



Recommendation ITU-R F.699-8
(01/2018)

**Reference radiation patterns for fixed
wireless system antennas for use in
coordination studies and interference
assessment in the frequency range
from 100 MHz to 86 GHz**

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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.699-8*

**Reference radiation patterns for fixed wireless system antennas
for use in coordination studies and interference assessment
in the frequency range from 100 MHz to 86 GHz**

(Question ITU-R 110-3/5)

(1990-1992-1994-1995-1997-2000-2004-2006-2018)

Scope

This Recommendation provides reference radiation patterns for, and information on, fixed wireless system antennas in the frequency range from 100 MHz to 86 GHz. This information may be used in coordination studies and interference assessments when particular information concerning the fixed wireless system (FWS) antenna is not available.

Keywords

Fixed service, antenna, reference radiation pattern, azimuth and elevation beamwidths, side-lobe envelope, cross polarization, frequency sharing

Abbreviations/Glossary

λ	wave length
φ	Off-axis angle (mainly in azimuth)
Θ	Off-axis angle (mainly in elevation)
D	Diameter
FSS	Fixed satellite service
FWS	Fixed wireless system
G	Antenna gain
H	Horizontal
P-P	Point to point
V	Vertical
VV	Vertical Vertical co-polarization

Related ITU Recommendations

Recommendation ITU-R F.1245	Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz
Recommendation ITU-R F.1336	Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 6 and 7.

The ITU Radiocommunication Assembly,

considering

- a) that, for coordination studies and for the assessment of mutual interference between fixed wireless systems (FWS) and between stations of such systems and earth stations of space radiocommunication services and other radiocommunication services sharing the same frequency band, it may be necessary to use reference radiation patterns for FWS antennas;
- b) that, for the above studies, radiation patterns based on the level exceeded by a small percentage of the side-lobe peaks may be appropriate;
- c) that the side-lobe patterns of antennas of different sizes are strongly influenced by the ratio of the antenna diameter to the operating wavelength;
- d) that the antenna gain may be estimated by the ratio of the antenna diameter to the operating wavelength;
- e) that in cases where only the maximum antenna gain is known, the ratio between the antenna diameter and the wavelength (D/λ) may be estimated for antennas with circular symmetry;
- f) that reference radiation patterns are required for the case where information concerning the antenna diameter is not available;
- g) that, at large angles, the likelihood of local ground reflections must be considered;
- h) that the use of antennas with the best available radiation patterns will lead to the most efficient use of the radio-frequency spectrum,

recommends

1 that, in the absence of particular information concerning the radiation pattern of the FWS antenna involved (see Note 1), the reference radiation pattern as stated below should be used for:

1.1 interference assessment between FWS;

1.2 coordination studies and interference assessment between FWS stations and stations in space radiocommunication and other services sharing the same frequency band;

2 that the following reference radiation pattern should be adopted for frequencies in the range 100 MHz to 86 GHz;

2.1 in cases where the ratio between the antenna diameter and the wavelength is greater than 100, the following equations should be used (see Notes 6 and 7):

2.1.1 for frequencies in the range 1 GHz to 70 GHz

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

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

$$G(\varphi) = 32 - 25 \log \varphi \quad \text{for } \varphi_r \leq \varphi < 48^\circ$$

$$G(\varphi) = -10 \quad \text{for } 48^\circ \leq \varphi \leq 180^\circ$$

2.1.2 for frequencies in the range 70 GHz to 86 GHz,

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

$$\begin{aligned}
 G(\varphi) &= G_1 && \text{for } \varphi_m \leq \varphi < \varphi_r \\
 G(\varphi) &= 32 - 25 \log \varphi && \text{for } \varphi_r \leq \varphi < 120^\circ \\
 G(\varphi) &= -20 && \text{for } 120^\circ \leq \varphi \leq 180^\circ
 \end{aligned}$$

where:

$G(\varphi)$: gain relative to an isotropic antenna (dBi)
 φ : off-axis angle (degrees)
 D : antenna diameter
 λ : wavelength

} expressed in the same units

$$G_1: \text{ gain of the first side-lobe} = 2 + 15 \log \frac{D}{\lambda} \text{ (dBi)}$$

