

## RECOMMENDATION ITU-R S.731\*

**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)

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 quantitatively 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,

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\* Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

*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:

$$\begin{array}{llll}
 G_x(\varphi) = 23 - 20 \log \varphi & \text{dBi} & \text{for } \varphi_r \leq \varphi \leq 7^\circ \\
 G_x(\varphi) = 20.2 - 16.7 \log \varphi & \text{dBi} & \text{for } 7^\circ < \varphi \leq 26.3^\circ \\
 G_x(\varphi) = 32 - 25 \log \varphi & \text{dBi} & \text{for } 26.3^\circ < \varphi \leq 48^\circ \\
 G_x(\varphi) = -10 & \text{dBi} & \text{for } 48^\circ < \varphi \leq 180^\circ
 \end{array}$$

$\varphi_r$  is equal to  $1^\circ$  or  $100 \lambda/D$ , 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 between two networks which employ only 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  $D/\lambda$  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 § 2.

## ANNEX 1

### **Modelling of earth-station antenna cross-polar characteristics**

This Annex presents background information used to develop cross-polarized patterns obtained from pattern measurements of different diameter antennas (1.2 m, 1.8 m, 2.4 m, 3.5 m and 3.7 m at 12.625 GHz). For each antenna type, a measured and an envelope pattern are described. Equations are then derived which describe cross-polarized envelopes for antennas of  $D/\lambda \geq 100$  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

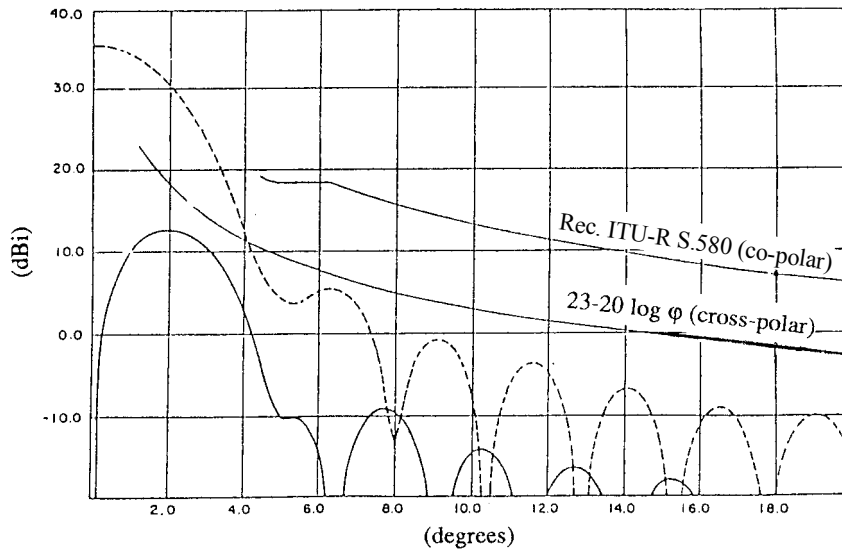


FIGURE 2  
 1.8 m single offset antenna co- and cross-polar pattern  
 calculated at 6.175 GHz – azimuth plane

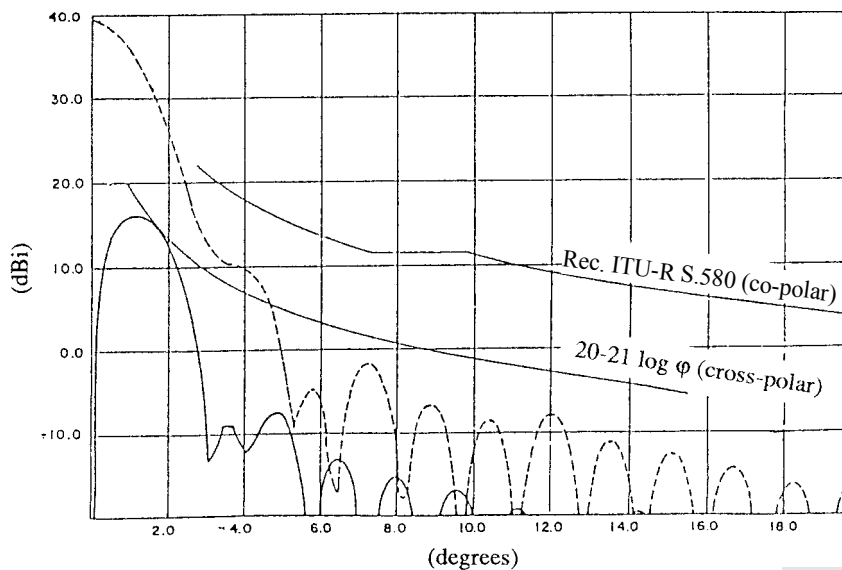
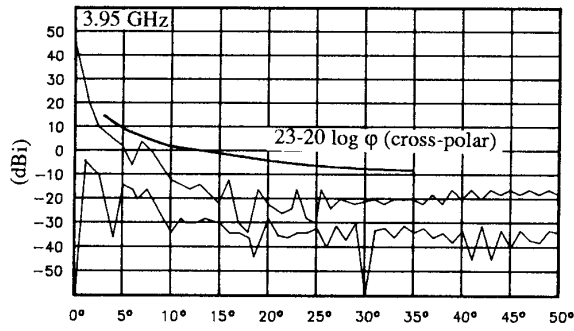
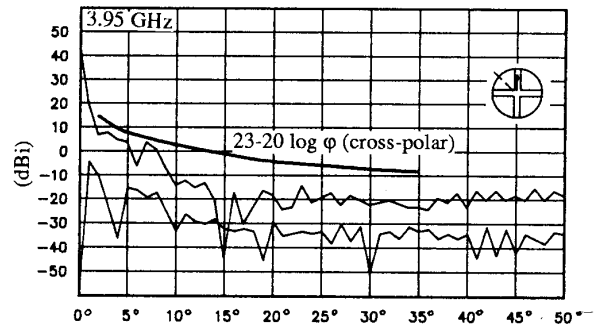


