RECOMMENDATION ITU-R S.731-1

Reference earth-station cross-polarized radiation pattern for use in frequency coordination and interference assessment in the frequency range from 2 to about 30 GHz

(1992-2005)

The ITU Radiocommunication Assembly,

considering

a) that, for coordination studies and for the assessment of mutual interference between radiocommunication-satellite systems and between earth stations of such systems and stations of other services sharing the same frequency band, it may be useful to use a cross-polarized radiation pattern for the earth-station antenna;

b) that, for the determination of coordination distance and for the assessment of interference between earth and terrestrial stations, a cross-polarized radiation pattern based on the level exceeded by a small percentage of the side-lobe peaks may be appropriate;

c) that, a reference earth-station co-polarized radiation pattern for use in frequency coordination and interference assessment is contained in Recommendation ITU-R S.465;

d) that some measurements have been made of the cross-polarized off-axis gain performance of earth stations and radiation patterns have been developed which are quantitively similar;

e) that a single cross-polarized off-axis reference pattern can be used which includes those contained in Annex 1;

f) that the use of antennas with the best achievable radiation patterns will lead to the most efficient use of the radio-frequency spectrum and the geostationary-satellite orbit,

recognizing

1 that further measured information on cross-polarization performance is desirable;

2 that the measured off-axis gain performance of earth-station antennas contains the cross-polarization emission from the source antenna;

3 that the cross-polarized radiation patterns are measured in the main beam of the source antenna,

recommends

1 that, in the absence of particular information concerning the cross-polarized radiation pattern of the antenna for the earth station involved, a single reference radiation pattern may be used for:

1.1 frequency coordination studies and interference assessment between earth stations in the fixed-satellite services and stations of other services sharing the same frequency band;

1.2 coordination studies and interference assessment between networks in the fixed-satellite service;

2 that the following cross-polarized radiation pattern may be used on an interim basis for angles between the directions considered and the axis of the main beam, for frequencies in the range 2-30 GHz:

$G_x(\varphi) = 23 - 20 \log \varphi$	dBi	for $\varphi_r \leq \varphi \leq 7°$
$G_x(\varphi) = 20.2 - 16.7 \log \varphi$	dBi	for $7° < \varphi \leq 26.3°$
$G_x(\varphi) = 32 - 25 \log \varphi$	dBi	for $26.3° < \varphi \leq 48°$
$G_x(\varphi) = -10$	dBi	for $48° < \varphi \leq 180°$

φ_r is equal to 1° or 100 λ/D, whichever is greater;

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

NOTE 1 – The reference cross-polarized radiation pattern should be assumed to be rotationally symmetrical.

NOTE 2 – The reference cross-polarized pattern should be used for cases involving opposite polarizations.

NOTE 3 – Other cross-polarized radiation patterns of earth stations may be used by mutual agreement between the administrations concerned.

NOTE 4 – 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 and for antennas with D/λ less than 50.

NOTE 5 – This cross-polarized radiation pattern complements the co-polarized pattern of Recommendation ITU-R S.465.

NOTE 6 – Annex 1 contains several cross-polarized off-axis radiation patterns corresponding to the envelopes of the peaks of the measured gain characteristics of various antennas, in support of *recommends* 2.

Annex 1

Modelling of earth-station antenna cross-polar characteristics

This Annex presents background information used to develop cross-polarized patterns obtained for theoretical and measured patterns. Pattern measurements were obtained for different antenna diameters (1.2 m, 1.8 m, 2.4 m, 3.5 m at 12.625 GHz, and 3.7 m at 10.7 GHz). For each antenna diameter, the relative measured and envelope patterns are described. Equations are then derived which describe the relative cross-polarized envelopes for antennas with $D/\lambda \geq 100$ and $D/\lambda < 100$. A single function is developed which can be used to describe the off-axis cross-polarized pattern for all antennas.

Calculated co-polarized and cross-polarized patterns for single offset feed antennas are shown in Figs. 1 and 2 along with the respective envelope functions. The effects of feed supports for axisymmetric arrangements are shown in Fig. 3.

FIGURE 1

1.8 m single offset antenna co- and cross-polar pattern calculated at 3.95 GHz – azimuth plane

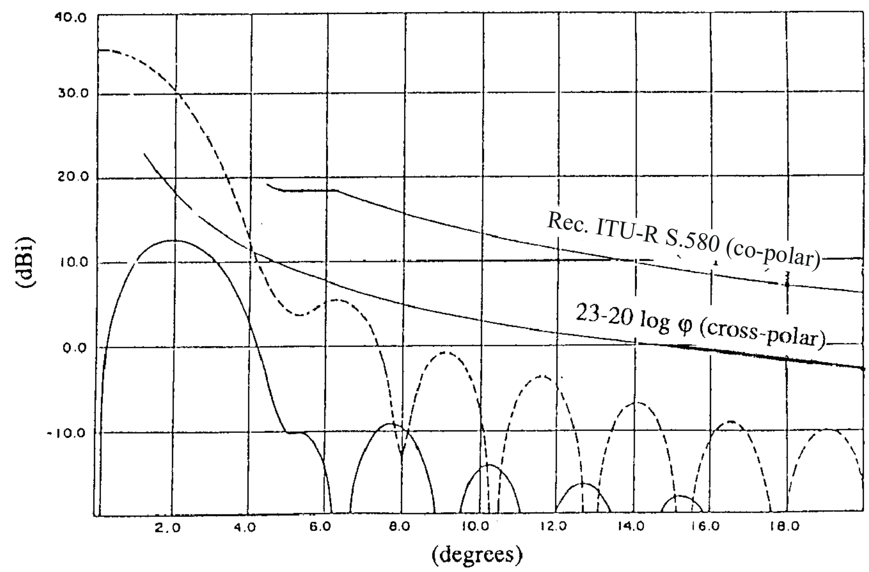
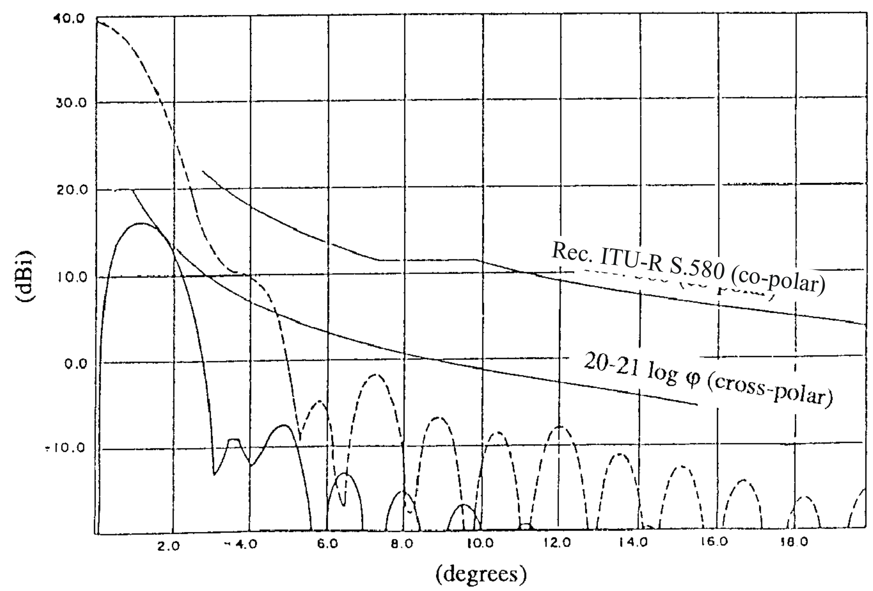


