RECOMMENDATION ITU-R BS.561-2*,**

Definitions of radiation in LF, MF and HF broadcasting bands

(1978-1982-1986)

The ITU Radiocommunication Assembly,

recommends

that the following terminology should be used to define and determine the radiation from sound-broadcasting transmitters:

1 Cymomotive force (c.m.f.) (in a given direction)

The product formed by multiplying the electric field strength at a given point in space, due to a transmitting station, by the distance of the point from the antenna. This distance must be sufficient for the reactive components of the field to be negligible; moreover, the finite conductivity of the ground is supposed to have no effect on propagation.

The cymomotive force (c.m.f.) is a vector; when necessary it may be expressed in terms of components along axes perpendicular to the direction of propagation.

The c.m.f. is expressed in volts; it corresponds numerically to the field strength in mV/m at a distance of 1 km.

2 Effective monopole-radiated power (e.m.r.p.) (in a given direction)

The product of the power supplied to the antenna and its gain relative to a short vertical antenna in the given direction. (Radio Regulations, No. 1.163.)

Radio Regulations No. 1.160 (c) defines the gain of an antenna in a given direction relative to a short vertical antenna G_V as the gain relative to a loss-free reference antenna consisting of a linear conductor, much shorter than one quarter of a wavelength, normal to the surface of a perfectly conducting plane which contains the given direction.

The reference antenna, when fed with a power of 1 kW, is considered to radiate an e.m.r.p. of 1 kW in any direction in the perfectly conducting plane and produces a field strength of 300 mV/m at 1 km distance (equivalent to a c.m.f. of 300 V).

An e.m.r.p. of 1 kW is assumed in the derivation of the ground-wave propagation curves of Recommendation ITU-R P.368. An e.m.r.p. of 1 kW at all angles of elevation is assumed in the presentation of the sky-wave curves of Recommendation ITU-R P.1147.

NOTE 1 – Definitions 1 and 2 are mainly used in LF and MF broadcasting.

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* This Recommendation should be brought to the attention of the CCV.

** Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2002 in accordance with Resolution ITU-R 44.

3 Equivalent isotropically radiated power (e.i.r.p.)

The product of the power supplied to the antenna and the antenna gain G_i in a given direction relative to an isotropic antenna (absolute or isotropic gain) (Radio Regulations, No. 1.161).

The idealized reference antenna, when fed with a power of 1 kW, is considered to provide an e.i.r.p. of 1 kW in all directions and to produce a field strength of 173 mV/m at 1 km distance.

4 Effective radiated power (e.r.p.) (in a given direction)

The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction (Radio Regulations, No. 1.162).

Radio Regulations No. 1.160 (b) defines the gain of an antenna in a given direction relative to a half-wave dipole G_d, as the gain relative to a loss-free reference antenna isolated in space whose equatorial plane contains the given direction.

The reference antenna, when fed with a power of 1 kW, is considered to radiate an e.r.p. of 1 kW in any direction in the equatorial plane and produces a field strength of 222 mV/m at 1 km distance.

NOTE 1 – Definitions 3 and 4 are mainly used in HF broadcasting.

NOTE 2 – The relationship between the radiated power expressed in the different units is given in Annex 1.

NOTE 3 – For information, some guidance on the determination of the radiated power is given in Annex 2.

NOTE 4 – For information, radiated power standards for propagation curves are discussed in Annex 3.

ANNEX 1

Relationship between radiated powers expressed in different units

1 Relationship between e.m.r.p. and c.m.f.

The value of the e.m.r.p. is related to the c.m.f. (V) by the expression:

$$\text{e.m.r.p.} = (\text{c.m.f.}/300)^2 \text{ (kW)}$$

Table 1 gives some practical examples of c.m.f. and e.m.r.p. in the absence of losses.