FIGURE 3

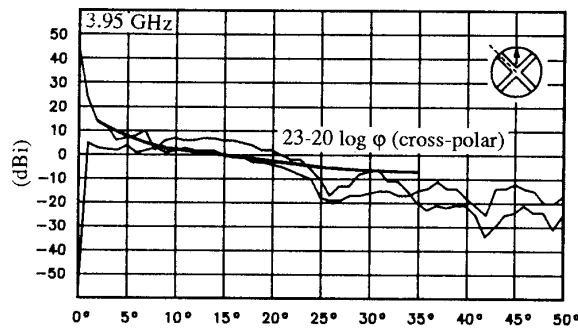
Theoretical analysis of strut effects on a 6 m double reflector axisymmetric linearly polarized antenna, at 3.95 GHz (a-c) and 6.175 GHz (d-e))



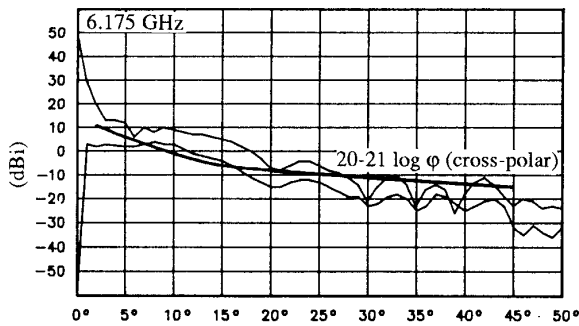
a) Co- and cross-polar 45° plane patterns, without struts



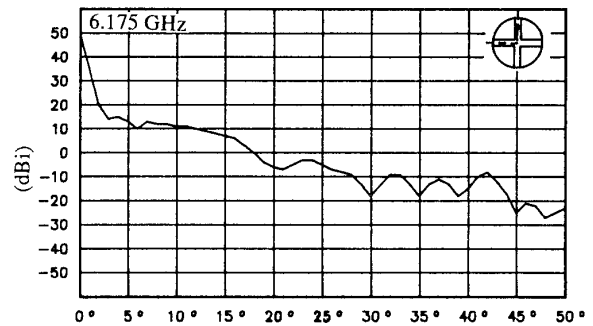
b) Same as a) including struts in vertical and horizontal planes



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

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

- a) In co-polarization, for the main lobe area where  $\varphi < \varphi_1$  ( $\varphi_1 = 1^\circ$  for large stations,  $\varphi_1 = 100 \lambda/D$  degrees for small antennas) the envelope pattern is extrapolated by a quadratic lobe defined between  $G_{//}(\varphi_1)$  for  $\varphi = \varphi_1$  and 0 dB for  $\varphi = 0^\circ$ .
- b) No constraints are placed on the cross-polarization, other than the co-polarized design objective pattern as defined by the ITU-R. The cross-polarization level is such as  $G_{+}(\varphi) < G_{//}(\varphi'_1)$  (with  $\varphi'_1 = 2 \varphi_1$ ) for  $0^\circ < \varphi < \varphi_1$ . The two co- and cross-polarized envelopes are overlapping as they reach the isotropic level ( $\varphi \geq \varphi_{ISO}$ ).

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

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

$G_0$ : gain of antenna main lobe

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

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

$$\varphi'_1 = 2.2 \varphi_1$$

$$\varphi_2 = 25.1^\circ$$

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

– for  $0 < \varphi < \varphi_1$

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

– for  $\varphi_1 < \varphi < \varphi_2$

$$G_{+}(\varphi) = G(\varphi) - [G(\varphi_1) - G(\varphi'_1)] \cdot (\varphi_{ISO} - \varphi) (\varphi_{ISO} - \varphi_1) \tag{2}$$

(if  $\varphi > \varphi_{ISO}$ ,  $G_{+}(\varphi) = G_{//}(\varphi)$ )

– for  $\varphi_2 < \varphi < 180^\circ$

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

The envelopes shown in Figs. 4 and 5 are obtained for stations of the following diameters: 1.20 m and 1.80 m at 12.625 GHz. 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.

The patterns measured for these types of antennas are shown in Figs. 4a, 5a and 5b.

