RECOMMENDATION ITU-R BO.1443

REFERENCE BSS EARTH STATION ANTENNA PATTERNS FOR USE IN INTERFERENCE ASSESSMENT INVOLVING NON-GSO SATELLITES IN FREQUENCY BANDS COVERED BY RR APPENDIX S30

(Question ITU-R 93/11)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that for earth station antennas in the BSS the reference antenna radiation patterns for GSO BSS receive antennas in Annex 5 to RR Appendix S30 were used to develop the BSS Plans and prescribe a reference radiation pattern which represents an envelope of the side lobes;

b) that such reference radiation patterns are necessary for interference calculations involving fixed or transportable BSS receivers and GSO satellites to ensure adequate protection of the BSS Plans;

c) that in circumstances where there are multiple interfering sources whose positions vary substantially with time, the level of interference received inevitably depends on the troughs as well as the peaks in the gain pattern of the victim BSS earth station antenna;

d) that for BSS earth stations, suitable reference radiation patterns are needed for use in assessing interference from non-GSO FSS systems;

e) that to facilitate computer simulations of interference, the reference patterns should cover all off-axis angles from 0° to ±180° in all planes;

f) that the reference patterns should be consistent with the results of measurements on a wide range of consumer BSS earth station antennas;

g) that it is appropriate to establish different reference patterns for different ranges of antenna sizes;

h) that the patterns may exhibit characteristics that may be important when modelling non-GSO interference, for example in the case of small offset-fed antennas,

recommends

1 that for calculations of interference generated by non-GSO FSS satellites into BSS earth station antennas, the reference earth station antenna radiation patterns described in Annex 1 should be employed;

2 that the methodology described in Annex 2 be used to convert the relative azimuth and elevation angle of the non-GSO satellite under investigation into the same coordinate system as employed for the three-dimensional antenna pattern;

3 that the following NOTES be considered part of this Recommendation.

NOTE 1 – The cross-polarization radiation pattern may be of importance in non-GSO interference calculations. This issue requires further study.

NOTE 2 – This Recommendation is based on measurements and analysis of paraboloid antennas. If new earth station antennas are developed or are considered for use in the BSS, the reference antenna patterns in this Recommendation should be updated accordingly.

ANNEX 1

Reference BSS antenna radiation patterns

For $11 \leq D/\lambda \leq 25.5$

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D\varphi}{\lambda}\right)^2$	for	$0 \leq \varphi < \varphi_m$
$G(\varphi) = G_1$	for	$\varphi_m \leq \varphi < 95\lambda/D$
$G(\varphi) = 29 - 25 \log(\varphi)$	for	$95\lambda/D \leq \varphi < 36.3°$
$G(\varphi) = -10$	for	$36.3° \leq \varphi < 50°$

for $56.25° \leq \theta < 123.75°$

$G(\varphi) = M_1 \cdot \log(\varphi) - b_1$	for	$50° \leq \varphi < 90°$
$G(\varphi) = M_2 \cdot \log(\varphi) - b_2$	for	$90° \leq \varphi < 180°$

where:

$$M_1 = \frac{2 + 8 \cdot \sin(\theta)}{\log\left(\frac{90}{50}\right)} \quad \text{and} \quad b_1 = M_1 \cdot \log(50) + 10$$

where:

$$M_2 = \frac{-9 - 8 \cdot \sin(\theta)}{\log\left(\frac{180}{90}\right)} \quad \text{and} \quad b_2 = M_2 \cdot \log(180) + 17$$

for $0° \leq \theta < 56.25°$ and $123.75° \leq \theta < 180°$

$G(\varphi) = M_3 \cdot \log(\varphi) - b_3$	for	$50° \leq \varphi < 120°$
$G(\varphi) = M_4 \cdot \log(\varphi) - b_4$	for	$120° \leq \varphi < 180°$

where:

$$M_3 = \frac{2 + 8 \cdot \sin(\theta)}{\log\left(\frac{120}{50}\right)} \quad \text{and} \quad b_3 = M_3 \cdot \log(50) + 10$$

where:

$$M_4 = \frac{-9 - 8 \cdot \sin(\theta)}{\log\left(\frac{180}{120}\right)} \quad \text{and} \quad b_4 = M_4 \cdot \log(180) + 17$$

for $180° \leq \theta < 360°$

$G(\varphi) = M_5 \cdot \log(\varphi) - b_5$	for	$50° \leq \varphi < 120°$
$G(\varphi) = M_6 \cdot \log(\varphi) - b_6$	for	$120° \leq \varphi < 180°$

where:

$$M_5 = \frac{2}{\log\left(\frac{120}{50}\right)} \quad \text{and} \quad b_5 = M_5 \cdot \log(50) + 10$$

where:

$$M_6 = \frac{-9}{\log\left(\frac{180}{120}\right)} \qquad \text{and} \qquad b_6 = M_6 \cdot \log(180) + 17$$

where:

D: antenna diameter

λ: wavelength expressed in the same unit as the diameter

φ: off-axis angle of the antenna relative to boresight (degrees)

θ: planar angle of the antenna (degrees) (0° azimuth is the horizontal plane).

$$G_{max} = 20 \log\left(\frac{D}{\lambda}\right) + 8.1 \quad \text{dBi}$$

$$G_1 = 29 - 25 \log\left(95 \frac{\lambda}{D}\right) \quad \text{dBi}$$

$$\varphi_m = \frac{\lambda}{D}\sqrt{\frac{G_{max} - G_1}{0.0025}} \quad \text{degrees}$$

For 25.5 < D/λ ≤ 100

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} (D\varphi/\lambda)^2$	dBi	for 0	$< \varphi < \varphi_m$
$G(\varphi) = G_1$		for φ_m	$\leq \varphi < (95\lambda/D)$
$G(\varphi) = 29 - 25 \log \varphi$	dBi	for $(95\lambda/D)$	$\leq \varphi < 33.1°$
$G(\varphi) = -9$	dBi	for 33.1°	$< \varphi \leq 80°$
$G(\varphi) = -4$	dBi	for 80°	$< \varphi \leq 120°$
$G(\varphi) = -9$	dBi	for 120°	$< \varphi \leq 180°$

where:

$G_{max} = 20 \log (D/\lambda) + 8.1$ dBi

$G_1 = 29 - 25 \log (95\lambda/D)$ dBi

$$\varphi_m = (\lambda/D) \sqrt{\frac{G_{max} - G_1}{0.0025}}$$

For D/λ > 100

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} (D\varphi/\lambda)^2$	dBi	for 0	$< \varphi < \varphi_m$
$G(\varphi) = G_1$		for φ_m	$\leq \varphi < \varphi_r$
$G(\varphi) = 29 - 25 \log \varphi$	dBi	for φ_r	$\leq \varphi < 10°$
$G(\varphi) = 34 - 30 \log \varphi$	dBi	for 10°	$\leq \varphi < 34.1°$
$G(\varphi) = -12$	dBi	for 34.1°	$\leq \varphi < 80°$
$G(\varphi) = -7$	dBi	for 80°	$\leq \varphi < 120°$
$G(\varphi) = -12$	dBi	for 120°	$\leq \varphi \leq 180°$

where:

$G_{max} = 20 \log (D/\lambda) + 8.1$ dBi

$G_1 = -1 + 15 \log (D/\lambda)$ dBi

$$\varphi_m = (\lambda/D) \sqrt{\frac{G_{max} - G_1}{0.0025}}$$

$\varphi_r = 15.85 (D/\lambda)^{-0.6}$ degrees

ANNEX 2

Geometric conversions for use with the 3-D antenna model

1 Introduction

This Annex provides the supplemental orbital geometry to be used in conjunction with the 3-D patterns. The position of the non-GSO satellite under investigation is determined in the same coordinate system as the antenna pattern definition. In order to be able to use this 3-D model in non-GSO interference studies, it is necessary to translate the azimuth and elevation of the interfering non-GSO satellite into the off-axis and planar angles upon which the 3-D model is based.

2 Computation of off-axis angle

In Fig. 1, P is the location of the GSO earth station, N is the location of the non-GSO satellite, and S is the intersection of Plane II (defined below) and the boresight of the receiving earth station.

Construction steps:

Step 1: Draw Plane I tangential to earth surface at P.

Step 2: Draw Plane II through N perpendicular to Plane I and perpendicular to the projection of the GSO boresight onto Plane I.

Step 3: Connect the dots.

In Fig. 1, A is the projection of N and B is the projection of S on Plane I; S is the intersection of the boresight on Plane II, C is a point on SB such that NC is parallel to AB.

The assumed input parameters are:

– $\widehat{SPB}$, the elevation angle of the GSO satellite at P ($0° \le$ elevation(GSO) $\le +90°$).