FIGURE 2

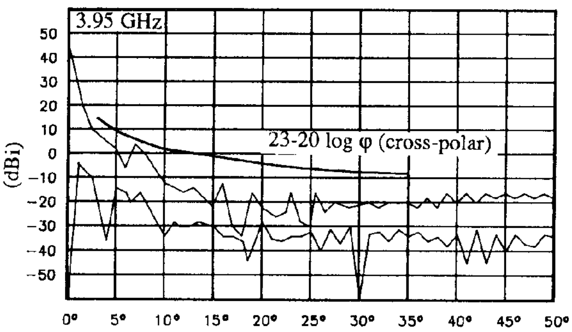
1.8 m single offset antenna co- and cross-polar pattern calculated at 6.175 GHz – azimuth plane



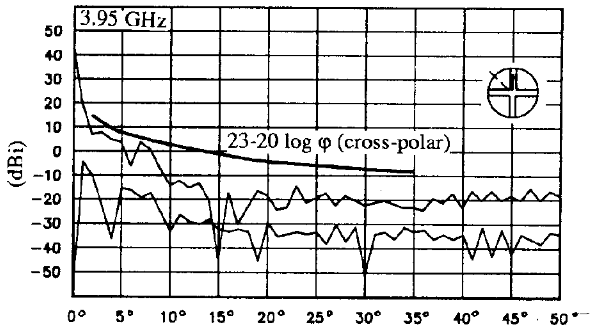
0731-0102

FIGURE 3

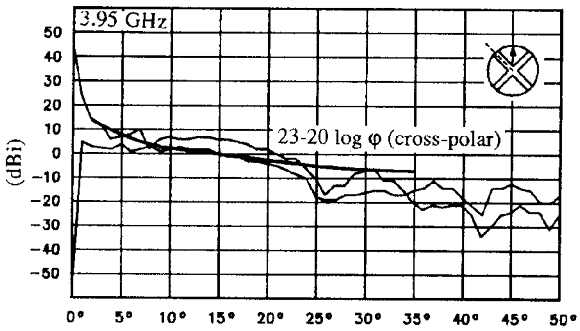
Theoretical analysis of strut effects on a 6 m double reflector axisymmetric linearly polarized antenna, at 3.95 GHz (a)-c)) and 6.175 GHz (d)-e))



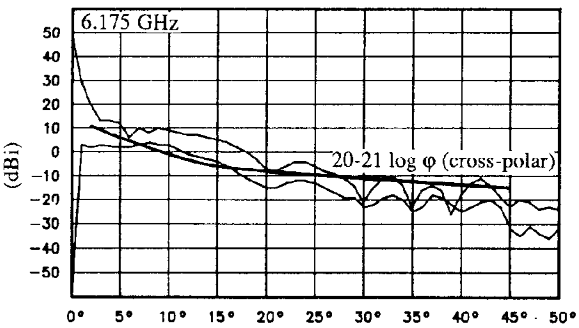
a) Co- and cross-polar 45° plane patterns, without struts



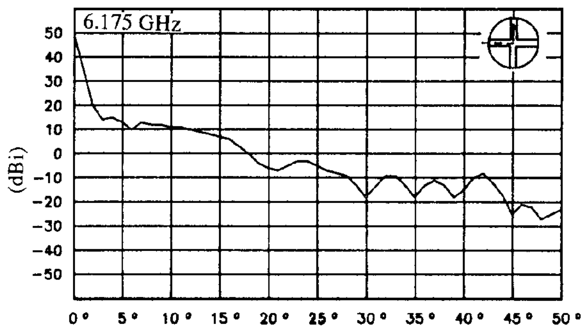
b) Same as a) including struts in vertical and horizontal planes



c) Same as a) including struts in 45° and 135° planes



d) Same as c) at the transmit band



e) Co- and cross-polar horizontal plane patterns, including struts in vertical and horizontal planes – transmit band

0731-03

In order to estimate the worst-case polarization discrimination (factor of polarization isolation), the relative co-polarized $G_{//}(\varphi)$ and cross-polarized $G_{+}(\varphi)$ envelopes have been obtained.

a) The relative co-polarized envelope used in this Annex is assumed as follows:

For systems with $D/\lambda \leq 100$:

$G_{//}(\varphi) = 52 - 10 \log(D/\lambda) - 25 \log \varphi - G_0$ dBi for $(100\ \lambda/D)° \leq \varphi \leq 48°$

$= 10 - 10 \log(D/\lambda) - G_0$ dBi for $48° < \varphi \leq 180°$

For systems with $D/\lambda > 100$:

$G_{//}(\varphi) = 32 - 25 \log \varphi - G_0$ dBi for $1° \leq \varphi \leq 48°$

$= 10 - G_0$ dBi for $48° < \varphi \leq 180°$

b) The cross-polarization level is such that $G_{+}(\varphi) = G_{//}(\varphi'_1)$ (with $\varphi'_1 = 2.2\ \varphi_1$ for small antennas, and $\varphi'_1 = 1.8\ \varphi_1$ for large antennas) for $0° < \varphi < \varphi_1$.

Finally, the relative cross-polarized envelopes could have the following envelopes:

1 Small antennas ($D < 100\lambda$)

G_0 = maximum co-polarized gain of antenna (dBi)

$G(\varphi) = 52 - 10 \log(D/\lambda) - 25 \log \varphi - G_0$ (dBi)

$\varphi_1 = 100\ \lambda/D$ (degrees)

$\varphi'_1 = 2.2\ \varphi_1$ (degrees)

$\varphi_2 = 25.1°$

$\varphi_{ISO} = 10^{\frac{52 - 10 \log(D/\lambda)}{25}}$ (degrees)

for $0 < \varphi \leq \varphi_1$:

$$G_{+}(\varphi) = G(\varphi'_1) \tag{1}$$

for $\varphi_1 < \varphi \leq \varphi_2$:

$$G_{+}(\varphi) = G(\varphi) - \big(G(\varphi_1) - G(\varphi'_1)\big)\frac{\varphi_{ISO} - \varphi}{\varphi_{ISO} - \varphi_1} \tag{2}$$

for $\varphi > \varphi_{ISO}$:

$$G_{+}(\varphi) = 52 - 10 \log(D/\lambda) - 25 \log \varphi - G_0 \tag{3}$$

for $\varphi_2 < \varphi \leq 180°$:

$$G_{+}(\varphi) = 10 - 10 \log(D/\lambda) - G_0 \tag{4}$$

The patterns shown in Figs. 4 and 6 are calculated for stations with antenna diameters of 1.2 m and 1.8 m operating at a centre frequency of 12.625 GHz. The patterns measured for these types of antennas are shown in Figs. 5, 7 and 8. In each case one example of the measured co- and cross-polarized pattern is given, but the envelopes shown are averages from measurements on several antennas of the same type.

