RECOMMENDATION ITU-R BO.652-1[*,**]

Reference patterns for earth-station and satellite antennas for the broadcasting-satellite service in the 12 GHz band and for the associated feeder links[***] in the 14 GHz and 17 GHz bands

(Question ITU-R 93/11)

(1986-1992)

The ITU Radiocommunication Assembly,

considering

a) that for broadcasting-satellite service planning purposes, simple antenna reference patterns are necessary;

b) that for reasons of cost, aesthetics, and ease of installation, antennas for individual reception should be small, simple, and amenable to mass-production techniques, and that within these general guidelines different design options should be possible;

c) that planning for the broadcasting-satellite service based on individual reception in frequency bands around 12 GHz has taken place and community reception may also be accommodated;

d) that easily applied antenna reference patterns are desirable to determine the levels of inter-regional interference;

e) that every effort should be made to avoid unnecessary spill-over into adjacent service areas;

f) that for the assessment of mutual interference between the 12 GHz broadcasting-satellite service and other services sharing the same frequency bands, it may be necessary to use a reference radiation pattern for both the earth-station receiving antenna and the satellite transmitting antenna;

g) that the use of antennas with the best achievable radiation pattern will lead to the most efficient use of the radio-frequency spectrum and the geostationary-satellite orbit;

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[*] *Note –* Reports ITU-R BO.810 and ITU-R BO.952 were referred to in preparing this Recommendation.

[**] Radiocommunication Study Group 6 made editorial amendments to this Recommandation in 2001 in accordance with Resolution ITU-R 44.

[***] The part of this Recommandation concerning feeder links should be brought to the attention of Radiocommunication Study Group 4.

h) that measured data for the radiation patterns of 12 GHz broadcasting-satellite earth-station receiving antennas and satellite transmitting antennas are available;

j) that planning for feeder links in frequency bands around 14 GHz and 17 GHz which is used for the 12 GHz broadcasting-satellite service has taken place;

k) that every effort should be made to avoid interference to adjacent broadcasting satellites;

l) that for the assessment of mutual interference between the 14 GHz/17 GHz feeder links for satellite broadcasting and other services sharing the same frequency bands, it may be necessary to use reference radiation patterns for both the earth-station transmitting antenna and the satellite receiving antenna for the feeder links;

m) that reference patterns for 14 GHz and 17 GHz feeder-link earth-station transmitting antennas and satellite receiving antennas are presented in Appendix 30A (Orb-88) of the Radio Regulations (RR),

recommends

1 that for earth-station receiving antennas, to ensure that interference up to the limit of the service area should not exceed that envisaged in Plans for the 12 GHz band:

1.1 in Regions 1 and 3 individual reception receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 1 by curves A and B respectively, taking $\varphi_0 = 2°$ (nominal half-power beamwidth);

1.2 in Region 2, individual reception receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 2 by curves A and B respectively, taking $\varphi_0 = 1.7°$ (nominal half-power beamwidth);

1.3 in Regions 1 and 3 community reception receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference pattern given in Fig. 1 by curves A′ and B respectively taking $\varphi_0 = 1°$ (nominal half-power beamwidth);

2 that for satellite transmitting antenna beams with circular or elliptical cross-section:

2.1 in Regions 1 and 3 the radiation pattern should conform to the applicable reference patterns given in Fig. 3;

2.2 in Region 2 the radiation pattern for normal roll-off should conform as a minimum requirement to the applicable reference pattern given in Fig. 4 and, for fast roll-off (see Note 1) to the reference pattern given in Fig. 5;

3 that for feeder-link earth-station antennas:

3.1 in Region 2 transmitting antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 6 by curves A and B respectively;

3.2 in Regions 1 and 3 the co-polar and cross-polar radiation patterns of transmitting antennas should not exceed the limits indicated in Fig. 7;

4 that for satellite receiving antennas:

4.1 in Region 2 receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 8 by curves A and B respectively;

4.2 in Region 2 the radiation pattern for fast roll-off receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 9 by curves A and B respectively;

4.3 in Regions 1 and 3 receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 10 by curves A and B respectively;

4.4 in Regions 1 and 3 the radiation pattern for fast roll-off receiving antennas should have co-polar and cross-polar radiation patterns not exceeding the reference patterns given in Fig. 11 by curves A and B respectively.

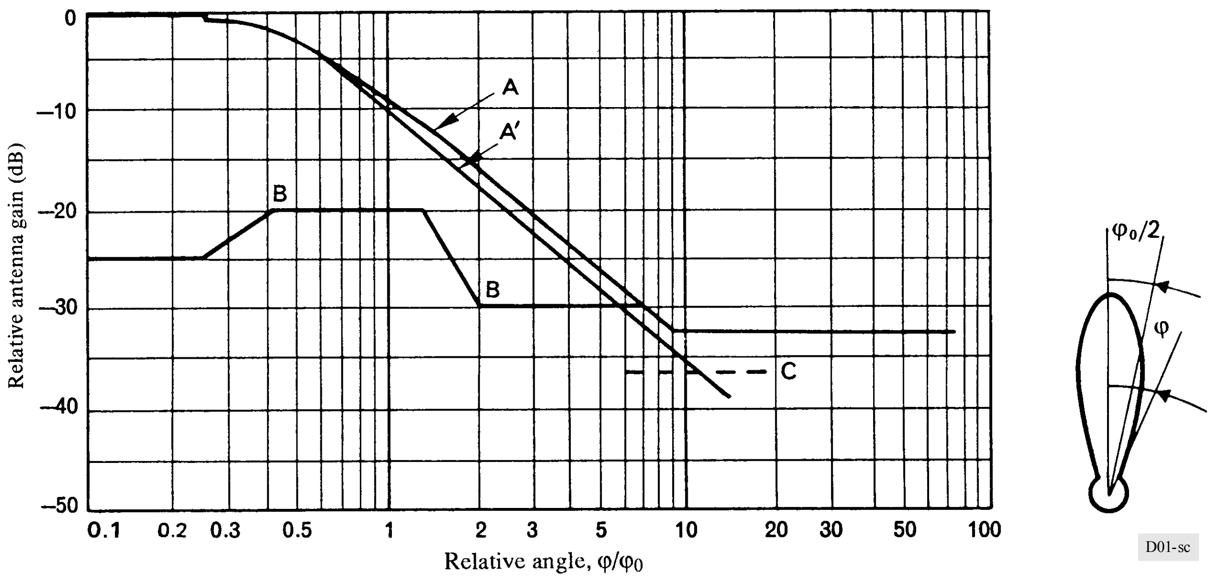
NOTE 1 – In Region 2, when necessary to reduce interference, the pattern shown in Fig. 5 was used to develop the Plan; this use is indicated in the Plan by an appropriate symbol. This pattern is derived from an antenna producing an elliptical beam with fast roll-off in the main lobe. Three curves for different values of φ_0 are shown as examples.

NOTE 2 – The patterns in Figs. 1-5 and 8-11 are given as functions of the relative angle φ/φ_0, where φ is the angle measured from the axis of the beam, and φ_0 is the angular width of the beam measured between the –3 dB levels. The levels are expressed in dB relative to the maximum (on-axis) gain of the antenna.

NOTE 3 – Annex 1 provides supporting analytic data for the BSS reference antenna patterns (i.e. transmitting space stations and receiving earth stations).

