

3A b: Antennas characteristics

RECOMMENDATION 162-3*

USE OF DIRECTIONAL TRANSMITTING ANTENNAS IN THE FIXED SERVICE OPERATING IN BANDS BELOW ABOUT 30 MHz

(Question 150/9)

(1953-1956-1966-1970-1992)

The CCIR,

considering

- a) that there is serious congestion in the fixed service bands between 4 and 28 MHz;
- b) that occupancy of the radio-frequency spectrum is represented, not only by occupancy in bandwidth and time, but also by the spatial distribution of the radiated power;
- c) that radiation outside the directions necessary for the service can be effectively reduced by the use of directional antennas;
- d) that Articles 5, 18 and 19 of the Radio Regulations would seem to justify explicit requirements for the use of directional antennas in these bands;
- e) that the Panel of Experts, in Recommendation No. 13 of its Final Report, Geneva, 1963, advocates the use of directional antennas for transmission and reception in the fixed service;
- f) that the request by the Panel of Experts in Recommendation No. 38 of its Final Report, and the urgent question of the IFRB, Question 150/9, ask for specification of reasonable standards of directivity for antennas in the various types of radio services in the bands between 4 and 28 MHz, with due regard to economy of cost;
- g) that the adoption of minimum standards for directional antennas would contribute to the solution of frequency sharing problems;
- h) that antenna performance materially better than these minimum standards is attainable at economic cost using modern techniques,

recommends

- 1. that the following definitions should be used in specifying the performance of directional antennas:

1.1 *Directivity, G_0 ***

In a given direction, 4π times the ratio of the intensity of radiation (power per unit solid angle (steradian)), in that direction, to the total power radiated by the antenna.

1.2 *Service sector, S*

The horizontal sector containing the main beam of the antenna radiation and including the direction required for service. It is very close to twice the angular width of the main beam measured to the half-power (-3 dB) points.

* This Recommendation should be brought to the attention of the IFRB. This text concludes the studies of Question 150/9.

** See No. 154 of the Radio Regulations for a definition of power gain.

1.3 Interference sector, I

The horizontal sector outside the main beam

$$I^\circ = 360^\circ - S^\circ$$

1.4 Minimum standard antenna

The antenna having the specified minimum characteristics as regards directivity and service sector at its operating frequency or frequencies.

1.5 Economic standard antenna

The antenna having the specified characteristics as regards directivity and service sector at its operating frequency or frequencies which are justifiable on economic grounds (i.e. by savings in the cost of providing a given transmitter output power).

1.6 Antenna directivity factor, M^*

The ratio of the power flux-density in the wanted direction to the average value of power flux-density at crests in the antenna directivity pattern in the interference sector. This is equivalent to the average improvement in signal-to-interference ratio achieved by using the actual antenna in place of an isotropic radiator in free space;

2. that the minimum standard antenna should have a directivity factor given by:

$$M = 0.1f^2$$

f being the operating frequency in MHz;

3. that the economic standard antenna should have a directivity factor given by:

$$M = 0.25f^2$$

4. that, for a radiated power of 5 kW or greater, the directivity factor, M , of the antenna used should be equal to or greater than that of the minimum standard antenna;

5. that, for a radiated power of 10 kW or greater, antennas having performances not worse than that of the economic standard antenna should be used to the extent practicable;

6. that, for transmitter powers below 5 kW, the power flux-density in the interference sector should not exceed that radiated in this sector from the minimum standard antenna with a total radiated power of 5 kW;

7. that, in the interests of reducing the effects of interference, the directivity factor, M , of the receiving antenna should be equal to or greater than that of the minimum standard antenna and should, as far as practicable, attain that of the economic standard antenna.

Furthermore, when calculated gains, based on constant-current formulae, are used to determine the M -factor, adjustment should be made to allow for the current decay along the actual antenna. Methods of making these adjustments are described in Annex 1.

No preferred polarization or type of antenna is established. Horizontal polarization offers better ground reflection characteristics and, for receiving, some reduction of interference due to man-made noise. Where reflection over sea water or over earth of very high conductivity takes place, the use of vertical polarization can enhance the low-angle performance needed for long paths. This important consideration is reflected in the computation of M , which includes a weighting factor $10/\Delta$, where Δ is the vertical angle of optimum radiation. There is no requirement for the transmitting and receiving antennas to have the same polarization characteristics because of the randomization of the polarization in the ionospheric transmission process.