FIGURE 4

1.2 m antenna, *f* = 12.625 GHz, relative co- and cross-polar calculated patterns

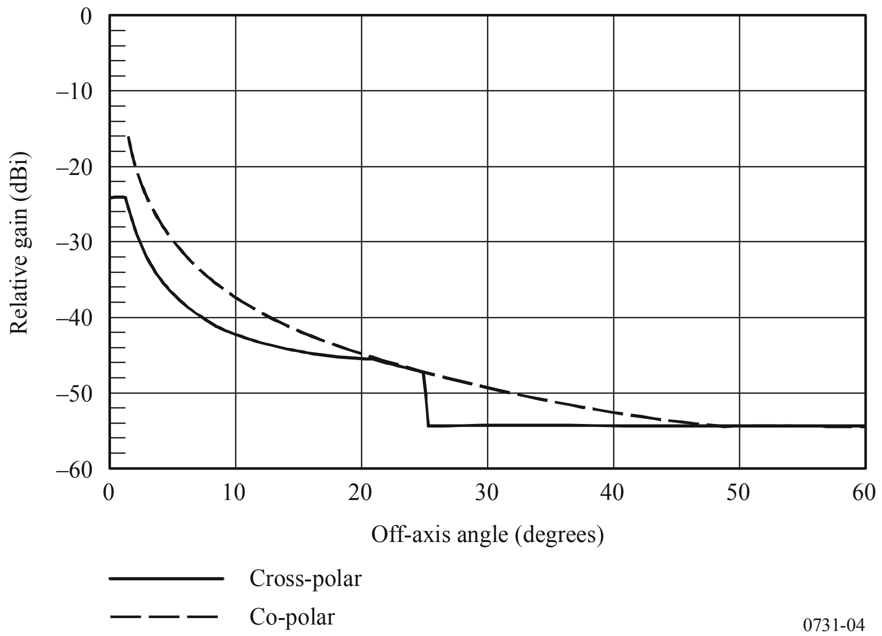


FIGURE 5

1.2 m antenna, *f* = 12.625 GHz, relative co- and cross-polar measured patterns

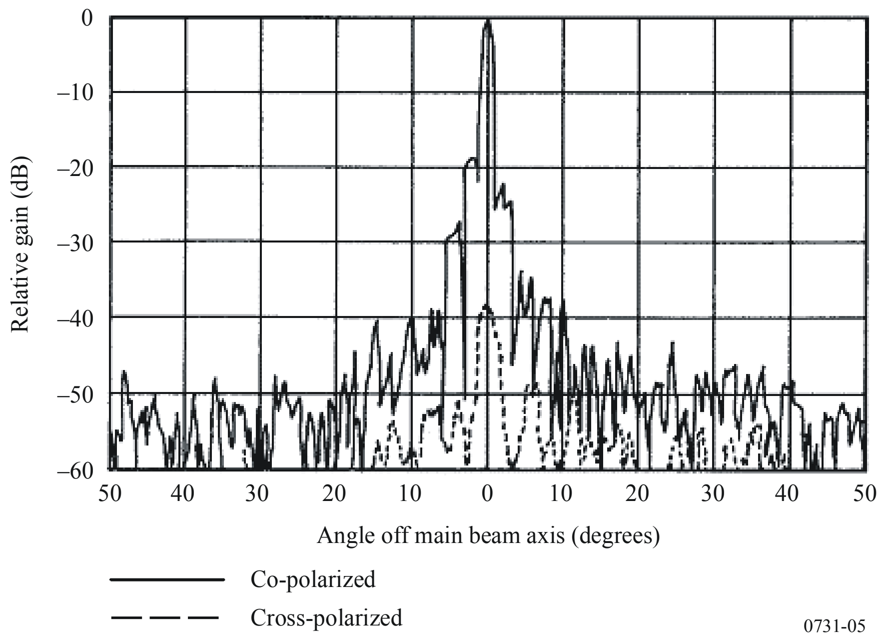


FIGURE 6

1.8 m antenna, *f* = 12.625 GHz, relative co- and cross-polar calculated patterns