FIGURE 1

Co-polar and cross-polar receiving earth-station antenna reference patterns in Regions 1 and 3



Curve A: Co-polar component for individual reception without side-lobe suppression (dB relative to main beam gain):

0	for	$0 \leq \varphi \leq 0.25\ \varphi_0$
$-12\ (\varphi/\varphi_0)^2$	for	$0.25\ \varphi_0 < \varphi \leq 0.707\ \varphi_0$
$-\ [9.0 + 20 \log (\varphi/\varphi_0)]$	for	$0.707\ \varphi_0 < \varphi \leq 1.26\ \varphi_0$
$-\ [8.5 + 25 \log (\varphi/\varphi_0)]$	for	$1.26\ \varphi_0 < \varphi \leq 9.55\ \varphi_0$
-33	for	$\varphi > 9.55\ \varphi_0$

Curve A′: Co-polar component for community reception without side-lobe suppression (dB relative to main beam gain):

0	for	$0 \leq \varphi \leq 0.25\ \varphi_0$
$-12\ (\varphi/\varphi_0)^2$	for	$0.25\ \varphi_0 < \varphi \leq 0.86\ \varphi_0$
$-\ [10.5 + 25 \log (\varphi/\varphi_0)]$	for	$\varphi > 0.86\ \varphi_0$ up to intersection with curve C, (then curve C)

Curve B: Cross-polar component for both types of reception (dB relative to main beam gain):

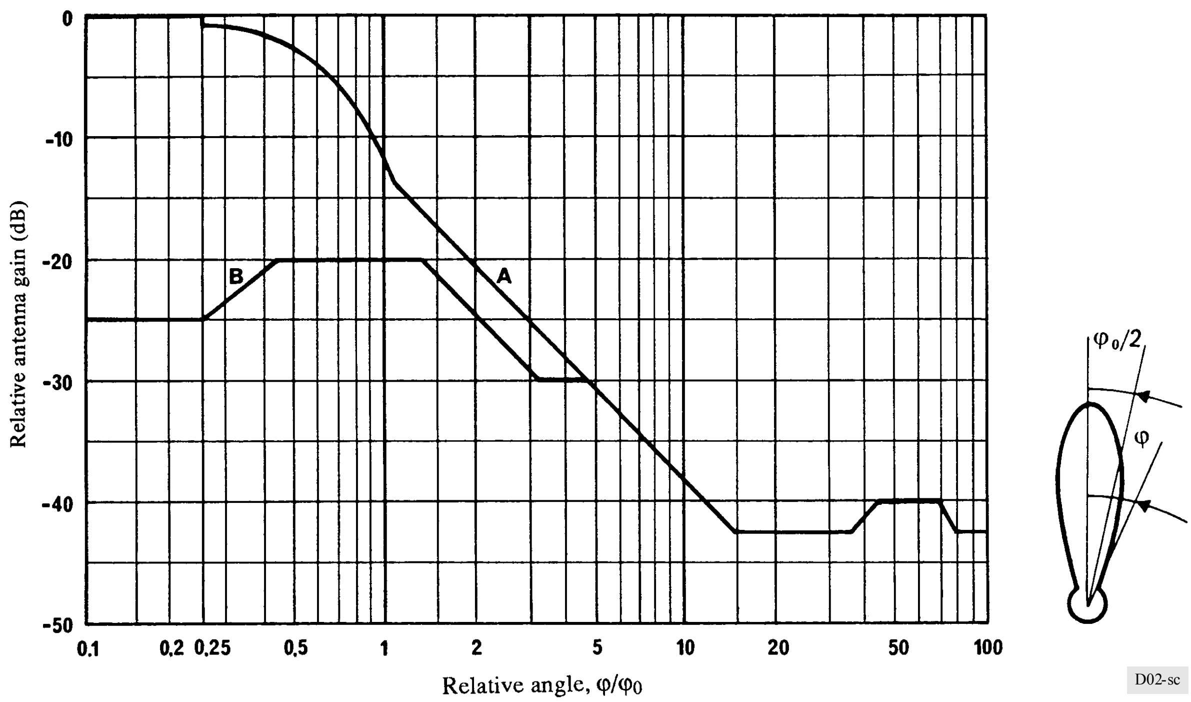
-25	for	$0 \leq \varphi \leq 0.25\ \varphi_0$
$-(30 + 40 \log \lvert\varphi/\varphi_0 - 1\rvert)$	for	$0.25\ \varphi_0 < \varphi \leq 0.44\ \varphi_0$
-20	for	$0.44\ \varphi_0 < \varphi \leq 1.4\ \varphi_0$
$-(30 + 25 \log \lvert\varphi/\varphi_0 - 1\rvert)$	for	$1.4\ \varphi_0 < \varphi \leq 2\ \varphi_0$

-30 until intersection with co-polar component curve; then co-polar component curve

Curve C: Minus the on-axis gain (curve C in this figure illustrates the particular case of an antenna with an on-axis gain of 37 dBi).

FIGURE 2

Reference patterns for co-polar and cross-polar components for receiving earth-station antennas in Region 2



Curve A: Co-polar component without side-lobe suppression (dB relative to main beam gain):

0	for $0 \leq \varphi \leq 0.25\ \varphi_0$
$-12\ (\varphi/\varphi_0)^2$	for $0.25\ \varphi_0 < \varphi \leq 1.13\ \varphi_0$
$-\{14 + 25 \log (\varphi/\varphi_0)\}$	for $1.13\ \varphi_0 < \varphi \leq 14.7\ \varphi_0$
-43.2	for $14.7\ \varphi_0 < \varphi \leq 35\ \varphi_0$
$-\{85.2 - 27.2 \log (\varphi/\varphi_0)\}$	for $35\ \varphi_0 < \varphi \leq 45.1\ \varphi_0$
-40.2	for $45.1\ \varphi_0 < \varphi \leq 70\ \varphi_0$
$-\{-55.2 + 51.7 \log (\varphi/\varphi_0)\}$	for $70\ \varphi_0 < \varphi \leq 80\ \varphi_0$
-43.2	for $80\ \varphi_0 < \varphi \leq 180°$

Curve B: Cross-polar component (dB relative to main beam gain):

-25	for $0 \leq \varphi \leq 0.25\ \varphi_0$
$-(30 + 40 \log \lvert\varphi/\varphi_0 - 1\rvert)$	for $0.25\ \varphi_0 < \varphi \leq 0.44\ \varphi_0$
-20	for $0.44\ \varphi_0 < \varphi \leq 1.28\ \varphi_0$
$-(17.3 + 25 \log \lvert\varphi/\varphi_0\rvert)$	for $1.28\ \varphi_0 < \varphi \leq 3.22\ \varphi_0$

