

RECOMMENDATION ITU-R F.699-5*

**REFERENCE RADIATION PATTERNS FOR LINE-OF-SIGHT RADIO-RELAY SYSTEM ANTENNAS
FOR USE IN COORDINATION STUDIES AND INTERFERENCE ASSESSMENT IN THE
FREQUENCY RANGE FROM 1 GHz TO ABOUT 70 GHz**

(Question ITU-R 110/9)

(1990-1992-1994-1995-1997-2000)

The ITU Radiocommunication Assembly,

considering

- a) that, for coordination studies and for the assessment of mutual interference between line-of-sight radio-relay systems and between stations of such systems and earth stations of space radiocommunication services sharing the same frequency band, it may be necessary to use reference radiation patterns for radio-relay system 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 reference radiation patterns are required for the case where information concerning the antenna diameter is not available;
- e) that, at large angles, the likelihood of local ground reflections must be considered;
- f) 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 line-of-sight radio-relay system antenna involved (see Note 1), the reference radiation pattern as stated below should be used for:

- 1.1** interference assessment between line-of-sight radio-relay systems;
- 1.2** coordination studies and interference assessment between line-of-sight radio-relay stations and stations in space radiocommunication services sharing the same frequency band;

2 that the following reference radiation pattern should be adopted for frequencies in the range 1 GHz to about 70 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 (see Note 6):

$$\begin{aligned}
 G(\varphi) &= G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda} \varphi \right)^2 && \text{for } 0^\circ < \varphi < \varphi_m \\
 G(\varphi) &= G_1 && \text{for } \varphi_m \leq \varphi < \varphi_r \\
 G(\varphi) &= 32 - 25 \log \varphi && \text{for } \varphi_r \leq \varphi < 48^\circ \\
 G(\varphi) &= -10 && \text{for } 48^\circ \leq \varphi \leq 180^\circ
 \end{aligned}$$

where:

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

φ : off-axis angle (degrees)

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 6, 7, and 8.

D : antenna diameter }
 λ : wavelength } expressed in the same units

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

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

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

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

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

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

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

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

3 that in cases where only the maximum antenna gain is known, D/λ may be estimated from the following expression:

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

where G_{max} is the main lobe antenna gain (dBi);

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 from the following expression:

$$D/\lambda \approx 69.3 / \theta$$

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 administrations 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 radio-relay antennas;

7 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 radio-relay system antennas.

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. The reference radiation pattern for antennas with asymmetrical apertures requires further study. For such antennas, the above reference patterns may be considered to be provisionally valid.

NOTE 6 – A mathematical model of average radiation patterns for use in certain coordination studies and interference assessment is given in Recommendation ITU-R F.1245.

NOTE 7 – Further study is required to ensure that reference radiation patterns continue to develop to take account of advances in antenna design.

NOTE 8 – 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).

ANNEX 1

Reference radiation patterns for radio-relay system antennas

1 Introduction

For the study of frequency sharing between radio-relay systems and the FSS or of the possibility of frequency reuse in a radio-relay 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, radio-relay 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 radio-relay 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 radio-relay network

In a radio-relay 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.

3 Results of measurements on the antennas of radio-relay links

Measurements with numerous antennas provide adequate confirmation of the reference radiation patterns in the main text of this Recommendation at least up to a value of D/λ of approximately 130. However, the following points must be borne in mind:

3.1 Some antennas of relatively old designs have less satisfactory performance characteristics than more recent models. The existence of such medium performance antennas should be taken into account for frequency sharing.

3.2 The above computation is based on the assumption that the antennas operate in free-space conditions. The performance characteristics of antennas installed in the field may, however, be slightly less satisfactory owing to reflection from neighbouring obstacles or from other antennas installed on the same mast.

4 Radiation patterns of high performance antennas

High performance antennas contribute greatly to the increase of nodal capacity in radio-relay systems. For the horn-reflector antennas, which were developed to comply with the requirements of terrestrial radio-relay systems in dense networks, the reference diagram above may be regarded as valid only in the horizontal plane. For planes away from the horizontal significant sensitivity variations are displayed.