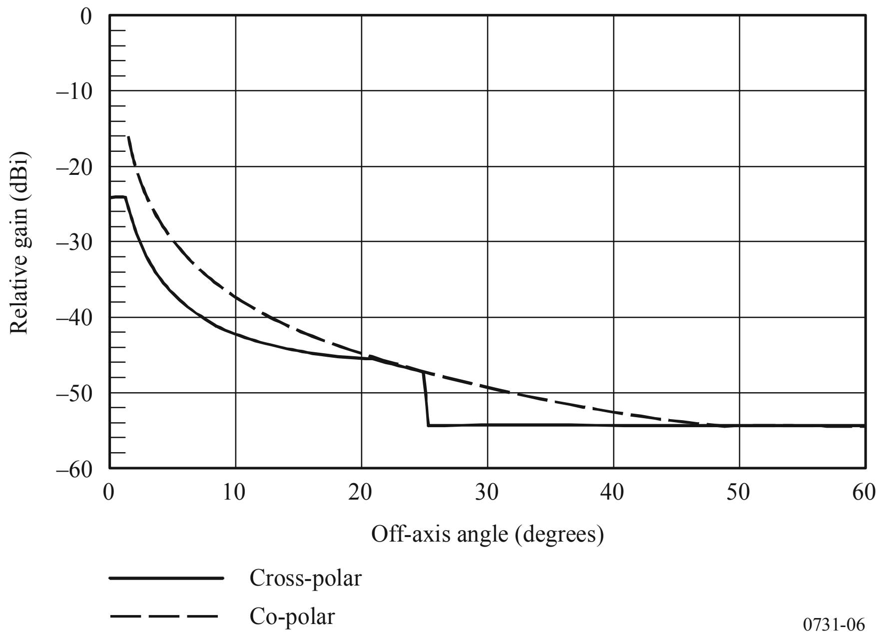


FIGURE 7

1.8 m antenna, *f* = 12.625 GHz, relative co-polar measured pattern

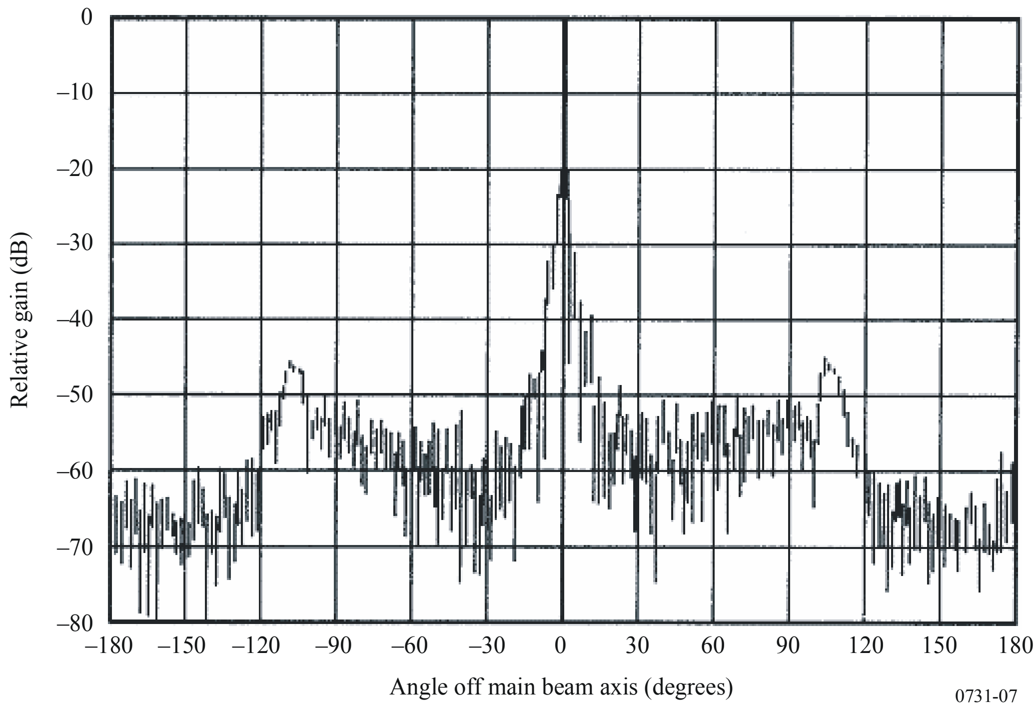
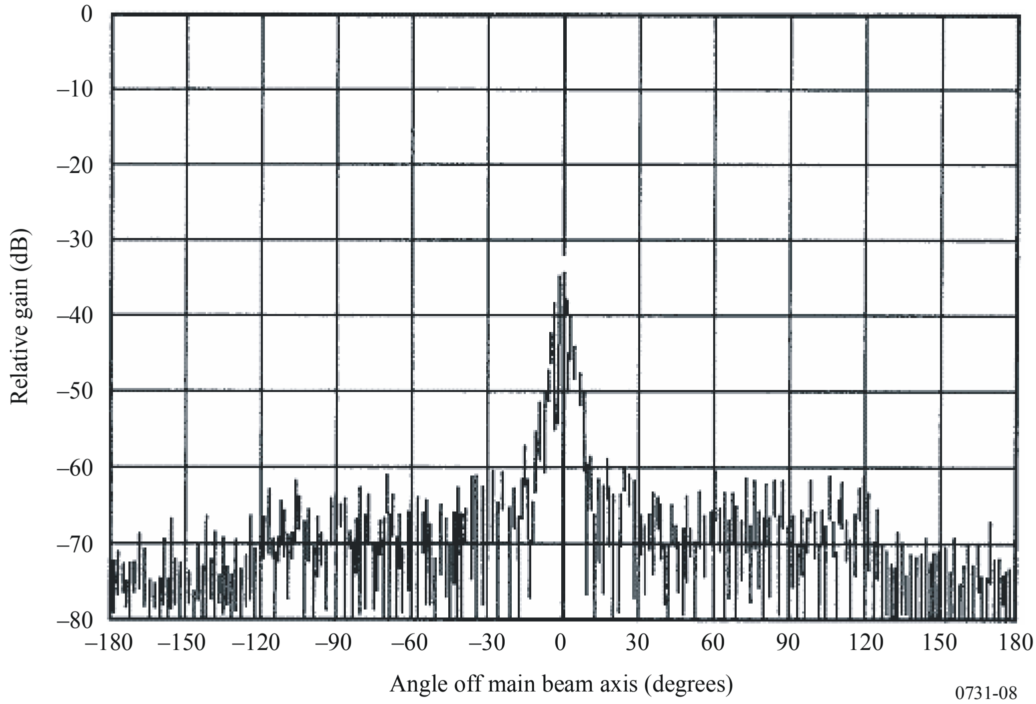


FIGURE 8

1.8 m antenna, *f* = 12.625 GHz, relative cross-polar measured pattern



2 Large antennas ($D \geq 100\lambda$)

G_0 = maximum co-polarized gain of antenna (dBi)

$$G(\varphi) = 29 - 25 \log \varphi - G_0 \text{ (dBi)}$$

$$\varphi_1 = 1^\circ$$

$$\varphi'_1 = 1.8\ \varphi_1 \text{ (degrees)}$$

$$\varphi_2 = 20^\circ$$

$$\varphi_3 = 33.1^\circ$$

$$\varphi_{ISO} = 10^{\frac{29}{25}} \cong 14.45^\circ$$

for $0 < \varphi \leq \varphi_1$:

$$G_+(\varphi) = G(\varphi'_1) \tag{5}$$

for $\varphi_1 < \varphi \leq \varphi_2$:

$$G_+(\varphi) = G(\varphi) - \left(G(\varphi_1) - G(\varphi'_1)\right) \frac{\varphi_{ISO} - \varphi}{\varphi_{ISO} - \varphi_1} \tag{6}$$

for $\varphi_2 < \varphi \leq \varphi_3$:

$$G_+(\varphi) = 32 - 25 \log \varphi - G_0 \tag{7}$$

for $\varphi_3 < \varphi \leq 180^\circ$:

$$G_+(\varphi) = -10 - G_0 \tag{8}$$

The patterns shown in the Figures below are calculated for stations with the following antenna diameters and frequencies: 2.4 m and 3.5 m at 12.625 GHz, and 3.7 m at 10.7 GHz. The patterns measured for these types of antennas are shown in Figs. 10, 11, 13, 14, 16 and 17. In each case, one example of the co- and cross-polarized measurements is shown, but the envelopes given were derived from the average of several antennas of the same type.