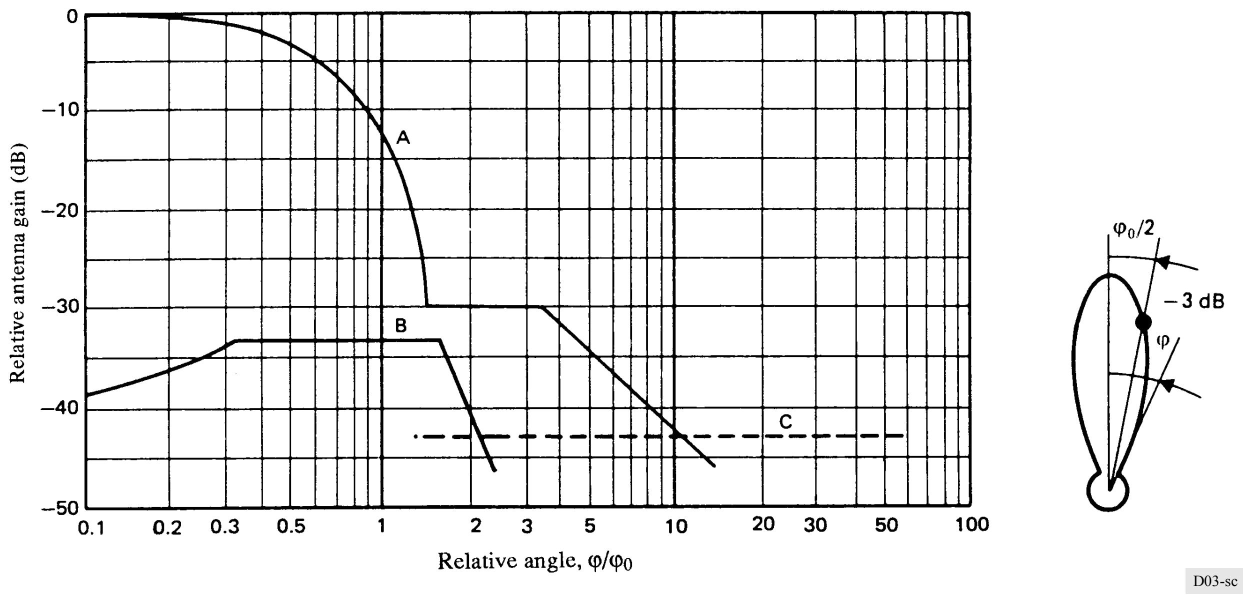
-30 until intersection with co-polar component curve; then co-polar component curve

NOTE 1 – In the angular range between 0.1 φ_0 and 1.13 φ_0 the co-polar and cross-polar gains must not exceed the reference patterns.

NOTE 2 – At off-axis angles larger than 1.13 φ_0 and for 90% of all side-lobe peaks in each of the reference angular windows, the gain must not exceed the reference patterns. The reference angular windows are 1.13 φ_0 to 3 φ_0; 3 φ_0 to 6 φ_0; 6 φ_0 to 10 φ_0; 10 φ_0 to 20 φ_0; 20 φ_0 to 40 φ_0; 40 φ_0 to 75 φ_0 and 75 φ_0 to 180°.

FIGURE 3

Reference patterns for co-polar and cross-polar components for satellite transmitting antennas in Regions 1 and 3



Curve A: Co-polar component (dB relative to main beam gain):

$-12\ (\varphi/\varphi_0)^2$	for	$0 \leq \varphi \leq 1.58\ \varphi_0$
-30	for	$1.58\ \varphi_0 < \varphi \leq 3.16\ \varphi_0$
$-[17.5 + 25 \log (\varphi/\varphi_0)]$	for	$\varphi > 3.16\ \varphi_0$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

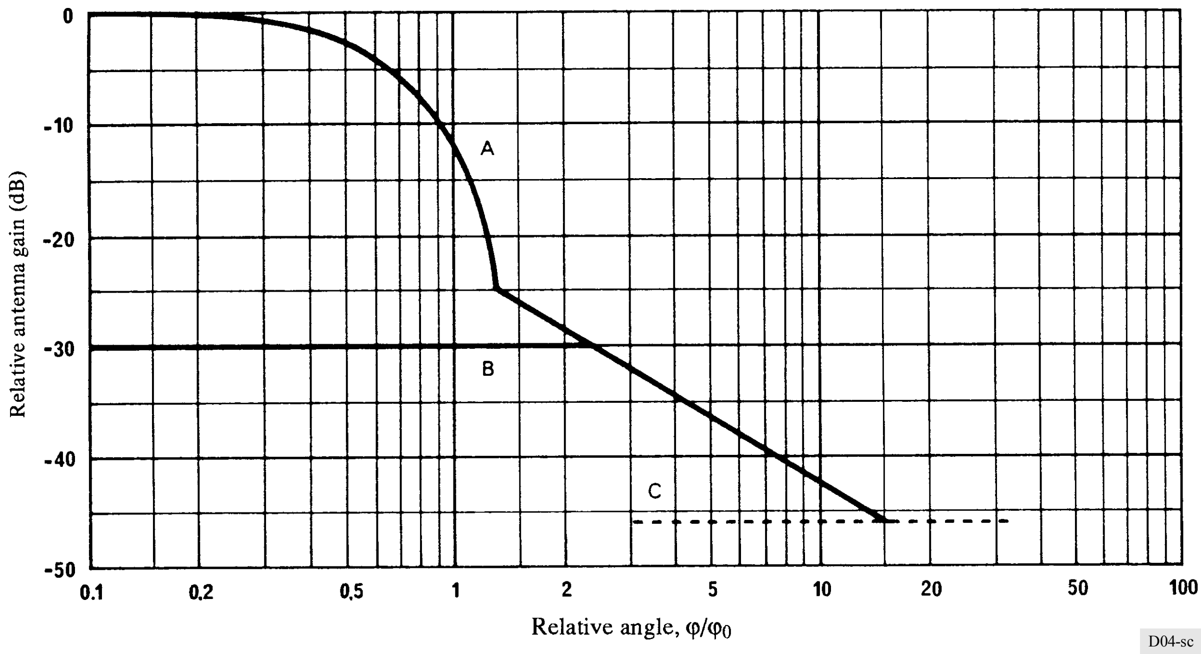
$-(40 + 40 \log \lvert\varphi/\varphi_0 - 1\rvert)$	for	$0 \leq \varphi \leq 0.33\ \varphi_0$
-33	for	$0.33\ \varphi_0 < \varphi \leq 1.67\ \varphi_0$
$-(40 + 40 \log \lvert\varphi/\varphi_0 - 1\rvert)$	for	$\varphi > 1.67\ \varphi_0$

after intersection with curve C: as curve C

Curve C: Minus the on-axis gain (curve C in this figure illustrates the particular case of an antenna with an on-axis gain of 43 dBi).

FIGURE 4

Reference patterns for co-polar and cross-polar components for satellite transmitting antennas in Regions 2



Curve A: Co-polar component (dB relative to main beam gain):

$-12\ (\varphi/\varphi_0)^2$ for $0 \leq \varphi/\varphi_0 \leq 1.45$

$-[22 + 20 \log (\varphi/\varphi_0)]$ for $\varphi/\varphi_0 > 1.45$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

