance

 : wavelength, and

*d* and  are expressed in the same unit.

Equation (3) can also be written using the frequency instead of the wavelength.

*Lbf* = 32.4  20 log  20 log *d*mmmmmmdB (4)

where:

*f*: frequency (MHz)

*d* : distance (km).

## 2.3 Relations between the characteristics of a plane wave

There are also relations between the characteristics of a plane wave (or a wave which can be treated as a plane wave) at a point:

 (5)

where:

*s* : power flux-density (W/m2)

*e* : r.m.s. field strength (V/m)

*pr* : power (W) available from an isotropic antenna located at this point

 : wavelength (m).

# 3. The free-space basic transmission loss for a radar system (symbols: *Lbr* or *A*0*r*)

Radar systems represent a special case because the signal is subjected to a loss while propagating both from the transmitter to the target and from the target to the receiver. For radars using a common antenna for both transmitter and receiver, a radar free-space basic transmission loss, *Lbr*, can be written as follows:

*Lbr*  103.4  20 log  40 log *d* – 10 log mmmmmmdB (6)

where:

 : radar target cross-section (m2)

*d*: distance from the radar to the target (km)

*f*: frequency of the system (MHz).

The radar target cross-section of an object is the ratio of the total isotropically equivalent scattered power to the incident power density.

# 4. Conversion formulae

On the basis of free-space propagation, the following conversion formulae may be used.

Field strength for a given isotropically transmitted power:

*E*  *Pt* – 20 log *d*  74.8 (7)

Isotropically received power for a given field strength:

*Pr*  *E* – 20 log *f* – 167.2 (8)

Free-space basic transmission loss for a given isotropically transmitted power and field strength:

*Lbf*  *Pt* – *E*  20 log *f*  167.2 (9)

Power flux-density for a given field strength:

*S*  *E* – 145.8 (10)

where:

*Pt* : isotropically transmitted power (dB(W))

*Pr* : isotropically received power (dB(W))

*E* : electric field strength (dB(V/m))

*f* : frequency (GHz)

*d* : radio path length (km)

*Lbf* : free-space basic transmission loss (dB)

*S* : power flux-density (dB(W/m2)).

Note that equations (7) and (9) can be used to derive equation (4).

1. \* Radiocommunication Study Group 3 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44. [↑](#footnote-ref-1)