Figure 1 gives an example for the radiation diagram of a specific but widely-used pyramidal horn reflector antenna. Radiation envelope contours are plotted (in dB below the main beam) in a coordinate system using angles φ and θ (the centre of the spherical coordinate system being the centre of the antenna aperture). The strong departure from the rotational symmetry assumed in the reference radiation patterns in *recommends 2* of this Recommendation is due to:

- the spill-over lobe around $\varphi = +90^\circ$ and $60^\circ < \theta < 80^\circ$,
- the weather cover lobe around $\varphi = -90^\circ$ and $50^\circ < \theta < 90^\circ$.

The spill-over lobe is a consequence of wave diffraction at the upper lip of the aperture caused by direct rays emanating from the pyramidal horn section. This effect is pronounced only for vertical polarization. The weather cover lobe is due to reflection of energy by the tilted plastic weather cover back onto the parabolic surface which then re-directs most of the energy downward over the lower lip of the aperture. This phenomenon is polarization and frequency insensitive.

An offset-reflector type antenna shows sharp directivity especially in the horizontal plane. Figure 2 illustrates examples of the radiation patterns of the offset-reflector antenna together with an example of the pyramidal horn-reflector antenna read from Fig. 1.

For horn reflector antennas and for offset antennas with a very low illumination on the edge of the reflector, the following formula may be provisionally used as a reference radiation pattern in the horizontal plane:

$$G = 88 - 30 \log \frac{D}{\lambda} - 40 \log \varphi \quad (1)$$

This formula is valid outside the main lobe for φ up to about 90° . However, when the illumination on the edge of the reflector is not very low, the level of side-lobes in certain directions may be higher than that given by equation (1).

FIGURE 1
Three-dimensional radiation pattern for a pyramidal horn-reflector
antenna at 3.9 GHz and vertical polarization
(note scale change at $\theta = 10^\circ$)