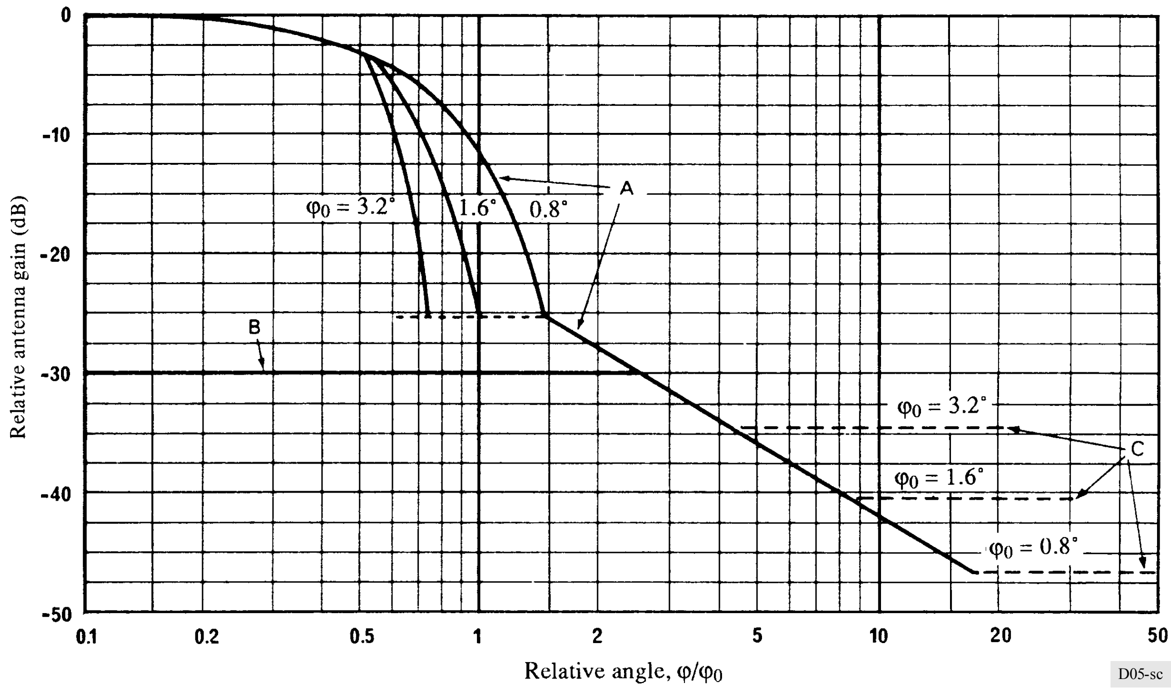
-30 for $0 \leq \varphi/\varphi_0 \leq 2.51$

after intersection with co-polar pattern: co-polar pattern

Curve C: Minus the on-axis gain (curve C in this figure illustrates the particular case of an antenna with an on-axis gain of 46 dBi).

FIGURE 5

Reference patterns for co-polar and cross-polar components for satellite transmitting antennas with fast roll-off in the main beam for Region 2



Curve A: Co-polar component (dB relative to main beam gain):

$-12\,(\varphi/\varphi_0)^2$	for	$0 \le \varphi/\varphi_0 \le 0.5$
$-18.75\,\varphi_0^2\,(\varphi/\varphi_0 - x)^2$	for	$0.5 < \varphi/\varphi_0 \le 1.16/\varphi_0 + x$
-25.23	for	$1.16/\varphi_0 + x < \varphi/\varphi_0 \le 1.45$
$-[22 + 20 \log (\varphi/\varphi_0)]$	for	$\varphi/\varphi_0 > 1.45$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

-30 for $0 \le \varphi/\varphi_0 < 2.51$

after intersection with co-polar pattern: co-polar pattern

Curve C: Minus the on-axis gain (curves A and C represent examples of three antennas having different values of φ_0 as labelled in Fig. 5. The on-axis gains of these antennas are approximately 34, 40 and 46 dBi, respectively),

where:

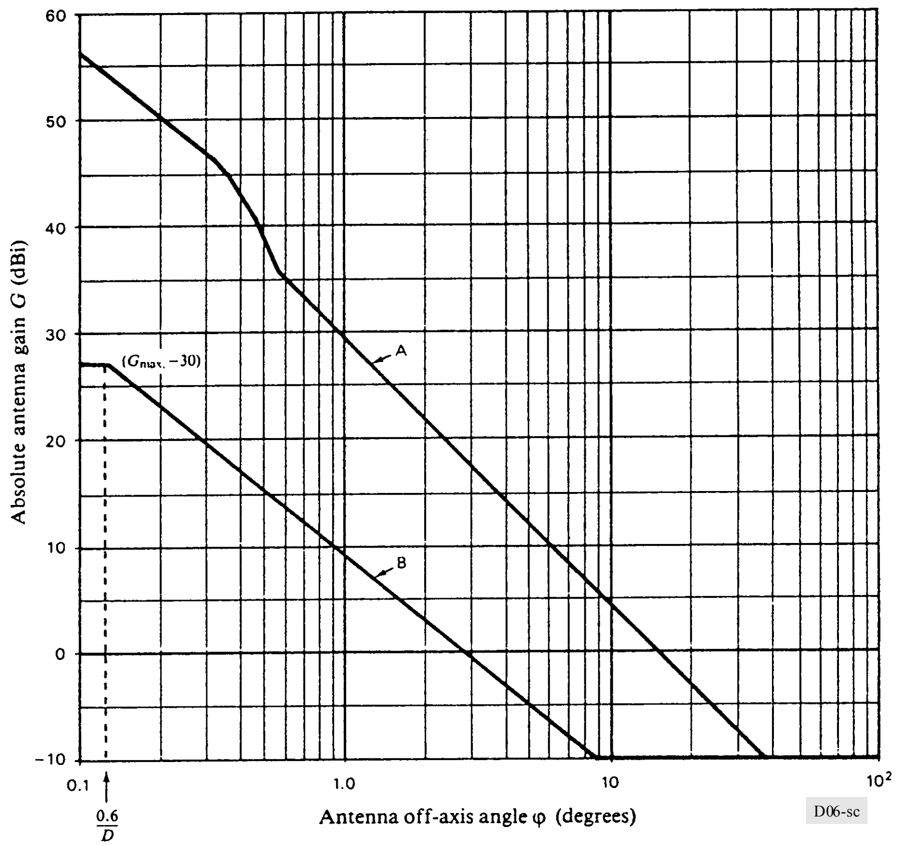
φ : off-axis angle (degrees)

φ_0 : dimension of the minimum ellipse fitted around the down-link service area in the direction of interest (degrees)

$x = 0.5\,(1 - 0.8/\varphi_0)$

FIGURE 6

Reference patterns for co-polar and cross-polar components for feeder-link earth-station antennas in Region 2



Curve A: Co-polar component (dBi):

$36 - 20 \log \varphi$	for	$0.1° \leq \varphi < 0.32°$
$51.3 - 53.2 \varphi^2$	for	$0.32° \leq \varphi < 0.54°$
$29 - 25 \log \varphi$	for	$0.54° \leq \varphi < 36°$
-10	for	$\varphi \geq 36°$

Curve B: Cross-polar component (dBi):

$G_{max} - 30$	for	$\varphi < (0.6/D)°$
$9 - 20 \log \varphi$	for	$(0.6/D)° \leq \varphi < 8.7°$
-10	for	$\varphi \geq 8.7°$

where:

φ : off-axis referred to the main-lobe axis (degrees)

G_{max} : on-axis co-polar gain of the antenna (dBi)

D : diameter of the antenna (m) ($D \geq 2.5$).

NOTE 1 – In the angular range between 0.1° and 0.54°, the co-polar gain must not exceed the reference pattern.