– $\widehat{NPA}$, the time varying elevation angle of the non-GSO satellite at P ($0° \le$ elevation(non-GSO) $\le +90°$).

– $\widehat{BPA}$, the time varying relative azimuth of the non-GSO satellite at P (clockwise assumed positive, $-180° \le$ azimuth $\le +180°$).

– The distance PN from the earth station to the non-GSO satellite.

  (NOTE 1 – Since the object is to determine angles which are dependent only on the ratio of distances, the actual distance is not essential but PN is used as a reference since it can be computed from known parameters if needed (e.g. in the determination of the path loss).)

– By construction, $\widehat{NAP}$, $\widehat{SBP}$, $\widehat{NAB}$, $\widehat{SBA}$, $\widehat{NCB}$, and $\widehat{ABP}$ are all right angles.

The required output parameter for this first stage is:

– $\widehat{SPN}$, the off-axis angle to the non-GSO satellite.

By conventional solution of triangles:

$$PA = PN \cos(\widehat{NPA})$$

$$NA = PN \sin(\widehat{NPA}) = CB$$

$$AB = PA \sin(\widehat{BPA}) = NC$$

$$PB = PA \cos(\widehat{BPA})$$

$$SB = PB \tan(\widehat{SPB})$$

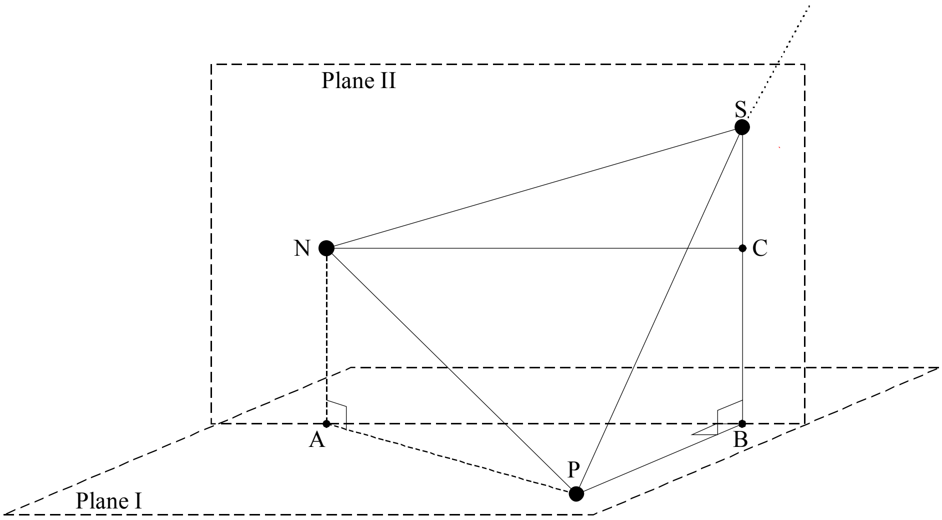
$$PS = PB \sec(\widehat{SPB})$$

$$NS = \sqrt{(NC^2 + (SB - CB)^2)}$$

$$\widehat{SPN} = \arccos((PN^2 + PS^2 - NS^2)/(2\ PN\ PS))$$

FIGURE 1

Geometry I of an exposure from a non-GSO satellite



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3 Computation of planar angle

The reference plane (corresponding to θ = 0°) assumed here is based on a standard mounting of the offset fed antenna with the feed assembly mounted at the bottom edge of the antenna. It is anticipated that this mounting arrangement will apply to the majority of such antennas. Other mounting arrangements will result in a different reference plane.

For the second stage of the computation, rotate Plane II about the axis NC so that the resulting Plane III is perpendicular to the GSO station boresight. Let G be the intersection of Plane III and the boresight, ND and GE are perpendicular to the join of Plane I and Plane III, PGH is the antenna reference plane, and A is the vertical projection of the non-GSO satellite onto Plane I as before (see Fig. 2).

The known parameters are:

– $\widehat{GPE}$, the elevation of the GSO satellite at P (= $\widehat{SPB}$ of the previous construction).

– $\widehat{GPN}$, the off-axis angle (= $\widehat{SPN}$ in computed in first construction).

– The distance PN from the earth station to the non-GSO satellite as before.

– The distance NA from the previous construction.

– By construction, $\widehat{PGN}$ and $\widehat{PGE}$ are right angles, $\widehat{GEP} = \widehat{NDA} = \pi/2 - \widehat{GPE}$, and ND = CE.