* The derivation of the directivity factor for any given antenna is explained in Annex 1.

The M -factors chosen are largely based upon the measured performance of typical rhombic antennas and typical antenna-arrays. The radiation characteristics of single rhombic antennas in the interference zone are, in general, somewhat inferior to other types of antenna (e.g. half-wave antenna arrays), a fact which is reflected in the M -factor. Provided the parameters are correctly chosen, the performance of antennas of differing types possessing the same M -factor is comparable;

8. that Annex 1 should be referred to for the values of directivity and service sector;
9. that Annex 2 should be referred to for a detailed explanation of directional antennas;
10. that Annex 3 should be referred to for a description of directional arrays with aperiodic reflector.

ANNEX 1

Values of directivity and service sector

The values of directivity and service sector appropriate to the specified values of M for the minimum standard antenna and the economic standard antenna respectively are given in the following Table 1:

TABLE 1

Operating frequency f (MHz)	Minimum standard antenna			Economic standard antenna		
	M	G_0 (dB)	S°	M	G_0 (dB)	S°
5	2.5	13.8	54	6.25	17.5	35
10	10	16.6	39	25	20.4	25
15	22.5	18.3	32	57	22.1	21
20	40	19.4	28	100	23.3	18

The antenna gain relative to a half-wave dipole above earth may be obtained by subtracting 8 dB from the value of G_0 . It should be noted that the S value is the minimum bound at the directivity specified and has been derived on the assumption that at least 40% of the total power is radiated in the main beam (a value appropriate to many rhombic antennas). Where (as is commonly the case) the (power) gain of the antenna (No. 154 of the Radio Regulations) is known, a suitable adjustment should be made to account for the efficiency of the antenna in deriving the directivity.

Use of directional antennas in the bands 4 to 28 MHz

1. Introduction

This Annex discusses the problem of specifying reasonable standards for the directivity of antennas in the various types of radio service, and for various distances, in the bands between 4 and 28 MHz with due regard to economy of cost. It is mainly concerned with point-to-point circuits longer than 4 000 km but, with suitable modifications, could be applied to shorter range circuits. The technique discussed requires a knowledge of the gain of the antenna under consideration and the angular widths in zenith and azimuth of its main beam of radiation. With this information a directivity factor is derived which, used in conjunction with certain other factors, for example, transmitter power and provision cost, may be used to assess the suitability of an antenna for any particular application.

2. Proposition

An antenna possessing a given directivity which radiates all its power in a single beam could be regarded as having the best attainable performance of its class. Communication systems using such antennas for emission and reception could operate on a common frequency with a given spatial distribution without risk of mutual interference, the only condition being that each receiving antenna should "see" only the wanted transmitting antenna. With such an ideal arrangement the number of systems sharing the same frequency would increase as a function of the gain of the antennas because of their smaller angular beamwidth.

By making certain simplifying but justifiable assumptions, it can be shown that to a high degree of approximation there is a fixed relationship between the directivity (relative to an isotropic radiator) and the angular widths of this single beam (to the null) as follows:

$$G = \frac{P_0}{P} = \frac{32 \pi^2}{(\pi^2 - 4) \theta_0 \varphi_0} = \frac{K}{\theta_0 \varphi_0} \quad (1)$$

(θ_0 and φ_0 are the horizontal and vertical angular widths respectively, in radians and P , P_0 are the total powers radiated from the ideal antenna and the isotropic radiator respectively to produce the same field in the desired direction).

Practical antennas fall some way short of this ideal in that a proportion of the power is radiated (or received) in directions other than in the main beam.

If the directivity of such an antenna is G' and the widths of its main beam are θ_0' , φ_0' , then from equation (1), the power radiated in the main beam:

$$P' = \frac{P_0 \theta_0' \varphi_0'}{K} \quad (2)$$

If this represents a fraction q of the total radiated power,

$$G' = \frac{P_0 q}{P'} = \frac{Kq}{\theta_0' \varphi_0'} \quad (3)$$

or

$$q = \frac{G' \theta_0' \varphi_0'}{K} \quad (4)$$