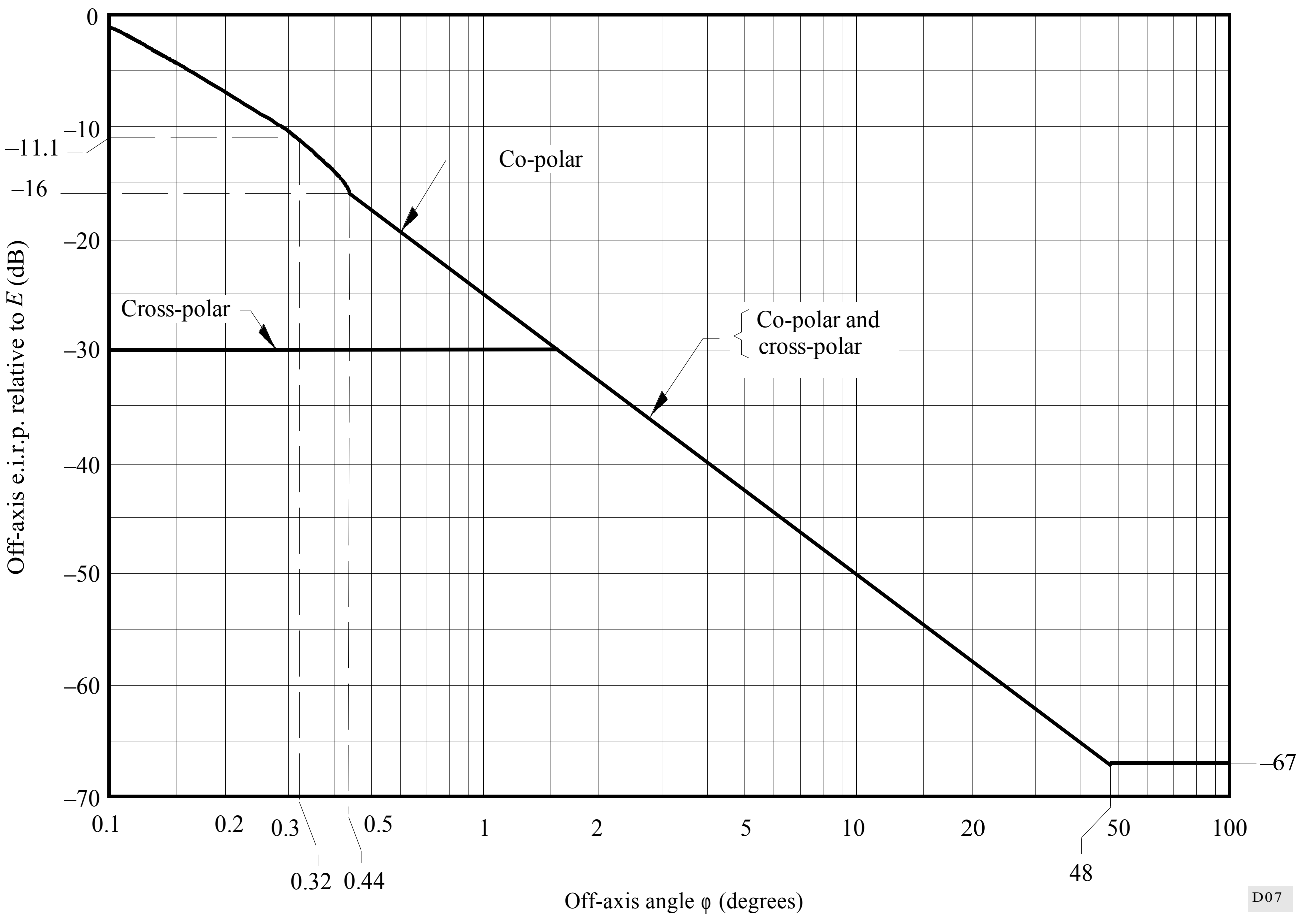
NOTE 2 – In the angular range between 0° and $(0.6/D)°$, the cross-polar gain must not exceed the reference pattern.

NOTE 3 – At the larger off-axis angles and for 90% of all side-lobe peaks in each of the reference angular windows, the gain must not exceed the reference pattern. The reference angular windows are 0.54° to 1°, 1° to 2°, 2° to 4°, 4° to 7°, 7° to 10°, 10° to 20°, 20° to 40°, 40° to 70°, 70° to 100° and 100° to 180°. The first reference angular window for evaluating the cross-polar component should be $(0.6/D)°$ to 1°.

NOTE 4 – *X*-axis is absolute value of angle. The feeder-link Plan is based on an earth-station transmitting antenna diameter of 5 m for the band 17.3-18.1 GHz.

FIGURE 7

Earth station e.i.r.p. at angles of antenna axis for feeder-link earth-station antennas in Regions 1 and 3



Co-polar component (dBW):

E	(dBW)	for	$0° < \varphi \leq 0.1°$
$E - 21 - 20 \log \varphi$	(dBW)	for	$0.1° < \varphi \leq 0.32°$
$E - 5.7 - 53.2\, \varphi^2$	(dBW)	for	$0.32° < \varphi \leq 0.44°$
$E - 25 - 25 \log \varphi$	(dBW)	for	$0.44° < \varphi \leq 48°$
$E - 67$	(dBW)	for	$\varphi > 48°$

Cross-polar component (dBW):

$E - 30$	(dBW)	for	$0° \leq \varphi \leq 1.6°$
$E - 25 - 25 \log \varphi$	(dBW)	for	$1.6° < \varphi \leq 48°$
$E - 67$	(dBW)	for	$\varphi > 48°$

where:

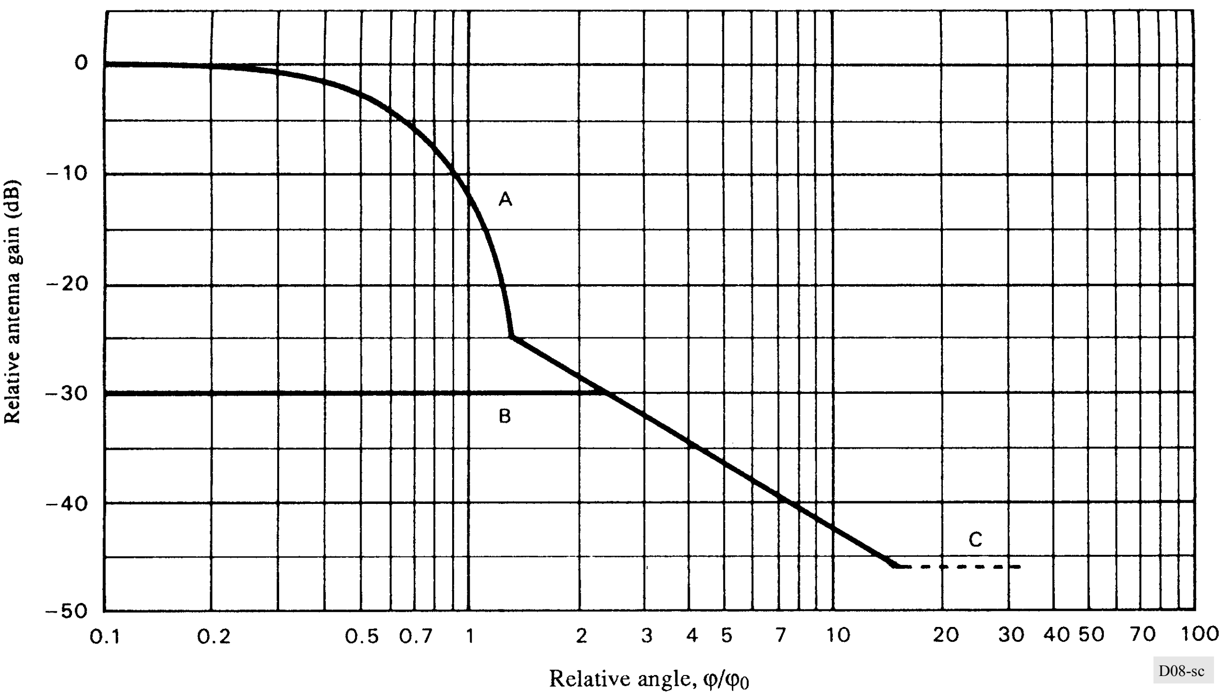
E: earth-station e.i.r.p. on the antenna axis (dBW)

φ: off-axis angle referred to the main lobe axis (degrees)

NOTE 1 – *X*-axis is absolute value of angle. The feeder-link Plan is based on an earth-station transmitting antenna diameter of 5 m for the band 17.3-18.1 GHz and 6 m for the band 14.5-14.8 GHz.