FIGURE 4

1.2 m antenna,  $f = 12.625$  GHz, co- and cross-polarized templates

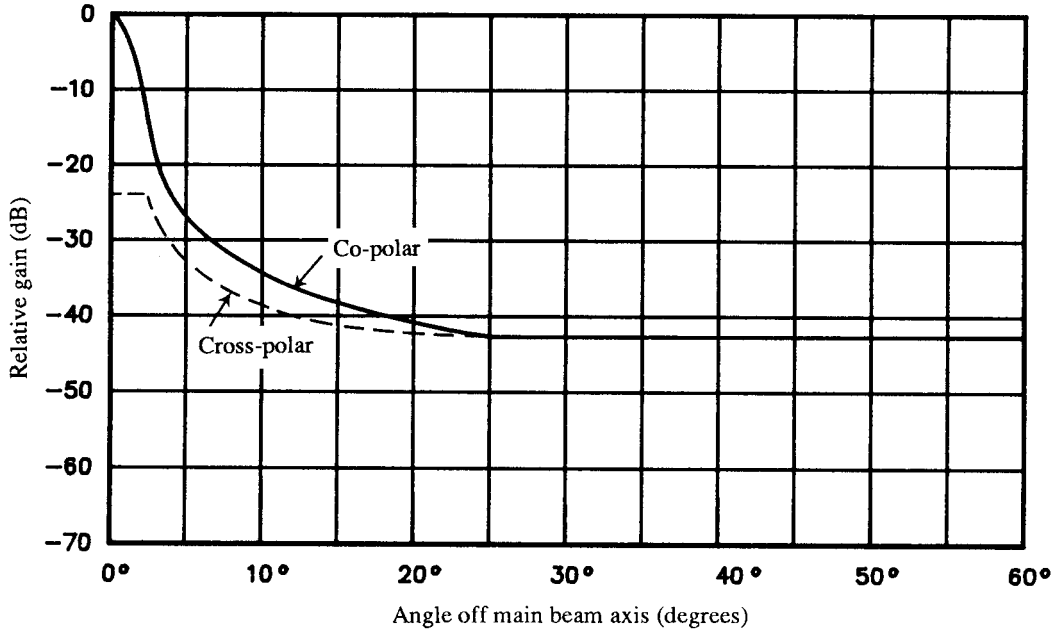


FIGURE 4a

1.2 m antenna, co- and cross-polarized measured patterns

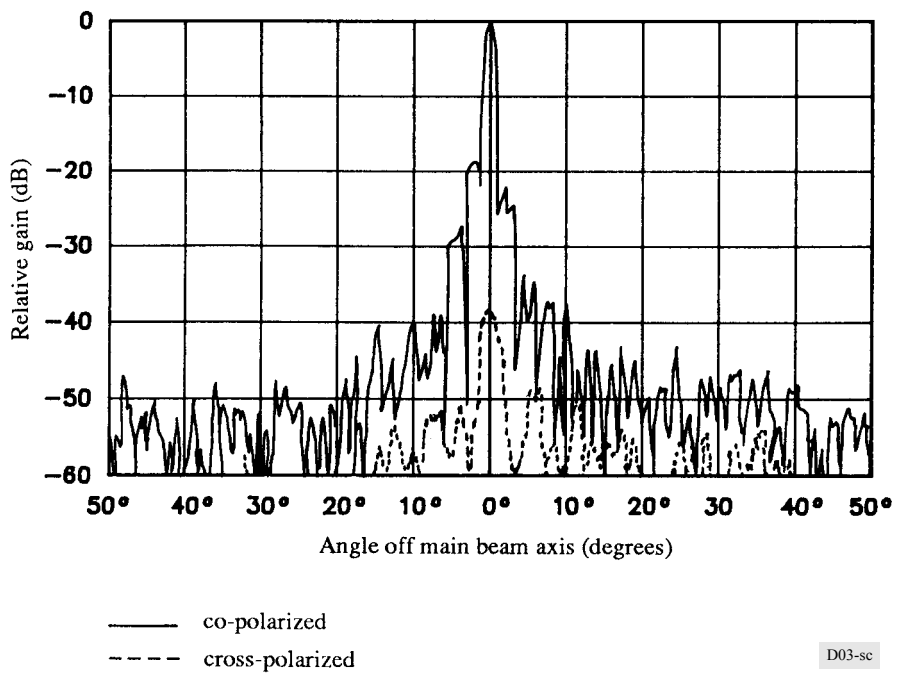


FIGURE 5  
 1.80 m antenna,  $f = 12.625$  GHz, co- and cross-polarized templates