The required output parameter is:

$\widehat{HGN}$ (= $-\widehat{GNC}$), the planar angle of the non-GSO satellite relative to the zero degree plane of the antenna model (plane PGH corresponding to a standard bottom mounted offset feed assembly).

NOTE 1 – For this standard orientation, the alignment of the zero degree plane embraces the local horizontal at P and is not parallel to the GSO arc at the wanted satellite.

As above, by conventional solution of planar triangles:

$NG \quad = PN \sin(\widehat{GPN})$

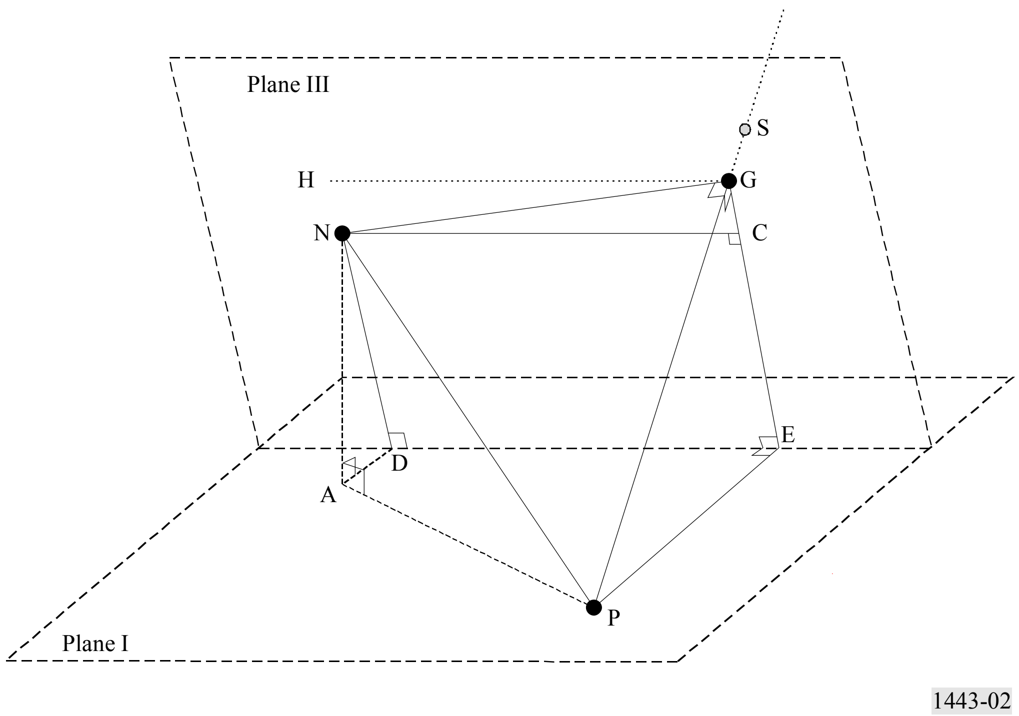
$GE \quad = PG \tan(\widehat{EPG})$

$ND \quad = NA \operatorname{cosec}(\widehat{NDA}) = NA \sec(\widehat{GPE})$

$\widehat{GNC} = \arcsin((GE - ND)/NG) = -\widehat{HGN}$

FIGURE 2

Geometry II of an exposure from a non-GSO satellite



4 Quadrant conventions

The off-axis angle φ and the planar cut angle θ and their derivatives must be continuous across the quadrant boundaries with the caveat that, since the planar cuts of the 3-D antenna pattern are defined between 0° and +180°, there will be transitions from, for example, a negative off-axis angle in a plane just below +180° to a positive off-axis angle in a plane just above 0°. This is illustrated in Fig. 4 which corresponds to the situation where the non-GSO satellite is at a lower elevation than the GSO satellite. Such a transition occurs near a relative azimuth angle of ±60° in this example. Figure 3 is the complementary situation – the non-GSO satellite is at a higher elevation than the GSO satellite. In both Figures, the relative azimuth is the running variable. The necessary adjustments to the computed off-axis and planar cut angles in order to conform with the quadrant and continuity constraints are given with each Figure.

Adjustments for continuity and range:

– Off-axis angle φ:

$\varphi = +\widehat{SPN}$ for $-180° \leq \text{azimuth} < 180°$

– Planar angle θ:

$\theta = 180° + \widehat{GNC}$ for $-180° \leq \text{azimuth} < 0°$

$\theta = -\widehat{GNC}$ for $0° \leq \text{azimuth} < +180°$

This example illustrates the 90° off-axis angle in the 90° planar cut – the offset feed spill-over region – which occurs at a relative azimuth of ±180°, i.e. when the non-GSO satellite is behind the GSO earth station.