The functions given above for $D < 100\lambda$ and $D \geq 100\lambda$ can be expressed in terms of absolute gain. The functions given for $D < 100\lambda$ can be normalized to a (32 – 25 log φ) co-polar function by letting (52 – 10 log φ) equal 32. Evaluation of these functions as absolute gain for various values of D/λ is as follows:

$$G_x(\varphi) = 22.70 + 0.29\,\varphi - 25 \log \varphi \quad \text{dBi} \quad \text{for } D/\lambda = 25 \tag{9}$$

$$= 22.69 + 0.37\,\varphi - 25 \log \varphi \quad \text{dBi} \quad \text{for } D/\lambda = 50 \tag{10}$$

$$= 22.87 + 0.42\,\varphi - 25 \log \varphi \quad \text{dBi} \quad \text{for } D/\lambda = 75 \tag{11}$$

$$= 22.15 + 0.47\,\varphi - 25 \log \varphi \quad \text{dBi} \quad \text{for } D/\lambda = 100 \tag{12}$$

The angles at which these gain functions are equal to a co-polar envelope gain of (32 – 25 log φ) are 31.7°, 25.2°, 21.4° and 20.8° respectively. Additional functions which have been developed are:

$$G_x(\varphi) = 20 - 21 \log \varphi \quad \text{dBi} \tag{13}$$

$$G_x(\varphi) = 23.6 - 20 \log \varphi \quad \text{dBi} \tag{14}$$

$$G_x(\varphi) = 22 - 25 \log \varphi \quad \text{dBi} \tag{15}$$

Equation (15) is based on a requirement that the cross-polar gain be 10 dB less than the co-polar gain out to 7°.

These functions are plotted in Fig. 18. From this Figure, a single function which adequately covers all the above functions is:

$$G_\lambda(\varphi) = 23 - 20 \log \varphi \quad \text{dBi} \quad \text{for } \varphi_r \leq \varphi \leq 7°$$

$$= 20.2 - 16.7 \log \varphi \quad \text{dBi} \quad \text{for } 7° < \varphi \leq 26.3°$$

$$= 32 - 25 \log \varphi \quad \text{dBi} \quad \text{for } 26.3° < \varphi \leq 48°$$

$$= -10 \quad \text{dBi} \quad \text{for } 48° < \varphi \leq 180°$$

φ_r is equal to 1° or 100 λ/D, whichever is greater.

FIGURE 9

2.4 m antenna, *f* = 12.625 GHz, relative co- and cross-polar calculated patterns