FIGURE 8

Reference patterns for co-polar and cross-polar components for satellite receiving antenna in Region 2



Curve A: Co-polar component (dB relative to main beam gain):

$-12\ (\varphi/\varphi_0)^2$ for $0 \leq \varphi/\varphi_0 \leq 1.45$

$-[22 + 20 \log (\varphi/\varphi_0)]$ for $\varphi/\varphi_0 > 1.45$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

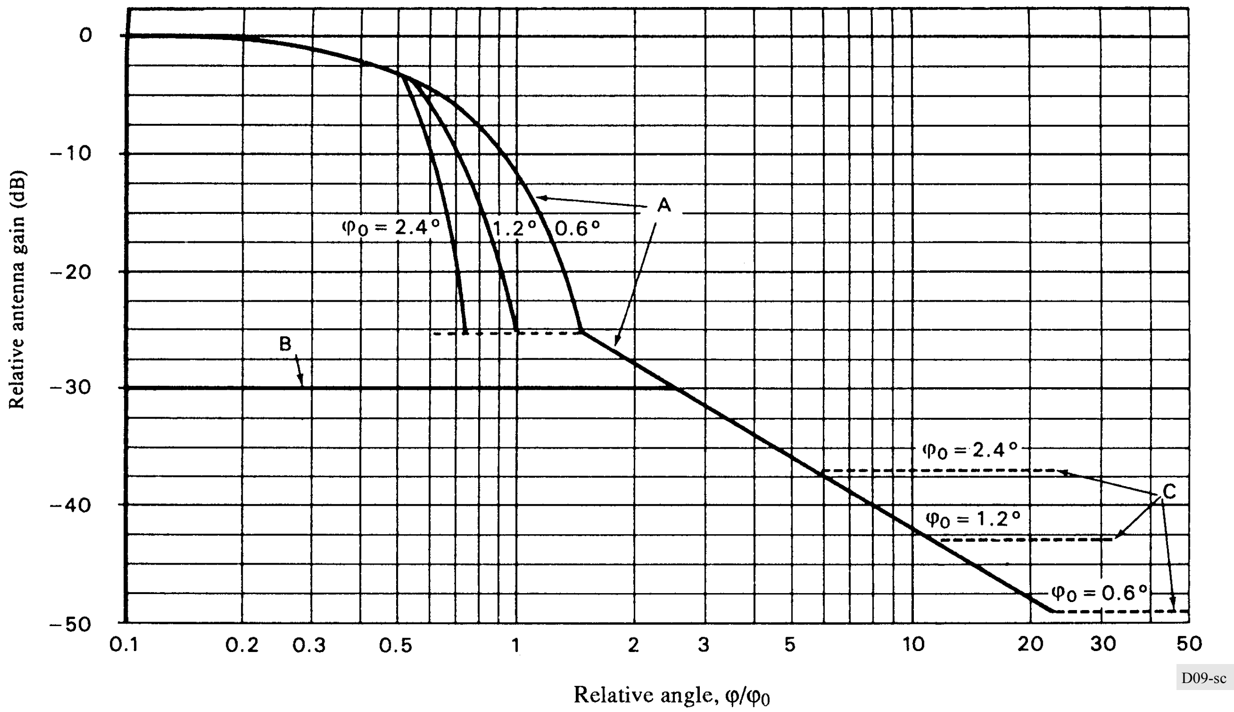
-30 for $0 \leq \varphi/\varphi_0 \leq 2.51$

after intersection with curve A: as curve A

Curve C: Minus the on-axis gain (curve C in this figure illustrates the particular case of an antenna with an on-axis gain of 46 dBi).

FIGURE 9

Reference patterns for co-polar and cross-polar components for satellite receiving antennas with fast roll-off in the main beam for Region 2



Curve A: Co-polar component (dB relative to main beam gain):

$-12\ (\varphi/\varphi_0)^2$	for	$0 \leq \varphi/\varphi_0 \leq 0.5$
$-33.33\ \varphi_0^2\ (\varphi/\varphi_0 - x)^2$	for	$0.5 < \varphi/\varphi_0 \leq 0.87/\varphi_0 + x$
-25.23	for	$0.87/\varphi_0 + x < \varphi/\varphi_0 \leq 1.413$
$-[22 + 20 \log (\varphi/\varphi_0)]$	for	$\varphi/\varphi_0 > 1.413$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

-30 for $0 \leq \varphi/\varphi_0 < 2.51$

after intersection with curve A: as curve A

Curve C: Minus the on-axis gain (curves A and C represent examples of three antennas having different values of φ_0 as labelled in Fig. 9. The on-axis gains of these antennas are 37, 43 and 49 dBi, respectively),

where:

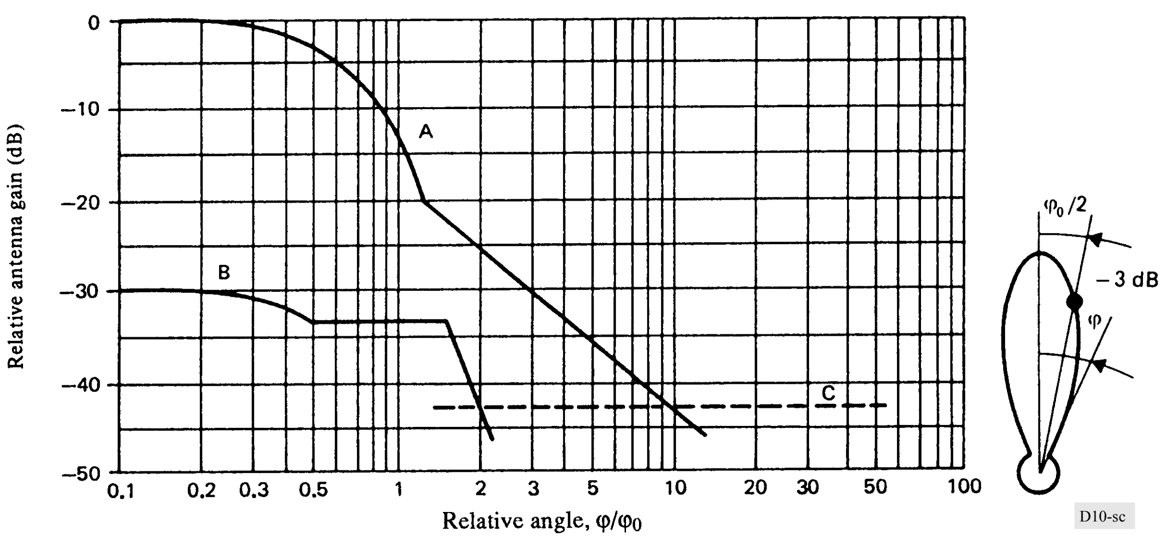
φ : off-axis angle (degrees)

