I n t e r n a t i o n a l   T e l e c o m m u n i c a t i o n   U n i o n

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R F.1245-1

(05/2000)

Mathematical model of average and related radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

F Series

Fixed service

International
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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 F.1245-1*

MATHEMATICAL MODEL OF AVERAGE AND RELATED RADIATION PATTERNS FOR LINE-OF-SIGHT POINT-TO-POINT RADIO-RELAY SYSTEM ANTENNAS FOR USE IN CERTAIN COORDINATION STUDIES AND INTERFERENCE ASSESSMENT IN THE FREQUENCY RANGE FROM 1 GHz TO ABOUT 70 GHz

(Question ITU-R 110/9)

(1997-2000)

The ITU Radiocommunication Assembly,

considering

a) that the reference radiation pattern of line-of-sight point-to-point radio-relay system antennas stated in Recommendation ITU-R F.699 gives the peak envelope of side-lobe patterns;

b) that if the peak envelope radiation pattern is used in the assessment of the aggregate interference consisting of many interference entries, the predicted interference will result in values that are greater than values that would be experienced in practice;

c) that, therefore, it is necessary to use the antenna radiation pattern representing average side-lobe levels in the following cases:

– to predict the aggregate interference to a geostationary or non-geostationary satellite from numerous radio-relay stations;
– to predict the aggregate interference to a radio-relay station from many geostationary satellites;
– to predict interference to a radio-relay station from one or more non-geostationary satellites under the continuously variable angle which should be averaged;
– in any other cases where the use of the radiation pattern representing average side-lobe levels is appropriate;

d) that a simple mathematical formula is preferable to the radiation pattern representing average side-lobe levels;

e) that a mathematical model is also required for generalized radiation patterns of antennas for statistical interference analyses involving a few interference entries such as from geostationary satellites into systems in the fixed service,

recommends

1 that, in the absence of particular information concerning the radiation pattern of the line-of-sight radio-relay system antenna involved, the mathematical model of the average radiation pattern as stated below should be used for the applications referred to in *considering* c);

2 that the following mathematical model of the average radiation pattern should be adopted for frequencies in the range 1-40 GHz and provisionally in the range 40 GHz to about 70 GHz;

2.1 in cases where the ratio between the antenna diameter and the wavelength is greater than 100 ($D/\lambda > 100$), the following equation should be used (see Note 1):

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 \quad \text{for} \quad 0^\circ < \varphi < \varphi_m$$

$$G(\varphi) = G_1 \quad \text{for} \quad \varphi_m \le \varphi < \max(\varphi_m, \varphi_r)$$

$$G(\varphi) = 29 - 25 \log \varphi \quad \text{for} \quad \max(\varphi_m, \varphi_r) \le \varphi < 48^\circ$$

$$G(\varphi) = -13 \quad \text{for} \quad 48^\circ \le \varphi \le 180^\circ$$

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* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4 (WP 4A), 6 (WP 6S) 7 (WP 7B), 8 (WP 8D) and Working Party 4-9S.

where:

G_{max}: maximum antenna gain (dBi) (see Note 2)

$G(\varphi)$: gain (dBi) relative to an isotropic antenna

φ: off-axis angle (degrees)

D: antenna diameter
λ: wavelength
(expressed in the same unit)

G_1: gain of the first side lobe
= $2 + 15 \log (D/\lambda)$

$$\varphi_m = \frac{20\,\lambda}{D} \sqrt{G_{max} - G_1} \qquad \text{degrees}$$

$$\varphi_r = 12.02\,(D/\lambda)^{-0.6} \qquad \text{degrees}$$

2.2 in cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100 ($D/\lambda \le 100$), the following equation should be used (see Notes 3 and 7):