Adjustments for continuity and range:

– Off-axis angle φ:

$\varphi = +\,\widehat{SPN}$ for –180° ≤ azimuth < –60°

$\varphi = -\,\widehat{SPN}$ for –60° ≤ azimuth < +60°

$\varphi = +\,\widehat{SPN}$ for +60° ≤ azimuth < +180°

– Planar angle θ:

$\theta = 180° - \widehat{GNC}$ for –180° ≤ azimuth < –60°

$\theta = -\,\widehat{GNC}$ for –60° ≤ azimuth < 0°

$\theta = 180° + \widehat{GNC}$ for 0° ≤ azimuth < +60°

$\theta = +\,\widehat{GNC}$ for +60° ≤ azimuth < +180°

NOTE 1 – The planar angle for a non-GSO satellite at a lower elevation angle than the GSO satellite would normally be computed as negative for small relative azimuths. However, since the planar cuts are not defined for negative angles, it is necessary to take the complement in both planar and off-axis angles.

NOTE 2 – For both situations (non-GSO satellite above and below the GSO satellite), the planar angle transitions at 0° relative azimuth.

NOTE 3 – The transitions at ±60° azimuth will vary with the elevation angles of the GSO satellite and the non-GSO satellite. This transition is easily determined with a suitable conditional branch statement on $\widehat{GNC}$.

NOTE 4 – The above illustrates that the spill-over lobe at 90° off-axis in the 90° plane may also be encountered in this configuration (consider, for example, the reverse situation from Fig. 3, i.e. GSO at 70° and non-GSO at 20°, then the spill-over lobe is encountered at 180° relative azimuth as before).

FIGURE 3

Planar cut and off-axis angles for non-GSO satellite at 70° elevation and GSO satellite at 20° elevation

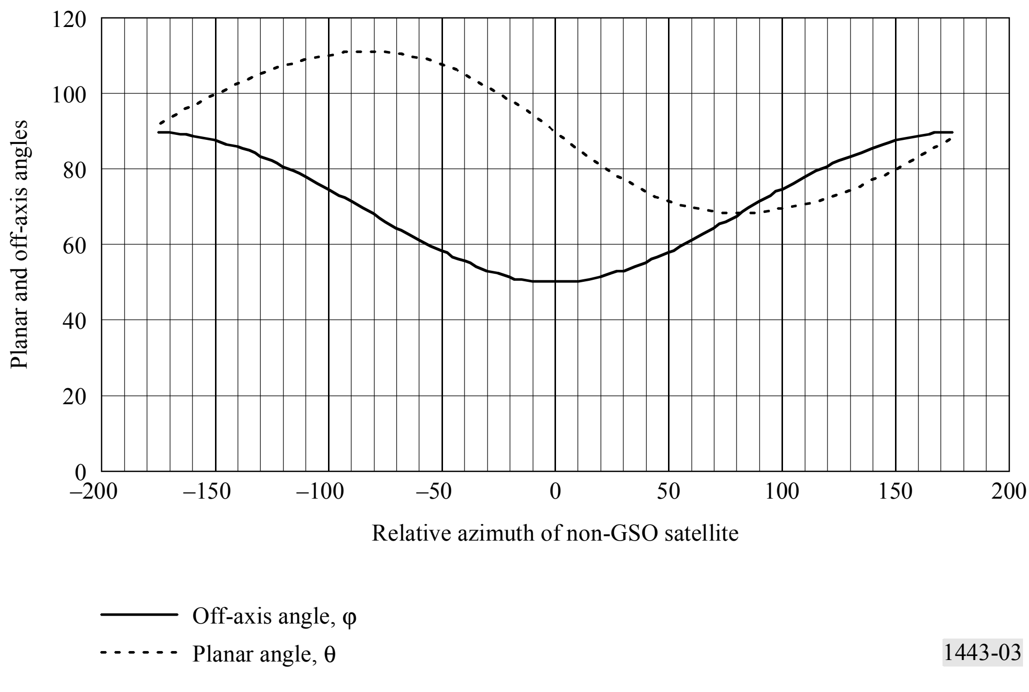


FIGURE 4

Planar cut and off-axis angles for non-GSO satellite at 20° elevation and GSO satellite at 40° elevation