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

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

2.2 in cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100, the following equations should be used (see Notes 6 and 7):

2.2.1 for frequencies in the range 1 GHz to 70 GHz

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

$$G(\varphi) = G_1 \quad \text{for } \varphi_m \leq \varphi < 100 \frac{\lambda}{D}$$

$$G(\varphi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{for } 100 \frac{\lambda}{D} \leq \varphi < 48^\circ$$

$$G(\varphi) = 10 - 10 \log \frac{D}{\lambda} \quad \text{for } 48^\circ \leq \varphi \leq 180^\circ$$

2.2.2 for frequencies in the range 70 GHz to 86 GHz,

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

$$G(\varphi) = G_1 \quad \text{for } \varphi_m \leq \varphi < 100 \frac{\lambda}{D}$$

$$G(\varphi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{for } 100 \frac{\lambda}{D} \leq \varphi < 120^\circ$$

$$G(\varphi) = -10 \log \frac{D}{\lambda} \quad \text{for } 120^\circ \leq \varphi \leq 180^\circ$$

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2.3 for frequencies in the range 100 MHz to less than 1 GHz, in cases where the ratio between the antenna diameter and the wavelength is greater than 0.63 (G_{max} is greater than 3.7 dBi), the following equations should be used:

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

$$G(\varphi) = G_1 \quad \text{for } \varphi_m \leq \varphi < 100 \frac{\lambda}{D}$$

$$G(\varphi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{for } 100 \frac{\lambda}{D} \leq \varphi < \varphi_s$$

$$G(\varphi) = -2 - 5 \log \frac{D}{\lambda} \quad \text{for } \varphi_s \leq \varphi \leq 180^\circ$$

where:

$$\varphi_s = 144.5 \left(\frac{D}{\lambda} \right)^{-0.2}$$

3 that in cases where only the maximum antenna gain is known, D/λ (both D and λ expressed in the same unit) may be estimated from the following expression (see Note 5):

$$20 \log \frac{D}{\lambda} \approx G_{max} - 7.7$$

where G_{max} is the main lobe antenna gain (dBi). Where only the ratio D/λ is known, the maximum antenna gain may be estimated from the following expression: $G_{max} \approx 20 \log \frac{D}{\lambda} + 7.7$.

Therefore, G_{max} approximates 48 dBi for $D/\lambda=100$;

4 that in cases where only the beamwidths of the antenna are known:

4.1 D/λ (expressed in the same unit) may be estimated approximately by the following expression:

$$D/\lambda \approx 70 / \theta$$

where θ is the beamwidth (−3 dB) (degrees);

4.2 given θ , G_{max} may be estimated approximately by:

$$G_{max} \text{ (dBi)} \approx 44.5 - 20 \log \theta$$

5 that the ITU-R membership submit measured radiation patterns or specifications to allow new and improved reference radiation patterns for use in coordination studies and interference assessment to be developed and proposed (see Appendix 1 of Annex 1);

6 that Annex 1 should be referred to for additional information concerning reference radiation patterns for FWS antennas;

7 that for the detailed calculation of interference levels on interference paths it is necessary to consider the cross-polar response of the victim and interfering system antennas;

7.1 that for the calculation in *recommends* 7, including the component of signal radiated on the intended polarity by the transmitting antenna and the co-polar response of the victim receive antenna

to the component of signal radiated on the unintended polarity by the transmitting antenna, the following equation may be used:

$$G_t(\varphi_t) + G_r(\varphi_r) = 10 \cdot \log \left(10^{\frac{G_{tH}(\varphi_t) + G_{rV}(\varphi_r)}{10}} + 10^{\frac{G_{tV}(\varphi_t) + G_{rH}(\varphi_r)}{10}} \right) \quad \text{dBi}$$

where the following parameters refer to antenna gain (dBi):

- $G_t(\varphi_t)$: transmit antenna effective gain in the direction of the victim antenna
- $G_r(\varphi_r)$: receive antenna effective gain in the direction of the interfering antenna
- $G_{tH}(\varphi_t)$: horizontally polarized gain component of the transmit antenna
- $G_{rV}(\varphi_r)$: vertically polarized gain component of the receive antenna
- $G_{tV}(\varphi_t)$: vertically polarized gain component of the transmit antenna
- $G_{rH}(\varphi_r)$: horizontally polarized gain component of the receive antenna.
- φ_t and φ_r : are the angles between the direction of main beam and direction towards victim and transmitting antenna respectively.