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 \qquad \text{for} \quad 0° < \varphi < \varphi_m$$

$$G(\varphi) = 39 - 5 \log (D/\lambda) - 25 \log \varphi \qquad \text{for} \quad \varphi_m \le \varphi < 48°$$

$$G(\varphi) = -3 - 5 \log (D/\lambda) \qquad \text{for} \quad 48° \le \varphi \le 180°$$

3 that Annex 1 may be provisionally referred to for generalized radiation patterns of point-to-point radio-relay system antennas which may be used only in statistical interference analyses involving a few interference entries such as from geostationary satellites into systems in the fixed service (see Note 9);

4 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – The average side-lobe levels in § 2.1 are 3 dB lower than peak envelope side-lobe levels in § 2.1 of Recommendation ITU-R F.699.

NOTE 2 – The relationship between G_{max} and D/λ is given in Recommendation ITU-R F.699.

NOTE 3 – The mathematical model in § 2.2 was derived from the condition that the total power emitted from the antenna should not exceed the total power fed into the antenna.

NOTE 4 – The radiation pattern in § 2 is only applicable for one polarization (horizontal or vertical).

NOTE 5 – The radiation pattern included in this Recommendation is only for antennas which are rotationally symmetrical.

NOTE 6 – The average radiation pattern in this Recommendation may be somewhat different from radiation patterns of actual antennas. The purpose of this Recommendation is solely to provide a mathematical model for use in interference assessment for the applications referred to in *considering* c).

NOTE 7 – Radio-relay antennas generally employ linear polarization. Therefore, when the interference from a system employing circular polarization, such as in the mainbeam-to-mainbeam coupling from space stations, is evaluated, the effective radio-relay antenna gain, $G_{eff}(\varphi)$, taking account of polarization advantage, may be estimated by using the following formula in the main-lobe region ($0 < \varphi < \varphi_m$) instead of the first formula in § 2.2:

$$G_{eff}(\varphi) = 10 \log \left(10^{0.1 G(\varphi)} + 0.02 \times 10^{0.1 G_{max}} \right) - 3 \qquad \text{dBi}$$

where $G(\varphi)$ is the gain according to the first formula in § 2.2.

The above formula assumes that the cross-polarized antenna gain for $0 < \varphi < \varphi_m$ is 17 dB lower than G_{max}. The polarization advantage should not be expected for $\varphi > \varphi_m$ or when the radio-relay station is outside the main beam of the antenna of the other service.

A similar formula applicable to § 2.1 requires further study.

NOTE 8 – Administrations and other members of ITU-R are encouraged to provide information comparing the average side-lobe levels and the generalized radiation patterns given in this Recommendation with those obtained by radiation pattern measurements on real antennas. This information may assist in the further development of this Recommendation.

NOTE 9 – Administrations and other members of ITU-R are encouraged to examine the feasibility of expanding the application of the model in Annex 1.

ANNEX 1

Mathematical model of generalized radiation patterns of point-to-point fixed-service antennas for use in statistical interference assessment

1 Introduction

Recommendation ITU-R F.699 gives the reference radiation patterns of point-to-point fixed service antennas, based on the peak envelope of side-lobe levels. Therefore, the interference assessment using this Recommendation will inevitably lead to overestimation of interference.

On the other hand, the main text of this Recommendation gives a mathematical model for average radiation patterns of point-to-point fixed service antennas, representing average side-lobe levels. However, this can be applied only in the case of multiple interference entries or time-varying interference entries.

A mathematical model is required for generalized radiation patterns of antennas for use only in spatial statistical analysis such as deriving the probability distribution function (pdf) of interference from a few GSO satellite systems into a large number of interfered with fixed service systems or stations.