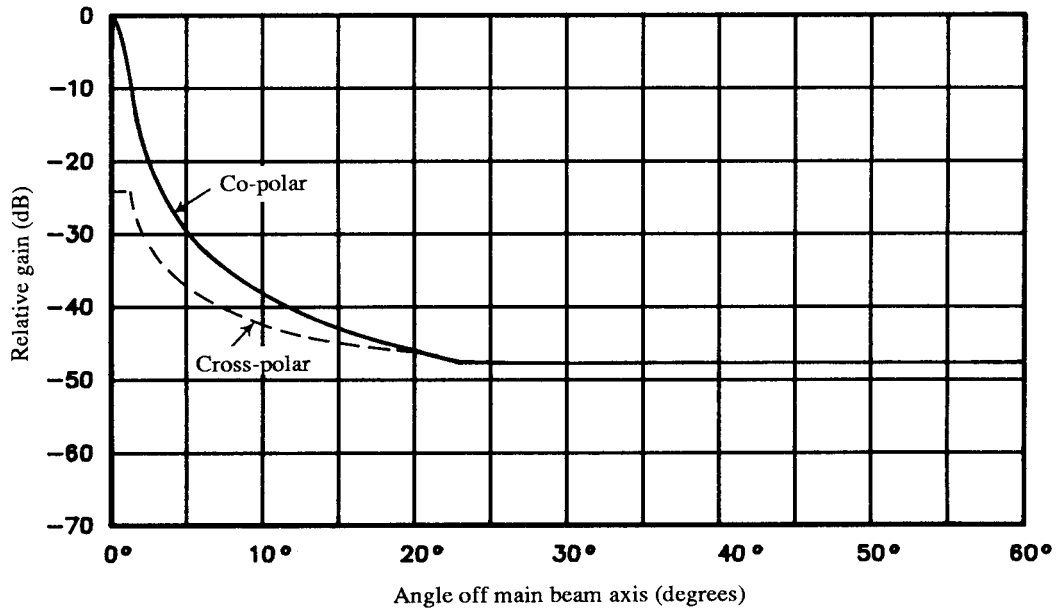


FIGURE 5a  
 1.80 m antenna, co-polarized measured pattern

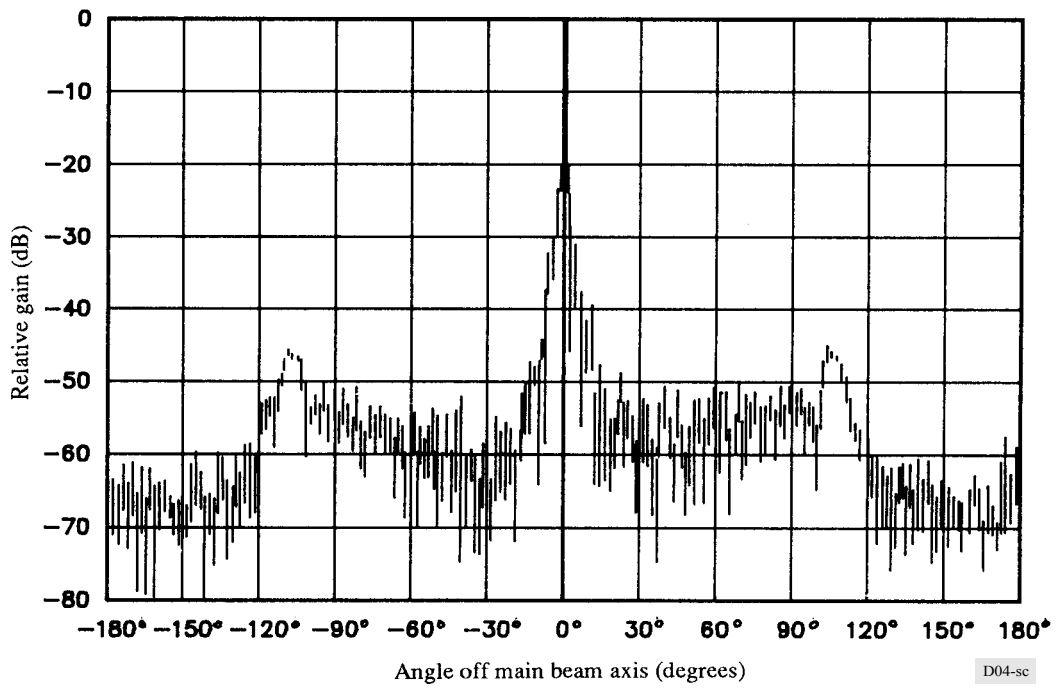
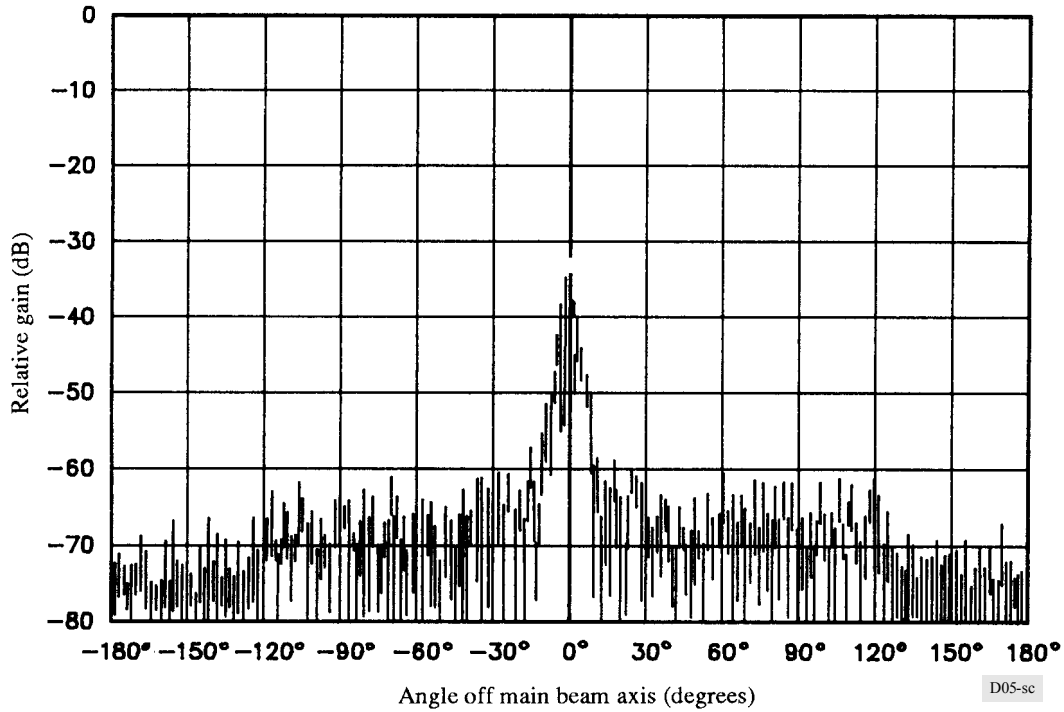


FIGURE 5b

1.80 m antenna, cross-polarized measured pattern



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

$G_0$ : gain of antenna main lobe

$$\varphi_1 = 1^\circ$$

$$G(\varphi) = 29 - 25 \log \varphi - G_0$$

$$\varphi'_1 = 1.8 \varphi_1$$

$$\varphi_2 = 20^\circ$$

$$\varphi_3 = 26.3^\circ$$

$$\varphi_4 = 33.1^\circ$$

$$\varphi_{ISO} = 10^{(29/25)} \text{ (degrees)}$$

– for  $0 < \varphi < \varphi_1$

$$G_+(\varphi) = G(\varphi'_1) \quad (4)$$

– for  $\varphi_1 < \varphi < \varphi_2$

$$G_+(\varphi) = G(\varphi) - [G(\varphi_1) - G(\varphi'_1)] \cdot (\varphi_{ISO} - \varphi) / (\varphi_{ISO} - \varphi_1) \quad (5)$$

– for  $\varphi_2 < \varphi < \varphi_3$

$$G_1(\varphi) = -3.5 - G_0$$

$$G_+(\varphi) = G_1(\varphi) - [G(\varphi_1) - G(\varphi'_1)] \cdot (\varphi_{ISO} - \varphi) / (\varphi_{ISO} - \varphi_1) \quad (6)$$

(if  $\varphi > \varphi_{ISO}$ ,  $G_+(\varphi) = G/(\varphi)$ )



– for  $\varphi_3 < \varphi < \varphi_4$

$$G_+(\varphi) = 32 - 25 \log \varphi - G_0 \quad (7)$$

– for  $\varphi_4 < \varphi < 180^\circ$

$$G_+(\varphi) = -10 - G_0 \quad (8)$$

The envelopes shown in Figs. 6, 7 and 8 are obtained for stations of the following diameters: 2.40 m, 3.50 m and 3.70 m at 12.625 GHz. 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 patterns measured for these types of antennas are shown in Figs. 6a, 7a, 8a, 6b, 7b and 8b.