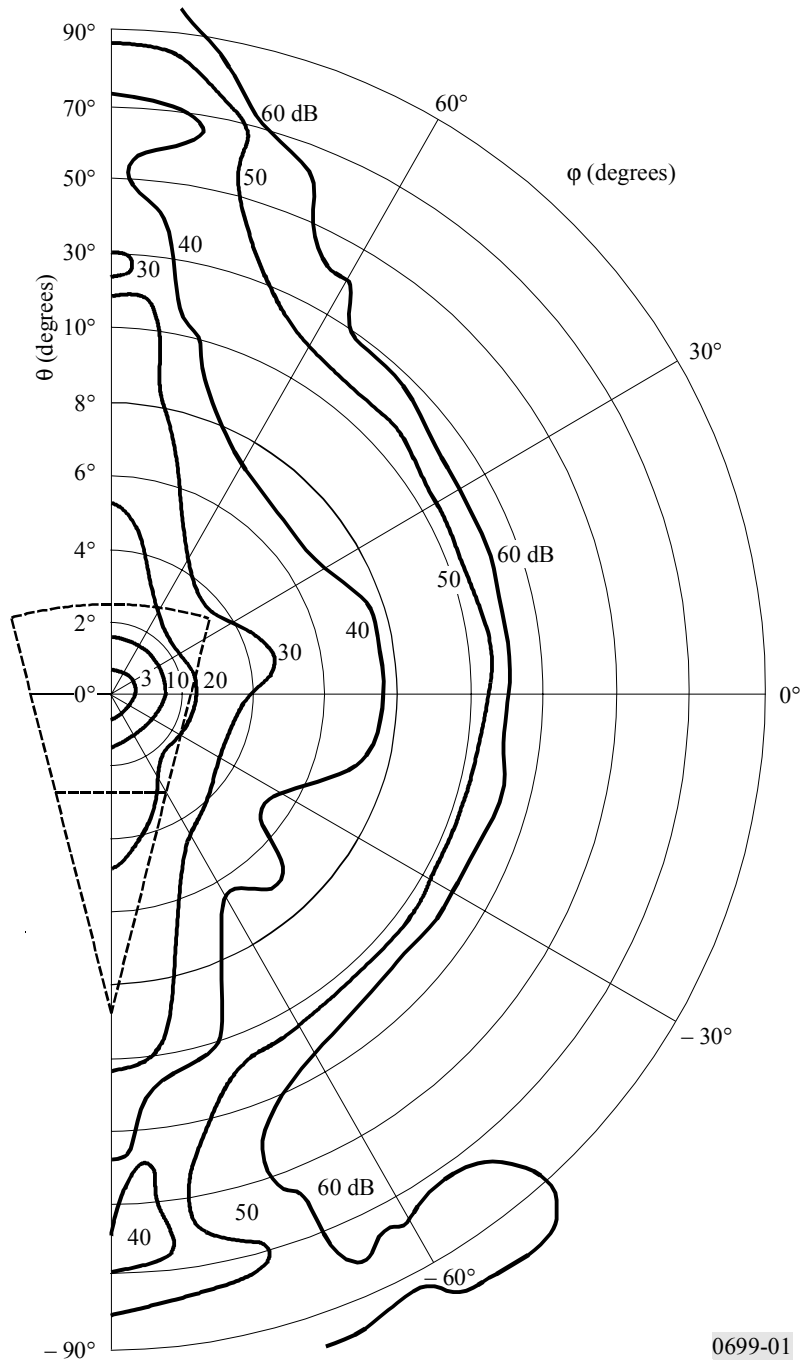