Further information and numerical examples on using the equation above is given in Annex 2.

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

NOTE 1 – It is essential that every effort be made to utilize the actual antenna pattern in coordination studies and interference assessment.

NOTE 2 – It should be noted that the radiation pattern of an actual antenna may be worse than the reference radiation pattern over a certain range of angles (see Note 3). Therefore, the reference radiation pattern in this Recommendation should not be interpreted as establishing the maximum limit for radiation patterns of existing or planned FWS antennas. Noting that for certification purpose, administrations may adopt standards, usually based on statistical measurements of real antennas, that may represent different values for the side-lobe radiation pattern levels.

NOTE 3 – The reference radiation pattern should be used with caution over the range of angles for which the particular feed system may give rise to relatively high levels of spill-over.

NOTE 4 – The reference pattern in § 2 is only applicable for one polarization (horizontal or vertical). Reference patterns for two polarizations (horizontal and vertical) are under study.

NOTE 5 – The reference radiation pattern included in this Recommendation is only for antennas which are rotationally symmetrical. It can be applied also to square/polygonal reflectors and flat panel antennas, provided that their equivalent D/λ ratio is derived from the maximum gain, using formula in *recommends* 3. The reference radiation pattern for antennas with asymmetrical apertures and for non-aperture FWS antennas in the frequency range from 100 MHz to 1 GHz requires further study. For such antennas, the above reference patterns may be considered to be provisionally valid. In this case, the D/λ value computed from G_{max} is an equivalent D/λ and not the actual D/λ .

NOTE 6 – Mathematical models of average radiation patterns for use in certain coordination studies and interference assessment are given in Recommendation ITU-R F.1245.

NOTE 7 – Reference radiation patterns of omnidirectional and sectoral antennas in point-to-multipoint systems are given in Recommendation ITU-R F.1336.

NOTE 8 – Further study is required to ensure that reference radiation patterns continue to develop to take account of advances in antenna design.

NOTE 9 – While generally applicable, the reference pattern in *recommends* 2 does not suitably model some practical fixed service antennas and it should be treated with caution over a range of angles from 5° to 70° (see also Notes 2 and 3).

NOTE 10 – In Annex 1, for some Figures representing antennas above 70 GHz, the patterns for equations in *recommends* 2.1 and 2.2 referring to antennas below 70 GHz are provided only for information.

Annex 1

Reference radiation patterns for FWS antennas

1 Introduction

For the study of frequency sharing between FWS and the FSS or of the possibility of frequency reuse in a FWS network, it is often necessary to use a reference diagram, because the actual radiation pattern of the antennas is not always accurately known or gives too many details. The reference pattern should therefore represent the side-lobe envelope in a simplified fashion.

The reference radiation pattern to be selected may, however, vary according to the use for which it is intended.

In general, the reference radiation patterns in the main text of this Recommendation shall be used.

2 Uses of reference radiation patterns

The two main uses of reference radiation patterns are the following:

2.1 Preliminary studies within the coordination area

In the determination of the coordination area around an earth station, FWS station antennas are assumed to point directly at the earth station. However, in most cases there will be some angular discrimination. The use of a simple reference radiation diagram makes it possible to eliminate from further consideration FWS stations situated in the coordination area but not likely to produce interference.

This diagram, must, of necessity, be conservative to prevent the elimination of critical contributing sources of interference. The precise calculation of the interference level, of course, requires more accurate information on the antenna diagram.

2.2 Frequency reuse in a fixed wireless network

In a fixed wireless network, the same frequency may be used many times, either on sections sufficiently distant from each other or on sections starting from the same station and lying in different directions, or on the same section using cross-polarization.

In the last two cases, the performance of the antenna is of great importance and a fairly precise reference radiation pattern must be used for the network project; this pattern may be less simple than that considered in § 2.1, administrations are encouraged to use high performance antenna types in high spectrum use areas.