φ_0 : dimension of the minimum ellipse fitted around the feeder-link service area in the direction of interest (degrees)

$x = 0.5\ (1 - 0.6/\varphi_0)$

FIGURE 10

Satellite receive antenna reference pattern generally used in Regions 1 and 3



Curve A: Co-polar component

The co-polar reference pattern is given by the formula:

Co-polar relative gain (dB)

$G = -12\ (\varphi/\varphi_0)^2$ for $0 \leq \varphi/\varphi_0 \leq 1.30$

$G = -17.5 - 25 \log (\varphi/\varphi_0)$ for $\varphi/\varphi_0 > 1.30$

after intersection with curve C: as curve C (curve C equals minus the on-axis gain)

Curve B: Cross-polar component

The cross-polar reference pattern is given by the formula:

Cross-polar relative gain (dB)

$G = -30 - 12\ (\varphi/\varphi_0)^2$ for $0 \leq \varphi/\varphi_0 \leq 0.5$

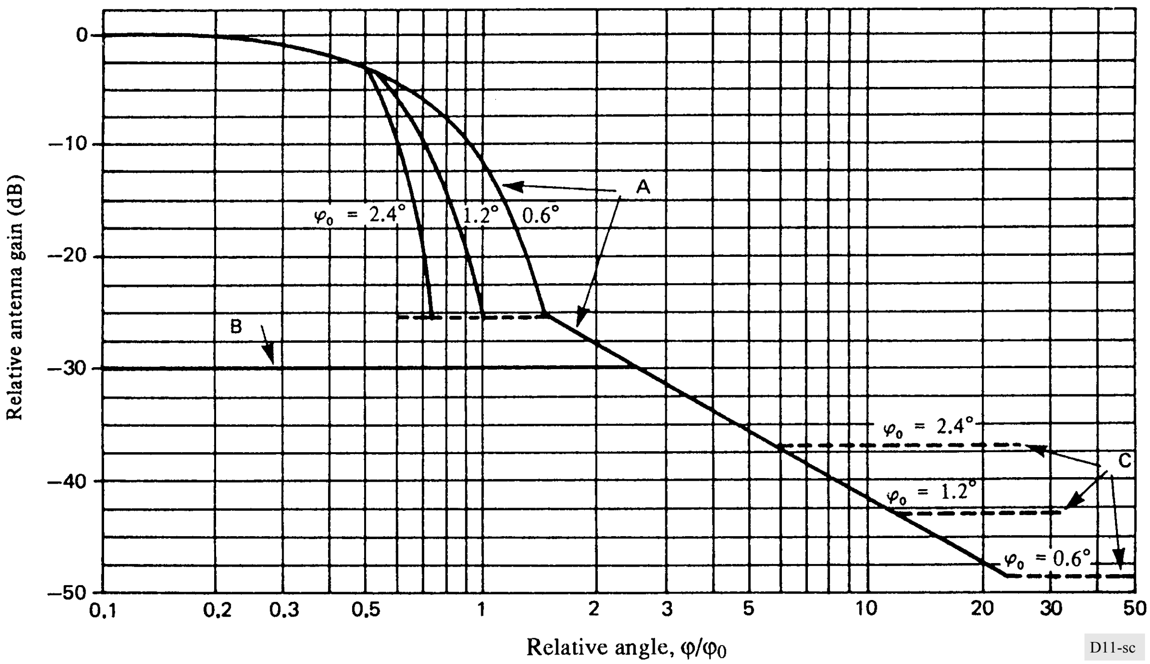
$G = -33$ for $0.5 < \varphi/\varphi_0 \leq 1.67$

$G = -40 - 40 \log (\varphi/\varphi_0 - 1)$ for $\varphi/\varphi_0 > 1.67$

after intersection with curve C: as curve C (curve C equals minus the on-axis gain).

FIGURE 11

Reference patterns for co-polar and cross-polar components for satellite receiving antennas with fast roll-off in the main beam for Regions 1 and 3



Curve A: Co-polar component (dB relative to main beam gain):

$-12\,(\varphi/\varphi_0)^2$	for	$0 \le \varphi/\varphi_0 \le 0.5$
$-33.33\,\varphi_0^2\,(\varphi/\varphi_0 - x)^2$	for	$0.5 < \varphi/\varphi_0 \le 0.87/\varphi_0 + x$
-25.23	for	$0.87/\varphi_0 + x < \varphi/\varphi_0 \le 1.413$
$-[22 + 20 \log(\varphi/\varphi_0)]$	for	$\varphi/\varphi_0 > 1.413$

after intersection with curve C: as curve C

Curve B: Cross-polar component (dB relative to main beam gain):

-30 for $0 \le \varphi/\varphi_0 < 2.51$

after intersection with curve A: as curve A

Curve C: Minus the on-axis gain (curves A and C represent examples of three antennas having different values of φ_0 as labelled in Fig. 11. The on-axis gains of these antennas are 37, 43 and 49 dBi, respectively),

where:

φ : off-axis angle (degrees)

φ_0 : dimension of the minimum ellipse fitted around the feeder-link service area in the direction of interest (degrees)

$x = 0.5\,(1 - 0.6/\varphi_0)$

ANNEX 1

1 Introduction

For planning the broadcasting-satellite service, it is necessary to make certain assumptions concerning the maximum gain of the antenna (both for transmitting and receiving), and the way in which the gain decreases as a function of the angle measured from the axis of the beam. This information is essential for calculating interference between the transmissions for different service areas. The patterns are given as functions of the relative angle φ/φ_0, where φ is the angle measured from the axis of the beam, and φ_0 is the angular width of the beam measured between the –3 dB levels. The levels are expressed in dB relative to the maximum (on-axis) gain of the antenna.

Patterns are specified separately for the co-polar and the cross-polar component. They apply equally to linear and circular polarization. It is intended that they should be applicable throughout the whole of the broadcasting band under consideration, and for all angles of azimuth.

2 Earth-station receiving antenna

2.1 Co-polar component

Because broadcasting-satellite systems involve the use of numerous receiving antennas (whether for individual or community reception), the standards of performance that are reasonable on economic grounds will tend to be poorer than for transmitting antennas. Moreover, when specifying the reference pattern, account must be taken of the probable inaccuracy of pointing the antenna towards the wanted satellite.

It is suggested that, to take account of the pointing error, the reference pattern should correspond to a relative gain of 0 dB for relative angles up to $\varphi/\varphi_0 = 0.25$. Thereafter, the curve may be expected to follow a square-law (that is, the relative level is equal to $-12\ (\varphi/\varphi_0)^2$ dB), in the same way as in the case of the transmitting antenna discussed in § 3.1, to a level of –6 dB.

At larger angles, the relative level will depend on the degree to which side-lobe reduction techniques are used.