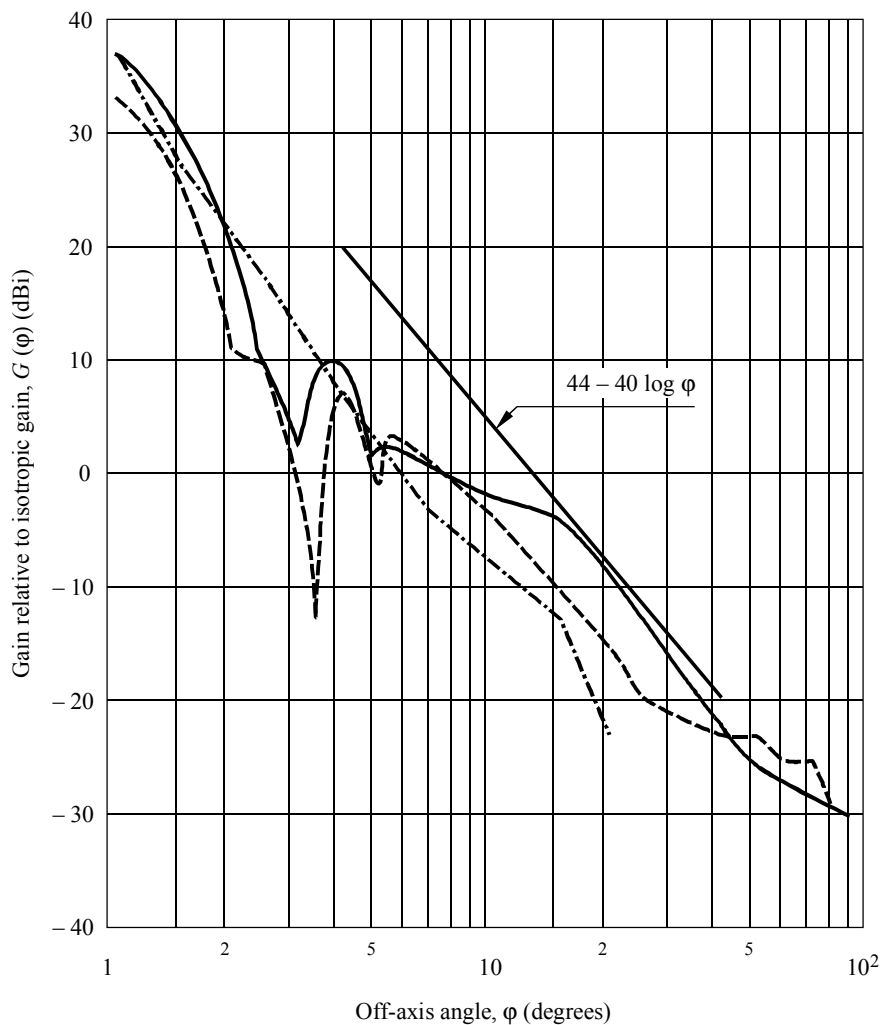