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  $32 - 25 \log \varphi$  co-polar function by letting  $52 - 10 \log \varphi$  equal 32. Evaluation of these functions as absolute gain for various values of  $D/\lambda$  is as follows:

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

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

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

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

The angles at which these gain functions are equal to a co-polar envelope gain of  $32 - 25 \log \varphi$  are  $31.7^\circ$ ,  $25.2^\circ$ ,  $21.4^\circ$  and  $20.8^\circ$  respectively. Additional functions which have been developed are:

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

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

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

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

These functions are plotted in Fig. 9. From this Figure a single function which adequately covers all the above functions is:

$$\begin{aligned} G_\lambda(\varphi) &= 23 - 20 \log \varphi & \text{dBi} & \quad \text{for } \varphi_r \leq \varphi \leq 7^\circ \\ &= 20.2 - 16.7 \log \varphi & \text{dBi} & \quad \text{for } 7^\circ < \varphi \leq 26.3^\circ \\ &= 32 - 25 \log \varphi & \text{dBi} & \quad \text{for } 26.3^\circ < \varphi \leq 48^\circ \\ &= -10 & \text{dBi} & \quad \text{for } 48^\circ < \varphi \leq 180^\circ \end{aligned}$$

$\varphi_r$  is equal to  $1^\circ$  or  $100 \lambda/D$ , whichever is greater.

FIGURE 6

2.40 m, antenna,  $f = 12.625$  GHz, co- and cross-polarized templates

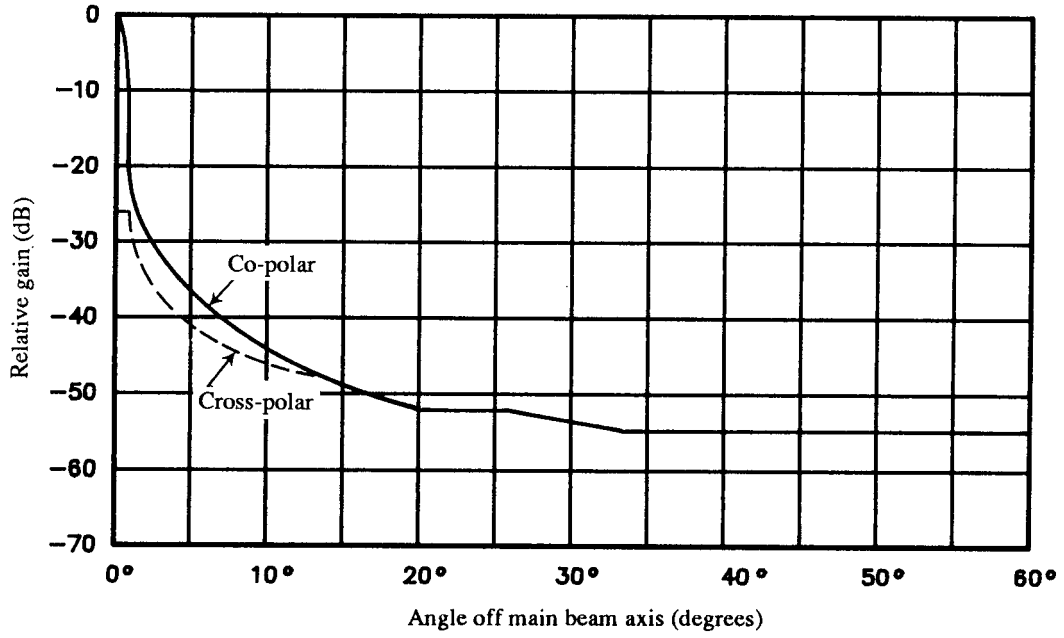
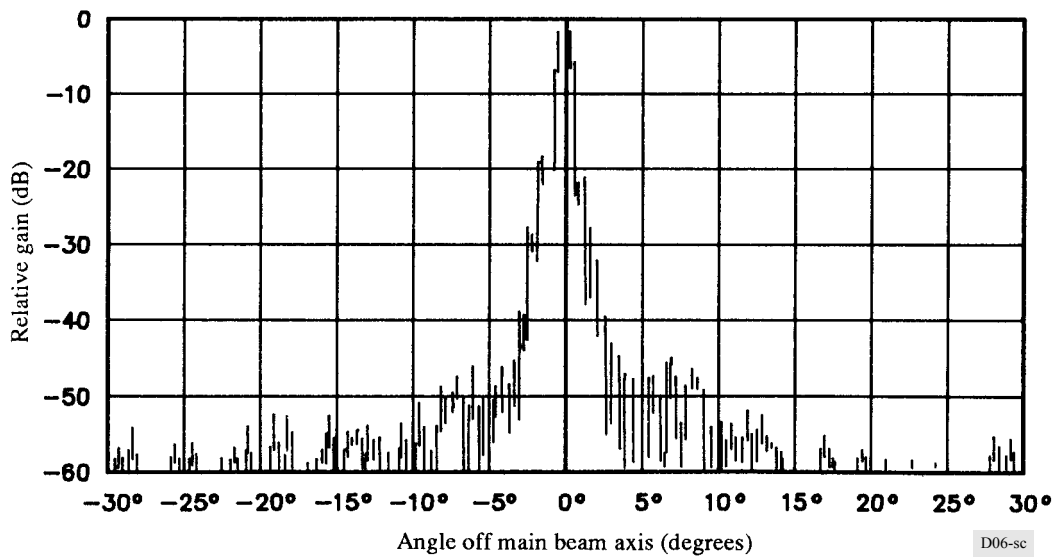