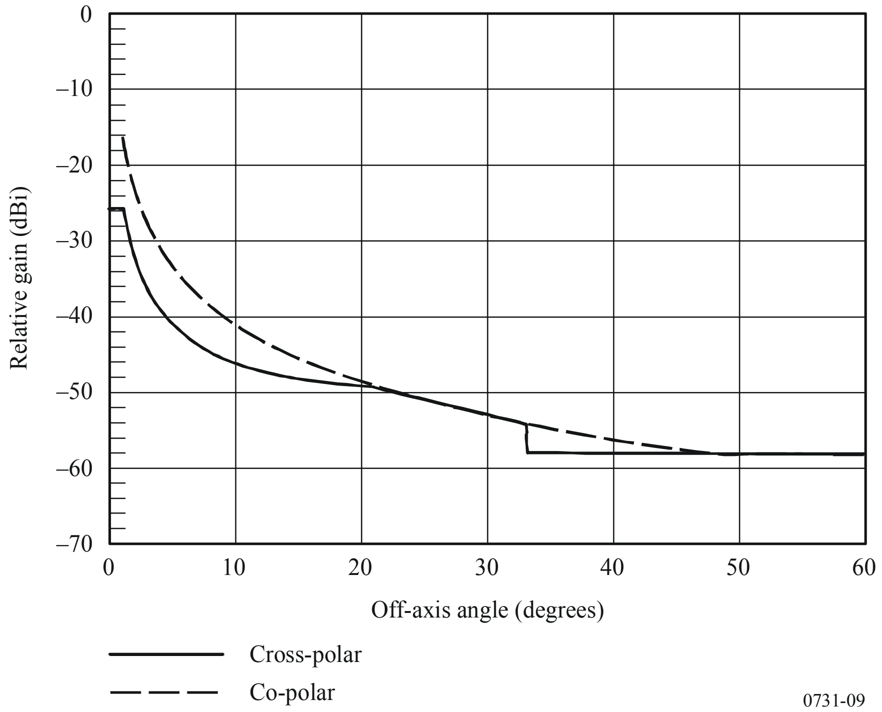


FIGURE 10

2.4 m antenna, *f* = 12.625 GHz, relative co-polar measured pattern

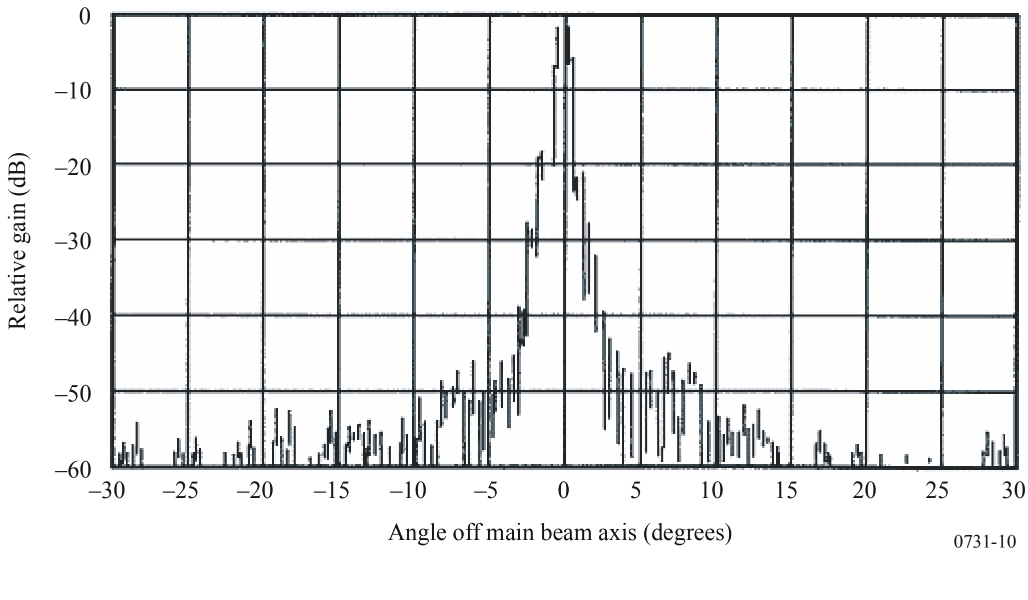


FIGURE 11

2.4 m antenna, *f* = 12.625 GHz, relative cross-polar measured pattern

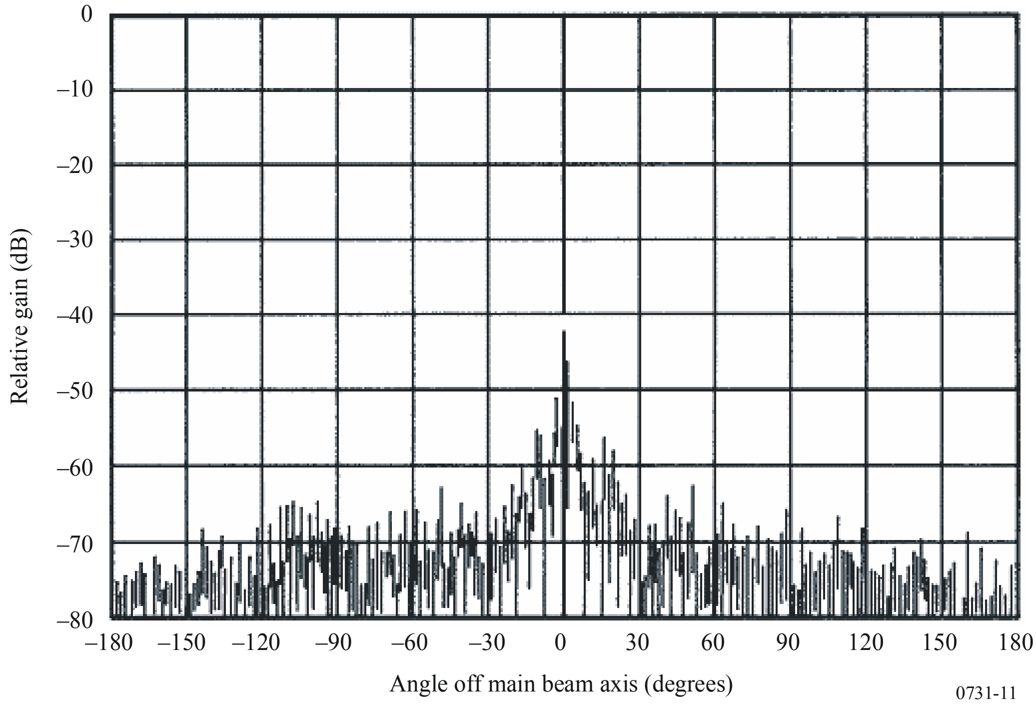


FIGURE 12

3.5 m antenna, *f* = 12.625 GHz, relative co- and cross-polar calculated patterns