FIGURE 2

The radiation pattern of high performance antennas



- 3.6 m diameter offset-reflector antenna, $\frac{D}{\lambda} = 46.8$ (3.9 GHz)
- - - 3.6 m diameter offset-reflector antenna, $\frac{D}{\lambda} = 74.1$ (6.175 GHz)
- · - · - Pyramidal horn-reflector antenna (3.9 GHz)

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APPENDIX 1

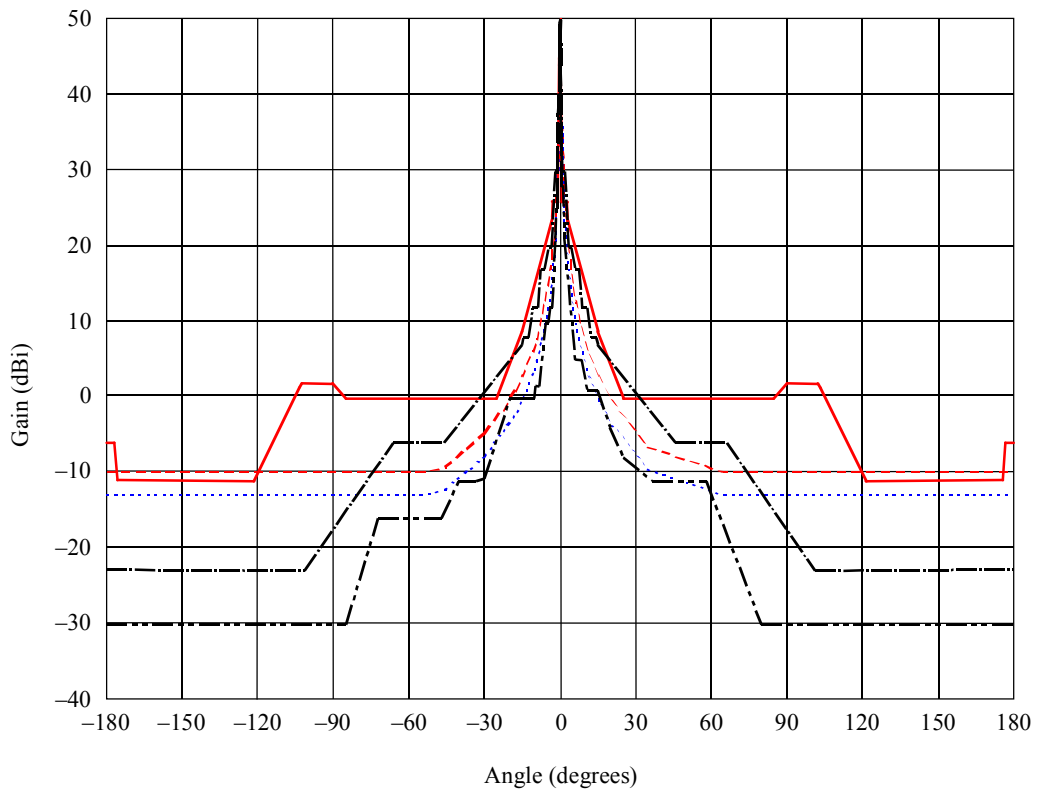
TO ANNEX 1

Measured patterns for use in the further development of this Recommendation

1 Introduction

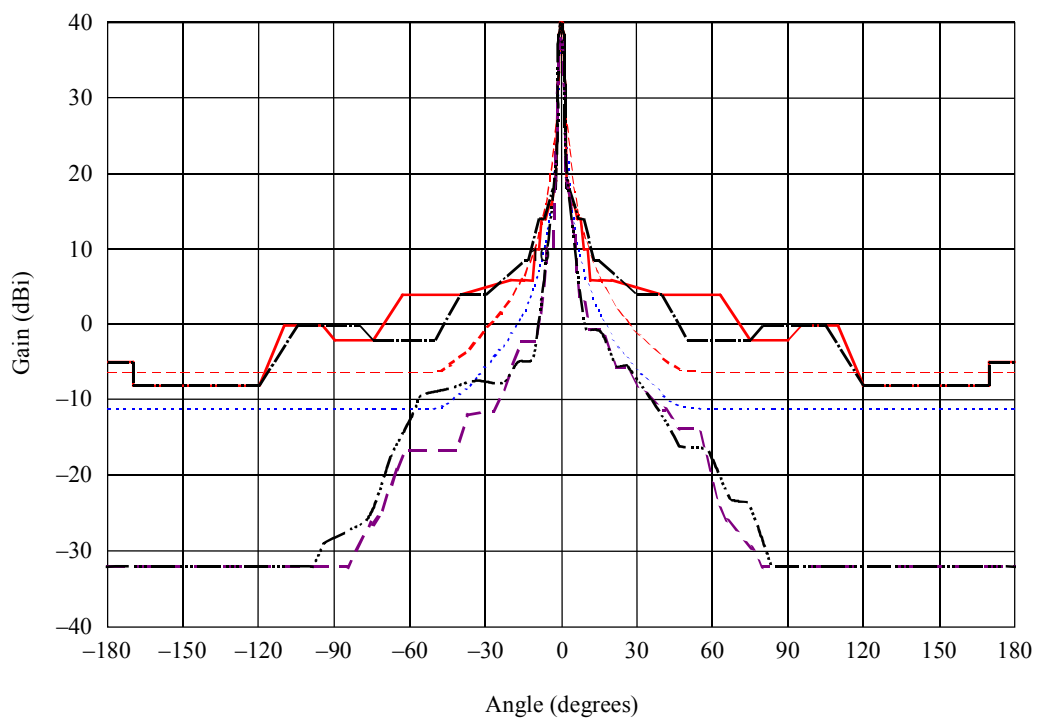
There is a continuing need to review and update the reference radiation patterns contained in this Recommendation. As the frequency bands being used for fixed service systems extend beyond 40 GHz, there is a need to widen the scope of these reference radiation patterns above 40 GHz. To assist with the above, this Appendix contains comparisons of some practical antenna pattern envelopes and radiation patterns with the corresponding reference patterns derived from this Recommendation and Recommendation ITU-R F.1245.

FIGURE 3
 10.7 GHz P-P antenna of 3 m diameter ($D/\lambda = 114$; gain = 49.8 dBi)
 (H: horizontal polarization, V: vertical polarization)



