RECOMMENDATION ITU-R F.1245*

MATHEMATICAL MODEL OF AVERAGE 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 TO ABOUT 40 GHz

(Question ITU-R 110/9)

(1997)

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,

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 § c);

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

2.1 in cases where the ratio between the antenna diameter and the wavelength is greater than 100, the following equation should be used (Note 2):

$$
\begin{array}{llll}
G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\dfrac{D}{\lambda} \varphi \right)^2 & \text{for} & 0 & \leq \varphi < \varphi_m \\
G(\varphi) = G_1 & \text{for} & \varphi_m & \leq \varphi < \max(\varphi_m, \varphi_r) \\
G(\varphi) = 29 - 25 \log \varphi & \text{for} & \max(\varphi_m, \varphi_r) & \leq \varphi < 48^\circ \\
G(\varphi) = -13 & \text{for} & 48^\circ & \leq \varphi \leq 180^\circ
\end{array}
$$

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4 (WP 4A), 7 (WP 7B), 8 (WP 8D), 10 and 11 (WP 10-11S), and Working Party 4-9S.

where:

G_{max}: maximum antenna gain (dBi) (Note 1)

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

φ: off-axis angle (degrees)

D: antenna diameter } expressed in the same unit
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, the following equation should be used (Notes 3 and 7):

$$\begin{aligned} G(\varphi) &= G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 && \text{for} \quad 0 \leq \varphi < \varphi_m \\ G(\varphi) &= 39 - 5\log(D/\lambda) - 25\log\varphi && \text{for} \quad \varphi_m \leq \varphi < 48^\circ \\ G(\varphi) &= -3 - 5\log(D/\lambda) && \text{for} \quad 48^\circ \leq \varphi \leq 180^\circ \end{aligned}$$

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

NOTE 1 – The relationship between G_{max} and D/λ is given in Recommendation ITU-R F.699.

NOTE 2 – 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 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 § 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:

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

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 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.