TABLE 1

Transmitter power (kW)	Antenna	Gain relative to a short vertical antenna (dB)	c.m.f. (V)	c.m.f. (dB (300V))	e.m.r.p. (kW)
0.01	short vertical	0	30	–20	0.01
0.1	short vertical	0	95	–10	0.1
1	short vertical	0	300	0	1
10	short vertical	0	950	+10	10
100	λ/2 vertical	2	3 800	+22	160
300	λ/2 vertical	2	6 600	+27	475
1 000	λ/2 vertical	2	12 000	+32	1 600

2 Relationship between e.r.p. and e.i.r.p.

The value of the e.r.p. is related to the e.i.r.p. by the expression:

e.r.p. = 0.61 e.i.r.p. (linear scale)

e.r.p. = e.i.r.p. – 2.2 dB (logarithmic scale)

ANNEX 2

Determination of the radiated power

1 Vertical antennas

For vertical antenna systems which are actually in operation, the radiation in a horizontal direction is obtainable by measurements of field strength on a radial line over the range, 2λ to 15λ, from the antenna system. Here, λ is taken to be either the wavelength or the maximum dimensions of the antenna, whichever is the greater, in order to avoid the effect of reactive fields. If E is the field strength at distance, d, the product, Ed, is plotted graphically against d. The line is extrapolated to $d = 0$, and the product ($E_0 d_0$) gives the c.m.f.

For a single mast, it is desirable to take the average of values for a few radials. For a multiple mast system, separate measurements are required on a number of radials to establish the radiated power as a function of bearing.

For directions above the horizontal, a correction should be derived theoretically from the behaviour over a perfectly conducting plane. Alternatively, field-strength measurements may be made from a helicopter.

For antenna systems which have not yet been constructed, or whenever for some other reason measurements cannot be made reliably, the radiated power may be estimated from a calculation of the system performance over a perfectly conducting surface, and from the estimated efficiency of the antenna system.

2 Horizontal antennas

In this case, the most practical method is a computation in which the gain of the antenna, assumed to be situated above perfectly conducting ground, and the total transmitter power (less the feeder loss) determine the radiated power. If applicable, the radiated power should be the combination of two orthogonal components, perpendicular to the direction of propagation, made on a root mean square basis.

3 Transmitter carrier power as a function of c.m.f.

For a single vertical mast radiator, neglecting losses:

$$p = (F_c/300)^2 \cdot (1/G_v) \tag{1}$$

where,

- p: transmitter carrier power (kW);
- F_c: c.m.f. in the horizontal direction (V);
- G_v: gain of antenna relative *to a short vertical antenna*.

More generally, the *total power radiated* into space (in other words, the power to be supplied to the antenna if losses are neglected) is related to the c.m.f. by:

$$W = \frac{1}{120\,\pi} \int\!\!\int_{sphere} F_c^2\,(\varphi, \theta) \cos\theta \cdot \mathrm{d}\theta\,\mathrm{d}\varphi \tag{2}$$

where F_c (φ, θ) is the c.m.f. as a function of the azimuth φ and the angle of elevation θ, (W is in watts and F_c is in volts).

ANNEX 3

Radiated power standards for propagation curves

The ground-wave propagation curves of Recommendation ITU-R P.368 and the sky-wave propagation curves given in Recommendation ITU-R P.1147 are drawn nominally for a field strength of 300 mV/m at 1 km and thus apply to a c.m.f. of 300 V. However, the sky-wave curves were established from measurements to which a correction was applied in each case for the vertical radiation pattern (over good ground) of the transmitting antenna; but no correction was applied for the effect of finite ground conductivity on the sky-wave field strength. These curves therefore, include the effect of average ground conductivity, which (as compared with a perfectly conducting ground) can cause significant reduction of sky-wave at low angles. This effect is discussed in Report ITU-R BS.401. It can be shown that for all types of vertical antenna systems of interest for applications in bands 5 (LF) and 6 (MF), the ground effect is substantially independent of the type of antenna, and correction for the antenna gain and vertical radiation pattern may be made with good accuracy by correcting the calculated pattern for a perfectly conducting flat earth.

The practice is already established for propagation curves at LF and MF to apply for an e.m.r.p. of 1 kW from a short vertical antenna and this corresponds to a c.m.f. in the horizontal direction of 0 dB relative to 300 V.

An e.i.r.p. of 1 kW at all angles of elevation is generally used in HF propagation prediction methods.