FIGURE 6a

2.40 m antenna, co-polarized measured pattern



D06-sc

FIGURE 6b  
2.40 m antenna, cross-polarized measured pattern

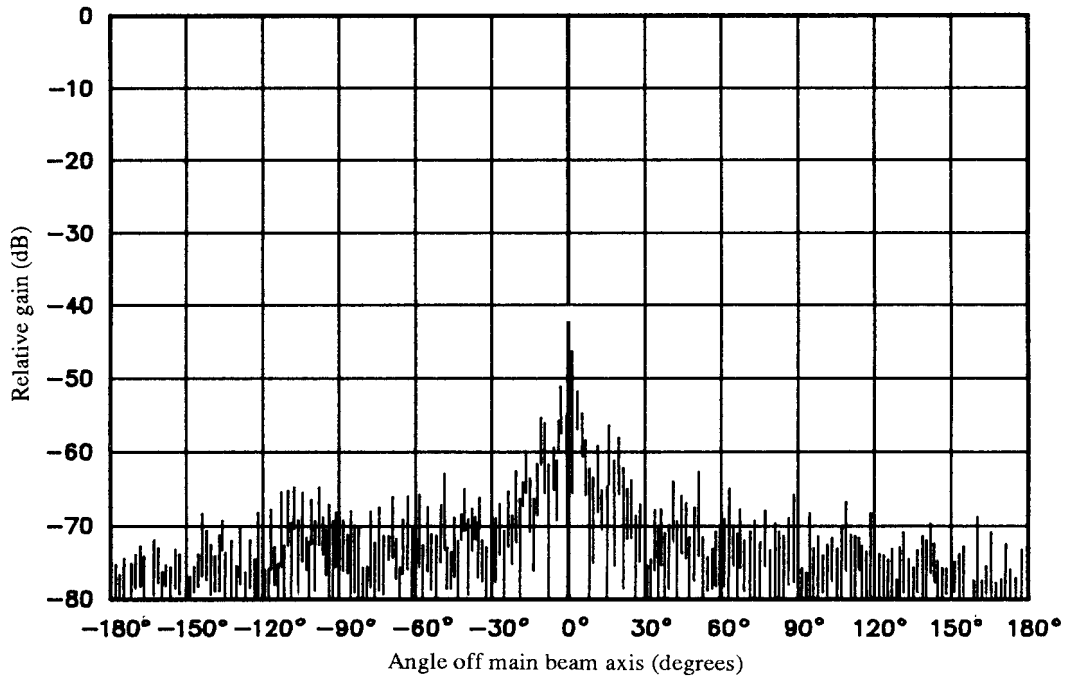


FIGURE 7  
3.50 m antenna,  $f = 12.625$  