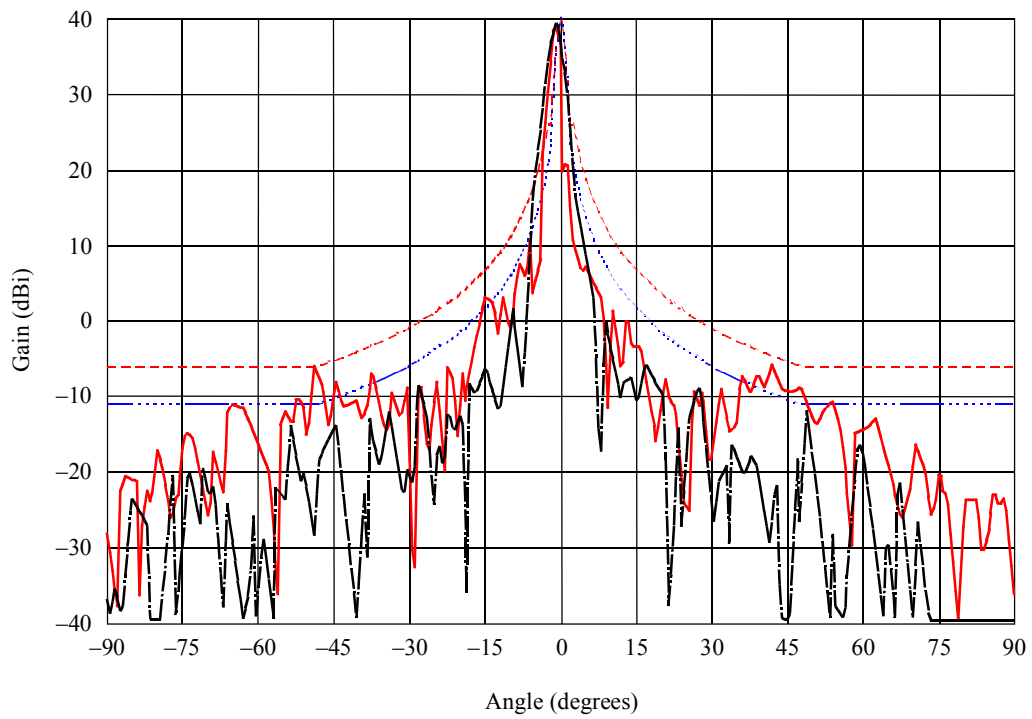
- Recommendation ITU-R F.699
- ... Recommendation ITU-R F.1245
- Low performance V
- · - Medium performance V
- - - High performance V

FIGURE 4
 10.5 GHz P-P antenna of 1.2 m diameter ($D/\lambda = 43$; gain = 39.9 dBi)
 (H: horizontal polarization, V: vertical polarization)



- Recommendation ITU-R F.699
- Recommendation ITU-R F.1245
- Low performance H
- Low performance V
- High performance H
- High performance V

FIGURE 5
 21 GHz lens horn P-P antenna of 50 cm diameter ($D/\lambda = 37$; gain = 40 dBi)



- Recommendation ITU-R F.699
- ... Recommendation ITU-R F.1245
- Measured values
- · - Measured values

FIGURE 6
31 GHz P-P antenna of 0.3 m diameter ($D/\lambda = 32$; gain = 36.9 dBi)
(H: horizontal polarization, V: vertical polarization)