2 Antennas with D/λ greater than 100

The reference radiation pattern of antennas with D/λ greater than 100 representing peak envelope side-lobe levels is given by *recommends* 2.1 of Recommendation ITU-R F.699. According to *recommends* 2.1 of this Recommendation, the average side-lobe level is 3 dB below the peak envelope side-lobe level. It seems reasonable to assume that the actual side-lobe levels vary sinusoidally. Therefore, the actual radiation pattern will be expressed as follows:

$$G(\varphi) = \max\,[G_a(\varphi), G_b(\varphi)] \qquad \text{for } 0 \le \varphi < \varphi_r \qquad (1a)$$

$$G(\varphi) = 32 - 25 \log \varphi + F(\varphi) \qquad \text{for } \varphi_r \le \varphi < 48^\circ \qquad (1b)$$

$$G(\varphi) = -10 + F(\varphi) \qquad \text{for } 48^\circ \le \varphi \le 180^\circ \qquad (1c)$$

where:

$$G_a(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 \qquad (1d)$$

$$G_b(\varphi) = G_1 + F(\varphi) \qquad (1e)$$

$$G_1 = 2 + 15 \log (D/\lambda) \qquad \text{dB} \qquad (2a)$$

$$\varphi_r = 15.85 \left(\frac{D}{\lambda} \right)^{-0.6} \qquad \text{degrees} \qquad (2b)$$

$$F(\varphi) = 10 \log \left(0.9 \sin^2 \left(\frac{3 \pi \varphi}{2 \varphi_r} \right) + 0.1 \right) \qquad \text{dB} \qquad (2c)$$

where φ_r is assumed to correspond to the off-axis angle of the peak of the first side-lobe and the phase at $\varphi = \varphi_r$ is assumed to be 1.5π. It should be noted that the argument of sin function in equation (2c) is expressed in radians and that the value of $F(\varphi)$ is nearly zero or negative. $F(\varphi) = 0$ corresponds to side-lobe peaks. The parameter 0.1 is introduced in equation (2c) in order to avoid the situation that $F(\varphi)$ falls below –10 dB.

3 Antennas with *D*/λ equal to or smaller than 100

In the case of antennas with D/λ equal to or smaller than 100, it will be assumed that side-lobe peak levels are 3 dB higher than the average side-lobe level given in the main text of this Recommendation.

Thus, the following pattern is provisionally presented as a generalized radiation pattern of the antenna with D/λ equal to or smaller than 100:

$$G(\varphi) = \max\,[G_a(\varphi),\, G_b(\varphi)] \qquad \text{for} \quad 0 \leq \varphi < \varphi_r \tag{3a}$$

$$G(\varphi) = 42 - 5\log(D/\lambda) - 25\log\varphi + F(\varphi) \qquad \text{for} \quad \varphi_r \leq \varphi < 48^\circ \tag{3b}$$

$$G(\varphi) = -5\log(D/\lambda) + F(\varphi) \qquad \text{for} \quad 48^\circ \leq \varphi \leq 180^\circ \tag{3c}$$

where:

$$G_a(\varphi) = G_{max} - 2{,}5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \tag{3d}$$

$$G_b(\varphi) = G_1 + F(\varphi) \tag{3e}$$

$$G_1 = 2 + 15\log(D/\lambda) \qquad \text{dB} \tag{4a}$$

$$\varphi_r = 39.8\left(\frac{D}{\lambda}\right)^{-0.8} \qquad \text{degrees} \tag{4b}$$

$$F(\varphi) = 10\log\left(0.9\sin^2\left(\frac{3\pi\varphi}{2\varphi_r}\right) + 0.1\right) \qquad \text{dB} \tag{4c}$$

Again, it should be noted that the argument of sin function in equation (4c) is expressed in radians and that the value of $F(\varphi)$ is nearly zero or negative and $F(\varphi) = 0$ corresponds to side-lobe peaks. The reason for introducing the parameter 0.1 in equation (4c) is the same as that for equation (2c).

4 Conclusion

Equations (1a) to (1e) (together with (2a) to (2c)) and (3a) to (3e) (together with (4a) to (4c)) are provisionally presented as mathematical models of generalized radiation patterns of point-to-point fixed service antennas for use only in spatial statistical interference assessment.