GHz, co- and cross-polarized templates

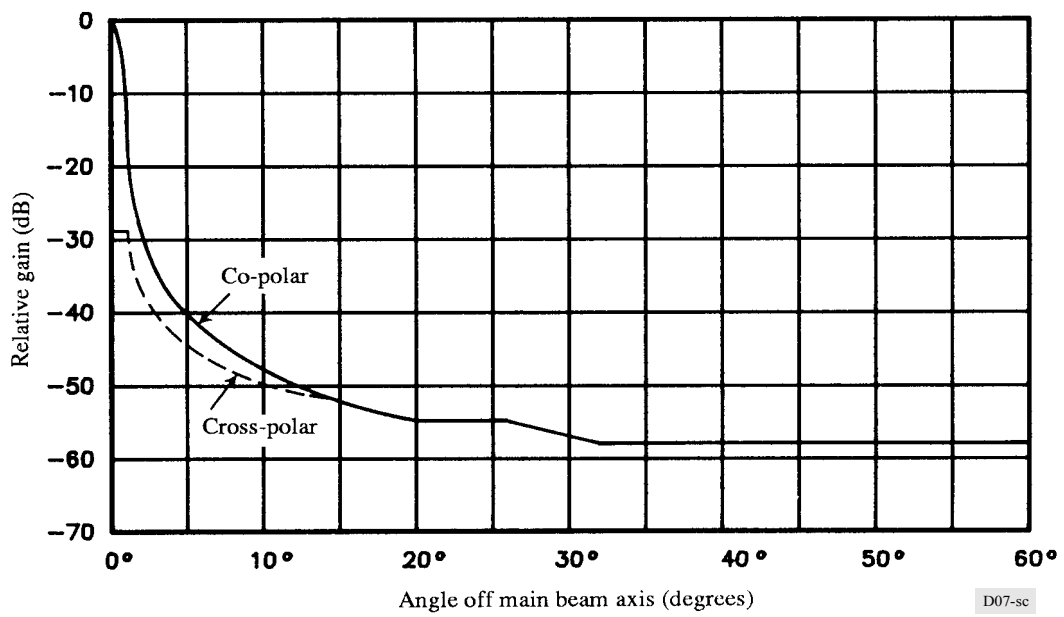


FIGURE 7a

3.50 m antenna, co-polarized measured pattern

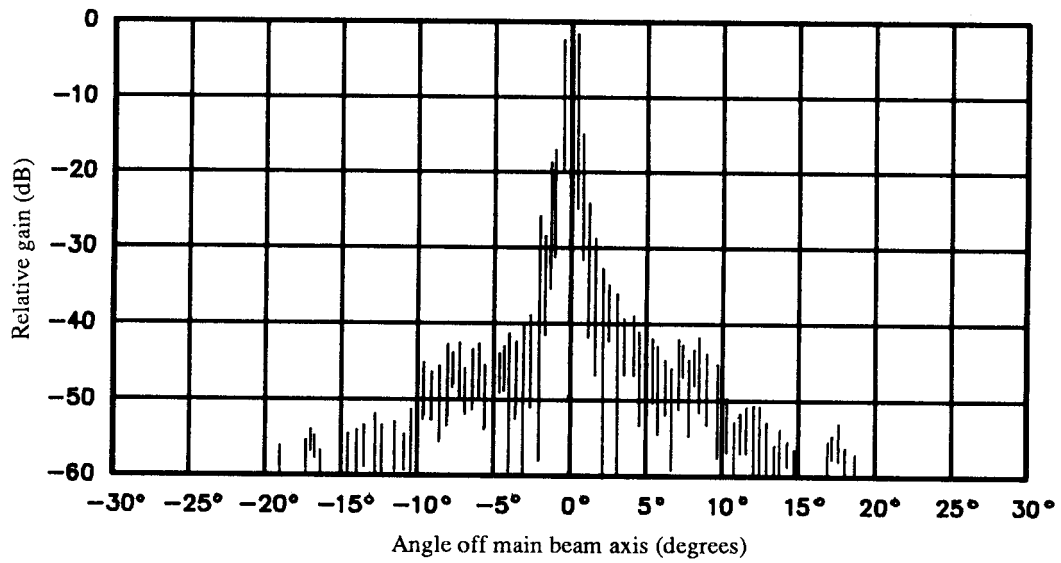
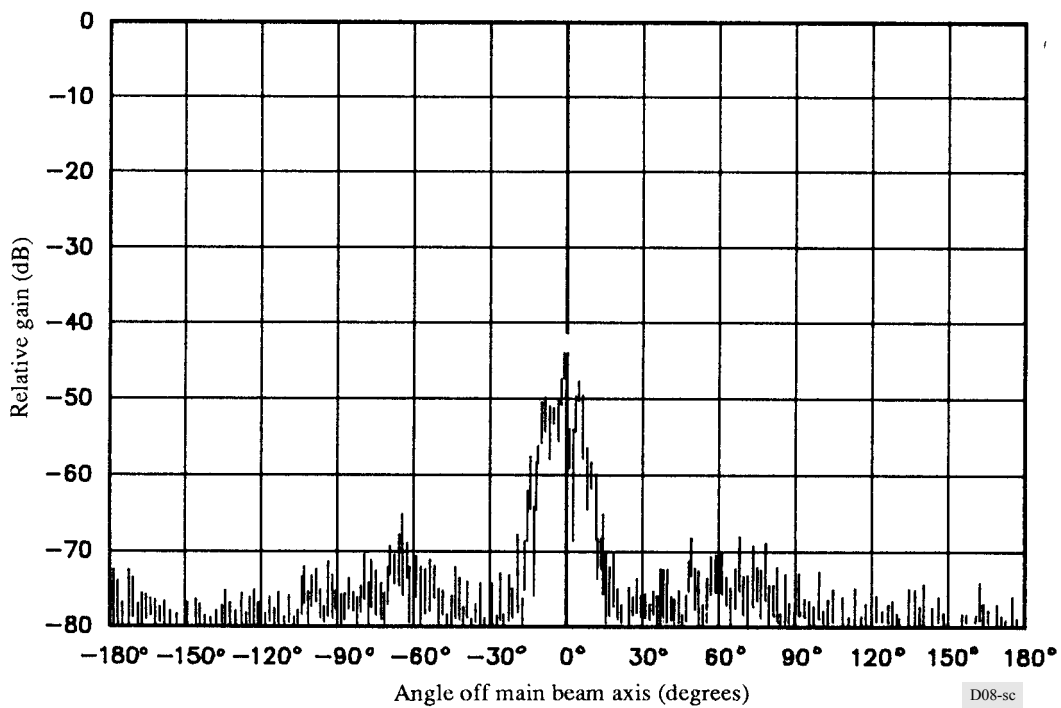