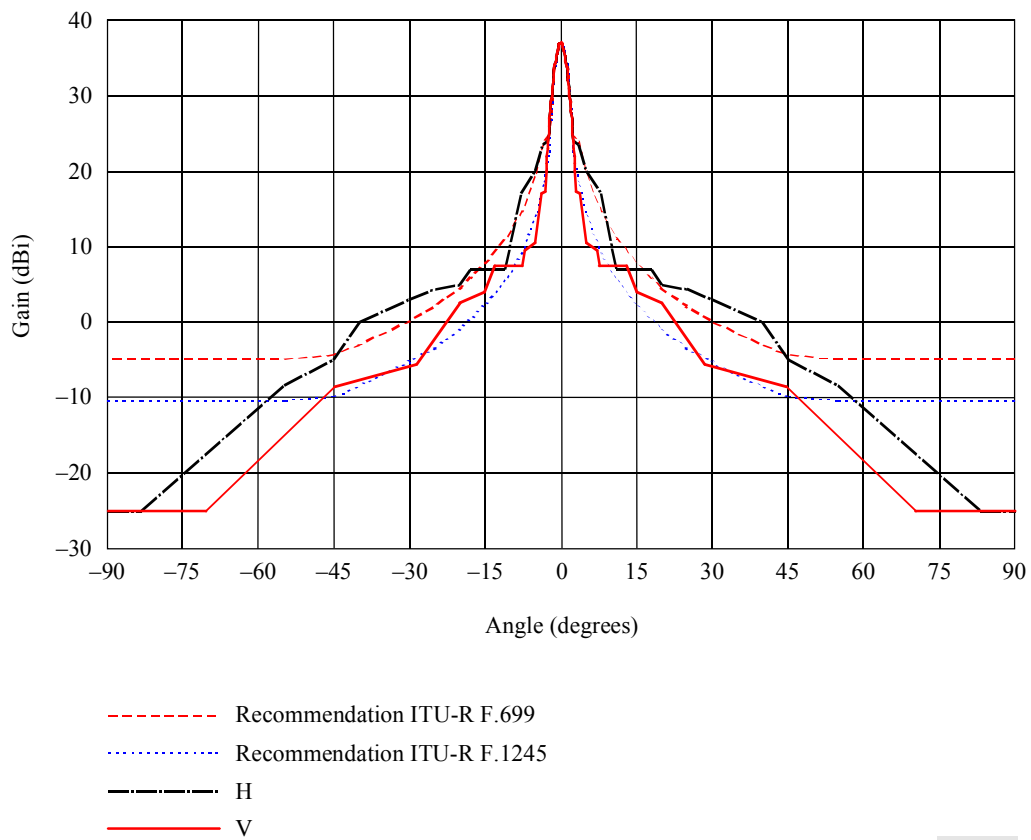
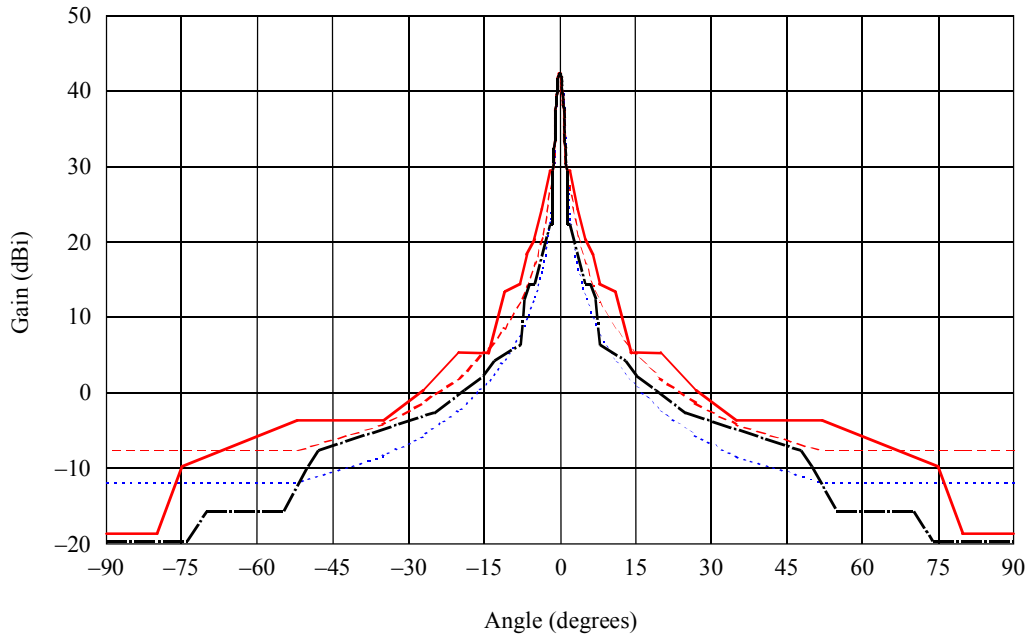


FIGURE 7
55 GHz P-P antenna of 0.3 m diameter ($D/\lambda = 57$; gain = 42.4 dBi)
(H: horizontal polarization, V: vertical polarization)



- Recommendation ITU-R F.699
- ... Recommendation ITU-R F.1245
- H
- · - V

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