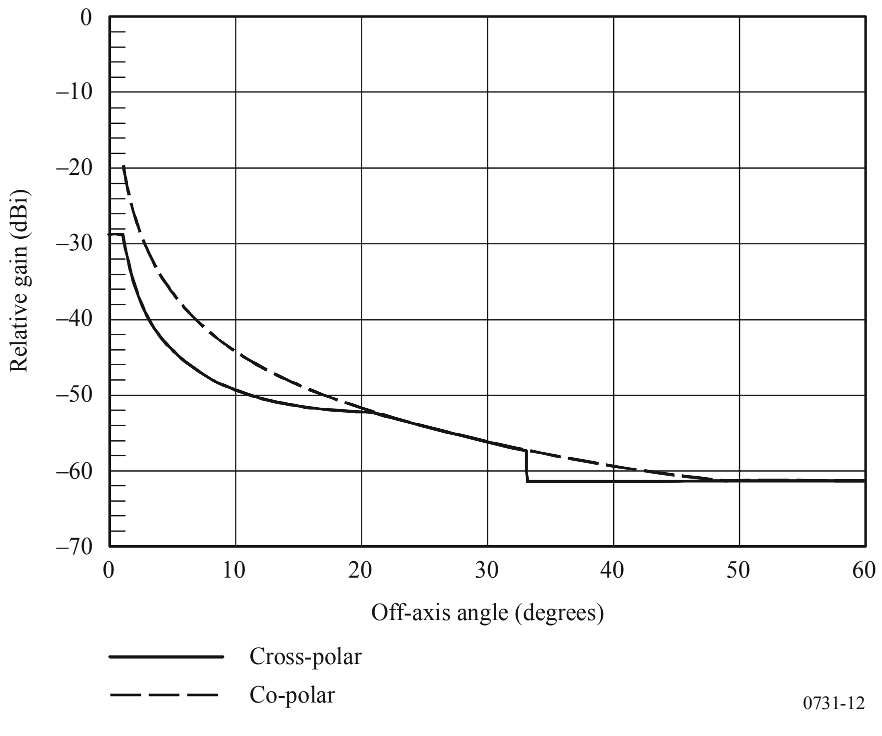


FIGURE 13

3.5 m antenna, *f* = 12.625 GHz, relative co-polar measured pattern

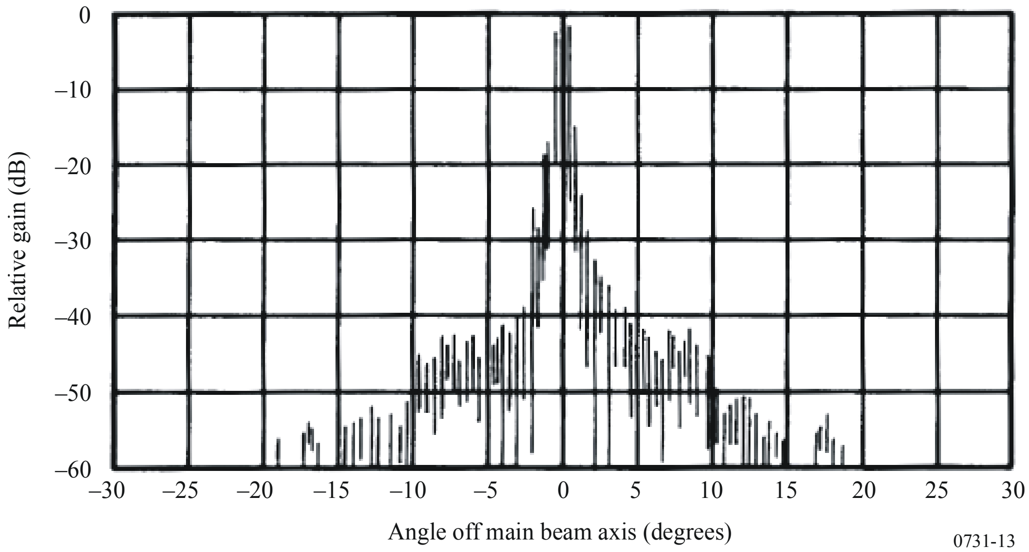


FIGURE 14

3.5 m antenna, *f* = 12.625 GHz, relative cross-polar measured pattern

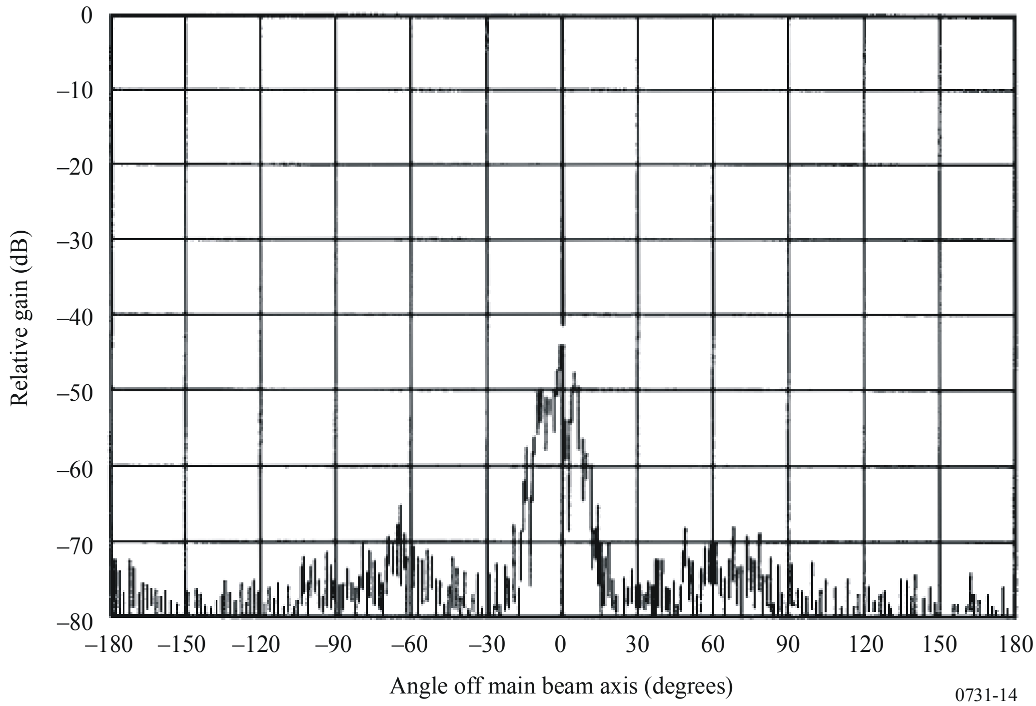


FIGURE 15

3.7 m antenna, *f* = 10.7 GHz, relative co- and cross-polar calculated patterns

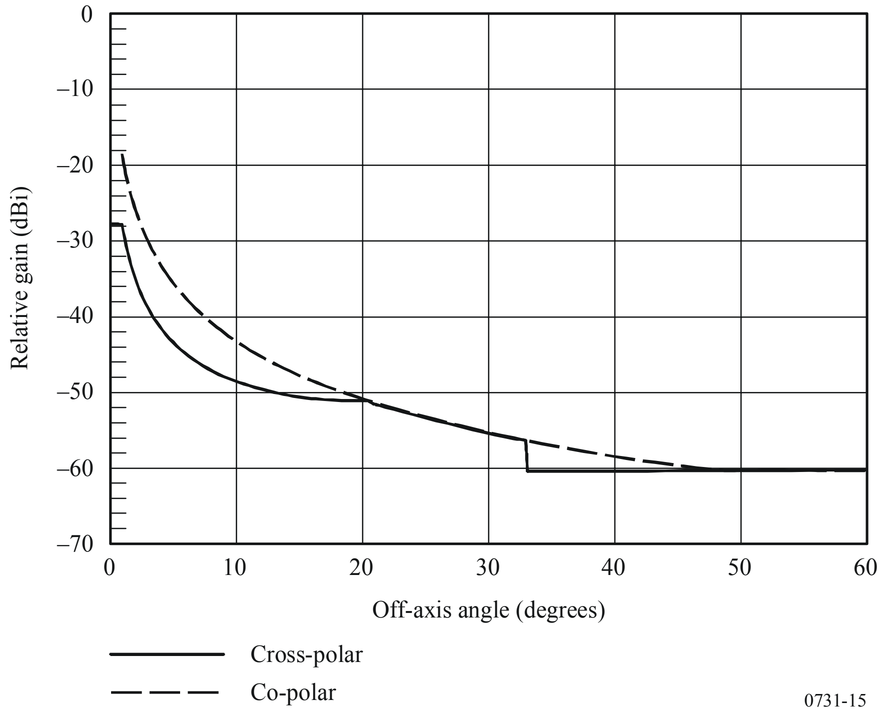


FIGURE 16

3.7 m antenna, *f* = 10.7 GHz, relative co-polar measured pattern

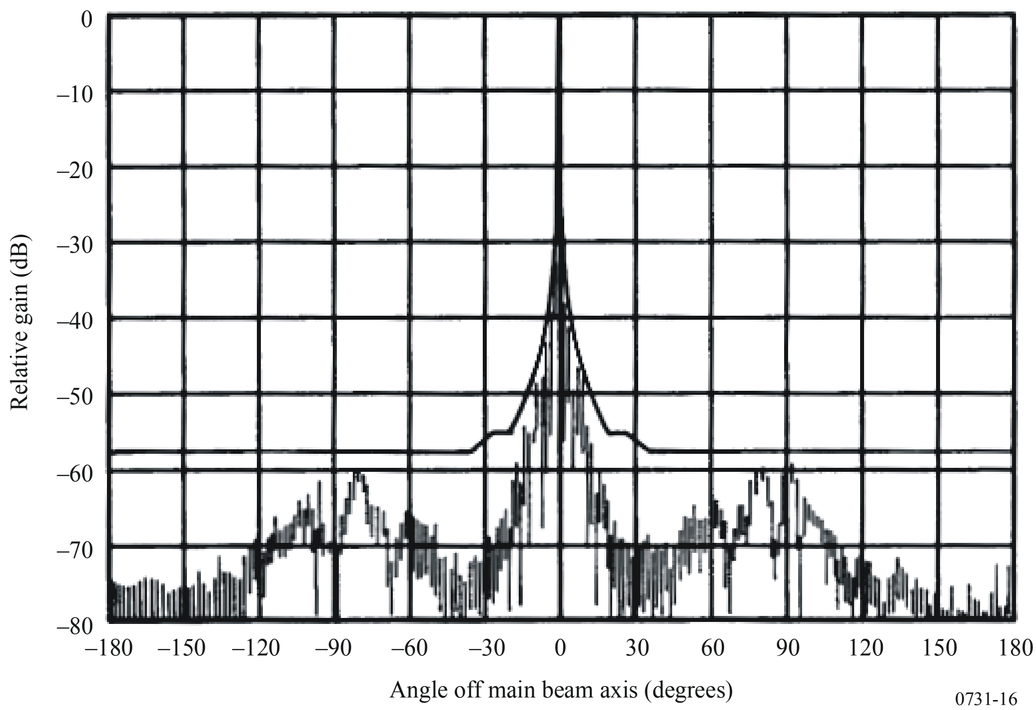


FIGURE 17

3.7 m antenna, *f* = 10.7 GHz, relative cross-polar measured pattern

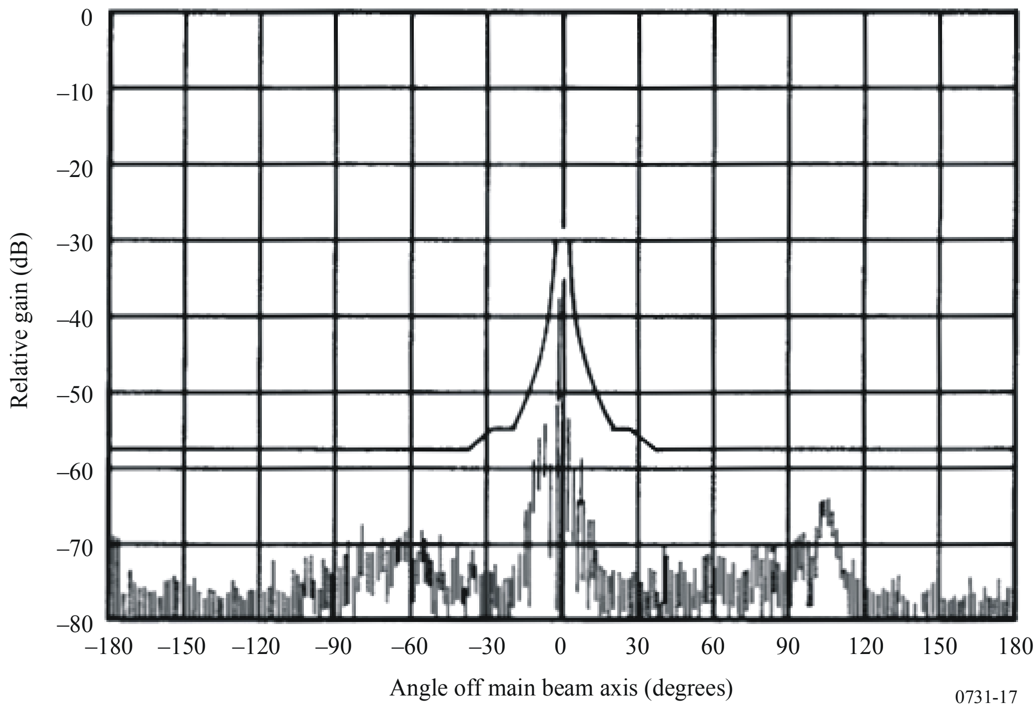
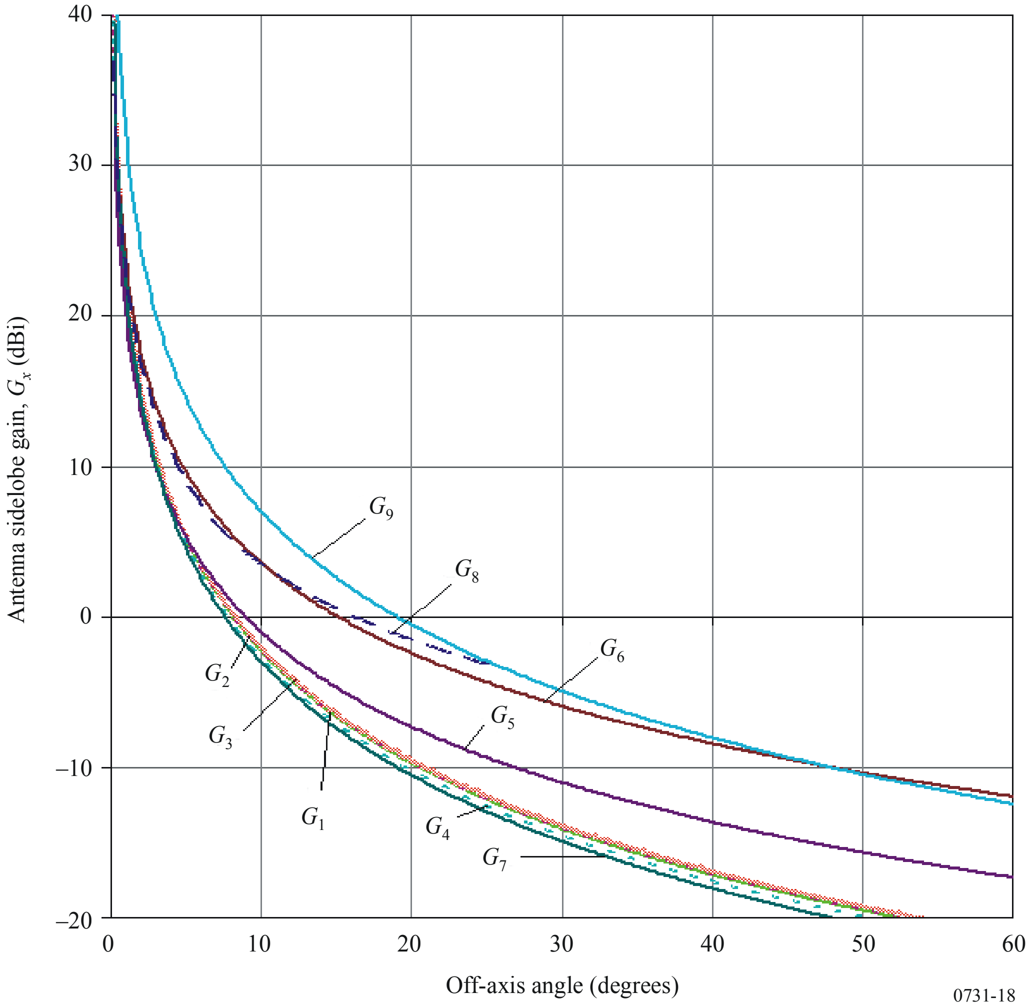


FIGURE 18

Absolute cross-polar side-lobe antenna gain pattern



$G_1(\varphi) = 22.70 + 0.29\varphi - 25 \log \varphi$ for $D/\lambda = 25$

$G_2(\varphi) = 22.69 + 0.37\varphi - 25 \log \varphi$ for $D/\lambda = 50$

$G_3(\varphi) = 22.87 + 0.42\varphi - 25 \log \varphi$ for $D/\lambda = 75$

$G_4(\varphi) = 22.15 + 0.47\varphi - 25 \log \varphi$ for $D/\lambda = 100$

$G_5(\varphi) = 20.0 - 21 \log \varphi$

$G_6(\varphi) = 23.6 - 20 \log \varphi$

$G_7(\varphi) = 22.0 - 25 \log \varphi$

$G_8(\varphi) = 23.0 - 20 \log \varphi$ for $\varphi_r \leq \varphi \leq 7°$

$= 20.2 - 16.7 \log \varphi$ for $7° < \varphi \leq 26.3°$

$= 32.0 - 25 \log \varphi$ for $26.3° < \varphi \leq 48°$

$G_9(\varphi) = 32 - 25 \log \varphi$