FIGURE 7b

3.50 m antenna, cross-polarized measured pattern



D08-sc

FIGURE 8  
 3.70 m antenna,  $f = 10.7$  GHz, co- and cross-polarized templates

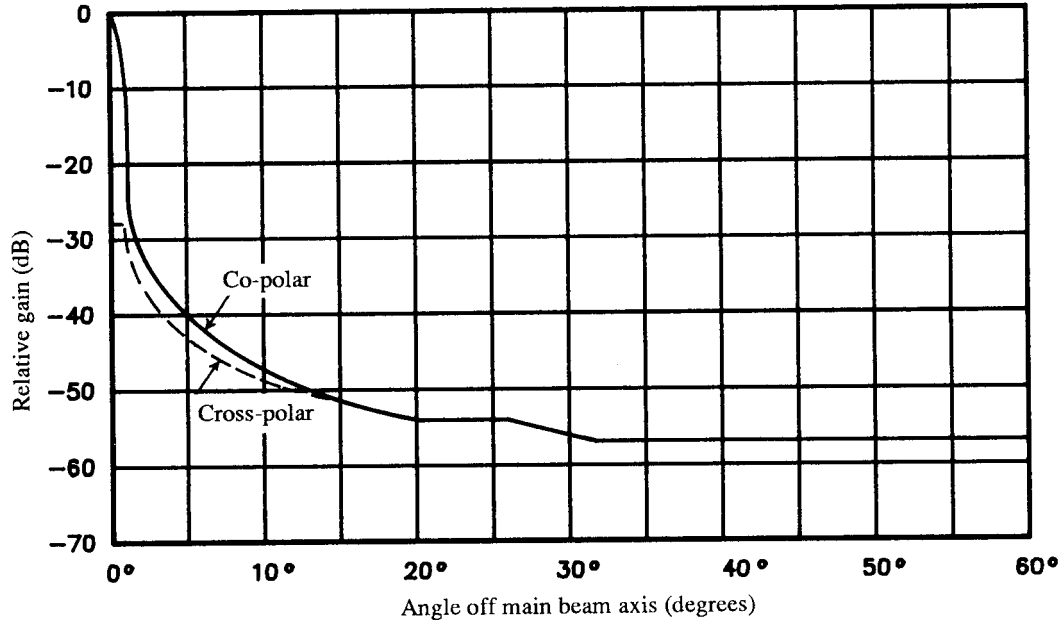
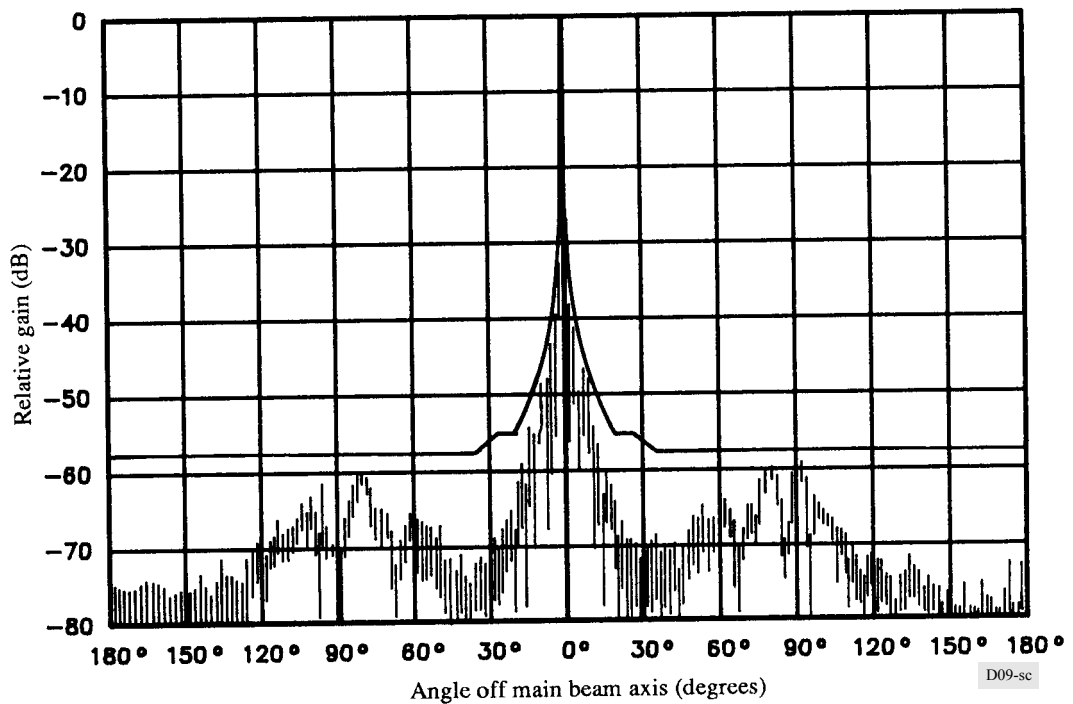
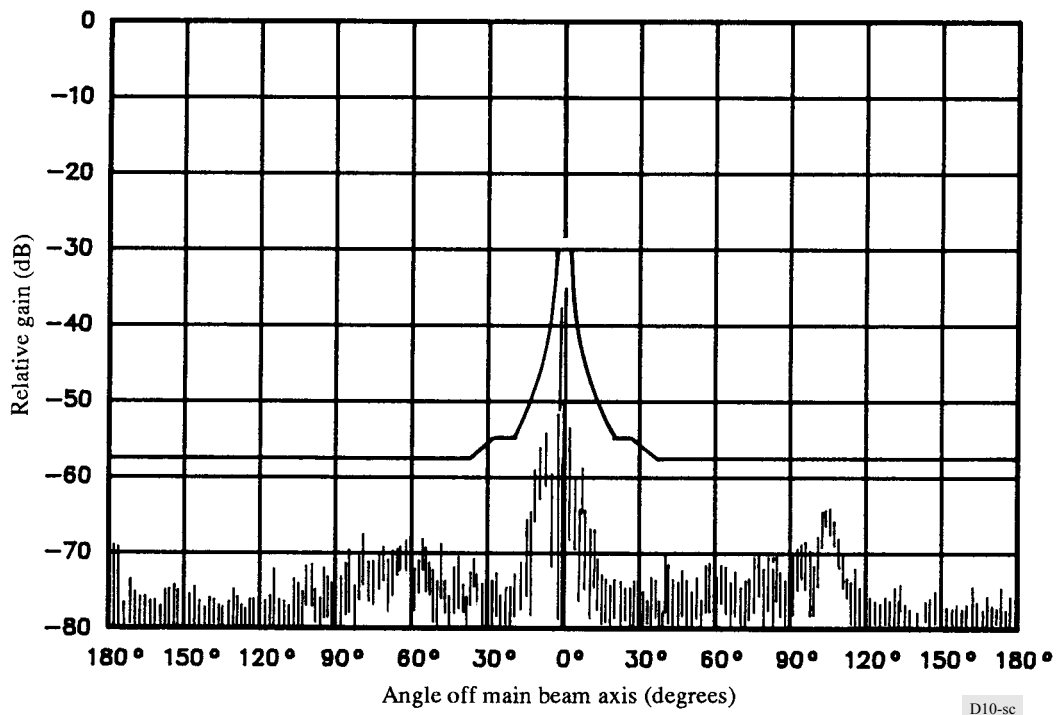


FIGURE 8a  
 3.70 m antenna, co-polar measured pattern



D09-sc

FIGURE 8b  
3.70 m antenna, co-polar measured pattern



D10-sc

FIGURE 9  
Cross-polarized side-lobe envelope gain functions