For individual-reception antennas, without the use of such techniques, the upper limit of the relative level decreases from the –6 dB point at a rate given by the expression:

$$-[9 + 20 \log (\varphi/\varphi_0)] \qquad \text{dB}$$

up to $\varphi/\varphi_0 = 1.26$, and from this point decreases at a faster rate given by:

$$-[8.5 + 25 \log (\varphi/\varphi_0)] \qquad \text{dB}$$

up to $\varphi/\varphi_0 = 9.55$. Beyond this point, a constant level of –33 dB is taken for the remainder of the envelope.

According to the WARC-BS-77, Curve A of Fig. 1 for individual reception (in Region 2) is extended up to a value of $\varphi/\varphi_0 = 15.14$ and has a constant value of –38 dB beyond that (see Annex 8 to the Final Acts of the WARC-BS-77).

For community reception, without side-lobe suppression techniques, the relative level is given by the expression:

$$-[10.5 + 25 \log (\varphi/\varphi_0)] \qquad \text{dB}$$

starting from $\varphi/\varphi_0 = 0.86$, and continuing until the level corresponding to minus the on-axis gain is reached. The pattern corresponding to a community receiver without side-lobe suppression is given in Curve A′ of Fig. 1.

If side-lobe suppression techniques are employed, the curve $-12\,(\varphi/\varphi_0)^2$ could be continued to a relative angle of $\varphi/\varphi_0 = 1.44$, corresponding to a relative level of –25 dB. The side lobes could be contained at less than this level to a relative angle of $\varphi/\varphi_0 = 3.8$, and thereafter the level falls according to a curve defined by:

$$-[10.5 + 25 \log (\varphi/\varphi_0)] \qquad \text{dB}$$

2.2 Cross-polar component

The level of the cross-polar component can be defined in the same way as in the case of the transmitting antenna, but a less stringent performance must be expected. Moreover, account must be taken of the probable pointing inaccuracy of the antenna. Thus, it is proposed that the level should be –25 dB to a relative angle $\varphi/\varphi_0 = 0.25$. It then rises according to the curve:

$$-(30 + 40 \log |(\varphi/\varphi_0) - 1|) \qquad \text{dB}$$

to a maximum of –20 dB, which is maintained to a relative angle $\varphi/\varphi_0 = 1.4$. It then decreases according to the curve:

$$-(30 + 25 \log |(\varphi/\varphi_0) - 1|) \qquad \text{dB}$$

to a level of –30 dB. It maintains the –30 dB level until it intersects with the co-polar component curve which it then follows. The resultant pattern is shown in Fig. 1 as Curve B. It may be taken as applying to both individual and community reception.

3 Satellite transmitting antenna

The planning was based on the assumption that the beams emitted from the satellite had elliptical or circular cross-sections, and the reference patterns were based on this case.

Nevertheless, antennas with specially-shaped beams may be very useful for broadcasting satellites, because they would facilitate the suppression of undesirable spillover to neighbouring countries, while maintaining an effective coverage in the intended area.

3.1 Co-polar component

It is convenient to consider the reference pattern as comprising three sections, namely:

– the main lobe, corresponding approximately to $0 < \varphi/\varphi_0 < 1.6$;

– the near side lobes, corresponding approximately to $1.6 < \varphi/\varphi_0 < 3.2$;

– the far side lobes, corresponding approximately to $\varphi/\varphi_0 > 3.2$.

The envelope of the main lobe can be satisfactorily approximated by a curve of the form $-12\ (\varphi/\varphi_0)^2$ (dB). This is confirmed by measurements on a number of antennas already produced in the United States of America.

The level of radiation in the region of the near side lobes is particularly important for broadcasting satellites, because it will have a significant effect upon the interference between different service areas. For this reason, it will be essential to employ antennas which are designed to reduce the level of the near side lobes.

Through the use of offset-feed configurations, such as a Cassegrain horn, side lobe levels less than −30 dB can be achieved.

For the far side lobes, the measurements made in the United States of America show that, with current technology, the level can be kept within an envelope defined by the curve:

$$-[17.5 + 25 \log (\varphi/\varphi_0)] \qquad \text{dB}$$

The studies made by European Space Agency (ESA) show that, if necessary, it would be possible to design antennas in which the level of the far side lobes falls off more rapidly, with respect to φ/φ_0, than indicated by the above expression.

It is recognized that, in practice, there must be some lower limit to which the level asymptotes. For the reference pattern, this is taken as being equal to minus the on-axis gain of the antenna.

Taking account of the above discussion, the proposed reference pattern for the co-polar component of the satellite transmitting antenna is defined in Fig. 3. In practice, the values near $\varphi/\varphi_0 = 1.5$ may be difficult to achieve. One method to improve this situation is to use a larger reflector with tapered illumination.

3.2 Cross-polar component

A study by the European Broadcasting Union suggests that the upper limit for the cross-polar component can be expressed in the form:

$$-(a + b \log |(\varphi/\varphi_0) - 1|) \qquad \text{dB} \qquad (1)$$

where a and b are constants.

Account is taken of the discontinuity which occurs at $\varphi/\varphi_0 = 1$ by applying a limit to the permitted values of the envelope.

Theoretically, the level can be kept arbitrarily low at all angles, and some studies have indicated that this could be as low as −40 dB. However, until more practical experience is obtained in the design and construction of antennas with a very low cross-polar radiation, it is prudent to adopt, for a reference pattern, a somewhat less stringent specification.

In practice, the level of cross-polar response depends primarily on the characteristics of the feed. If the feed for the transmitting antenna is used exclusively for transmission and does not have to be part of a multi-function feed assembly, then excellent cross-polar responses can be obtained in the range of –35 to –40 dB over the main beam.

Taking account of the limited amount of information on measured results which is so far available, it is proposed to make *a* and *b* equal to 40, in expression (1), with an upper limit of –33 at $\varphi/\varphi_0 < 1.5$, and a limit equal to minus the on-axis gain at $\varphi/\varphi_0 > 1.5$.

This proposed pattern is shown in Fig. 3. In practice, the values around boresight may be difficult to achieve.

If the feed assembly is used for both transmitting and receiving, or if a multiple-feed assembly is used to generate an irregularly-shaped beam, then it may not be possible to achieve the cross-polar performance indicated in Fig. 3.

3.3 Suggested values of φ_0

The suggested values of φ_0 to be assumed for different types of broadcasting service are given in Table 1.

Higher-gain antennas may be used in some receiving installations, for example, to obtain a better signal-to-noise ratio, but the table is intended to indicate the values of φ_0 for the types of antenna expected to be used in the majority of receiving installations.

Attention is drawn to the fact that antennas with smaller beamwidths will require careful alignment and careful mounting to prevent degradation in reception, and that they may also call for a specification of maximum satellite motion more demanding than that of satellites for other services.

TABLE 1

Half-power beamwidths, φ_0 of ground receiving antennas
(Typical diameters are given in brackets)

Frequency	Broadcasting-satellite service		Terrestrial broadcasting service
	Community reception	Individual reception	
12 GHz (1)	1.0° (1.8 m) (Regions 1 and 3)	2.0° (Regions 1 and 3) (0.9 m) 1.7° (Region 2) (1 m)	3.0° (2) (0.6 m)

(1) These are the values of φ_0 adopted at the WARC-BS-77 for planning of the 12 GHz broadcasting-satellite service in Regions 1 and 3 and at the RARC SAT-83 for planning of the 12 GHz broadcasting-satellite service in Region 2.

(2) Some administrations propose a different value for this parameter.