RECOMMENDATION ITU-R IS.848-1*

DETERMINATION OF THE COORDINATION AREA OF A TRANSMITTING EARTH STATION USING THE SAME FREQUENCY BAND AS RECEIVING EARTH STATIONS IN BIDIRECTIONALLY ALLOCATED FREQUENCY BANDS

(Questions ITU-R 3/12, ITU-R 4/12, ITU-R 5/12 and ITU-R 6/12)

(1992-1993)

The ITU Radiocommunication Assembly,

considering

a) that some frequency bands are allocated to space services in both the Earth-to-space and the space-to-Earth direction of transmission;

b) that, therefore, there is a possibility of interference from a transmitting earth station to a receiving earth station;

c) that such potential interference may be alleviated or avoided through the coordination of the two types of earth station;

d) that it is desirable to limit the number of coordinations that may have to be undertaken;

e) that it is possible to define an area around a transmitting earth station outside of which a receiving earth station would be subject to only negligible interference;

f) that the general methodology of Recommendation ITU-R IS.847 lends itself to the determination of such an area which would be known as the bidirectional coordination area;

g) that, to apply the methodology of Recommendation ITU-R IS.847 to the determination of the bidirectional coordination area, certain elements in the Recommendation ITU-R IS.847 methodology would have to be changed,

recommends

1. that, in frequency bands allocated to space services in both the space-to-Earth and the Earth-to-space direction of transmission, a bidirectional coordination area be determined for each transmitting earth station;

2. that, for that purpose, the methodology of Recommendation ITU-R IS.847 be used except for the specific modifications to this methodology set forth in Annex 1.

Note 1 – The reliance of the determination of the bidirectional coordination area on the methodology of Recommendation ITU-R IS.847 suggests that revisions of this Recommendation or of Recommendation ITU-R IS.847 be undertaken concurrently so as to maintain compatibility between the Recommendations.

ANNEX 1

Determination of the bidirectional coordination area for a transmitting earth station operating with a geostationary space station

1. Introduction

The following describes a procedure for the determination of the bidirectional coordination area for an earth station transmitting in a frequency band allocated to space services in both the Earth-to-space and space-to-Earth direction, to be used for the purpose of establishing whether or not coordination between the transmitting and receiving earth stations is required.

* Pending completion of appropriate studies, this Recommendation does not apply to the radiodetermination satellite and radionavigation-satellite services operating in the 1 610-1 626.5 MHz band.

The procedure applies to earth stations operating with geostationary satellites and uses the same basic concepts for determining the coordination area as that of Recommendation ITU-R IS.847. However, the method is different in a number of respects, and these differences are discussed in this Annex.

This Annex should be used in connection with Annex 1 to Recommendation ITU-R IS.847 which it modifies in certain areas.

2. Determination of the threshold interference level $P_r(p)$

The threshold interference level at a receiving earth station is calculated in the same way as set forth in Annex 1 to Recommendation ITU-R IS.847 except that the following earth station receiving system noise temperatures should be used:

Frequency range (GHz)	T_e (K)
1-10	75
10-17	150
> 17	300

This assumption is necessary because the receiving earth station takes the place of a receiving terrestrial station in Recommendation ITU-R IS.847; in both cases the location and precise characteristics of the station are unknown.

3. Determination of G_r for propagation mode (1)

Since not only the precise characteristics of the receiving earth station are unknown but also its precise location, use is made of the fact that the receiving earth station must be assumed to lie anywhere on the boundary of the bidirectional coordination area, and that this places it relatively close, in global geometric terms, to the transmitting earth station. Hence the simplifying assumptions are made that plane rather than spherical geometry between the two earth stations can be used, and that the receiving earth station site has the same latitude as the transmitting earth station around which the coordination area is to be determined.

As prescribed by equations (2) and (6) of Recommendation ITU-R IS.847, the horizon antenna gains of the transmitting and receiving antennas must be added for each azimuth on a common azimuth plot which is referred to the transmitting antenna. This allows the transmitting antenna gain to be directly plotted versus its azimuth, but a given azimuth at the transmitting antenna's locations is the opposite or "back" azimuth at the receiving antenna's location. Therefore to a value of G_t' found for each azimuth α at the transmitting earth station must be added a value of G_r which is found for the azimuth $\alpha' = (\alpha + 180°)$.

The determination of the antenna gain G_r of the receiving earth station which in this Annex takes the place of the receiving terrestrial station of Annex 1 to Recommendation ITU-R IS.847 recognizes that:

– the main beam is not directed towards the physical horizon but towards a satellite at some, perhaps a large, elevation angle;

– its direction is constrained by the possible locations of geostationary satellites.

Hence, to determine G_r, in the absence of any knowledge regarding the location of a receiving earth station, the procedure described in Appendix 1 to Annex 1 of Recommendation ITU-R IS.847 is used, noting that, in equation (6), $G_e = 42 + \Delta G$.

Since it is not known beforehand towards which orbit location a receiving earth-station antenna beam is directed, the horizon antenna gain must be determined for all geostationary-orbit locations. Also, since the horizon elevation is not known, 0° is used for all azimuths. Finally, the assumption that the latitude of the receiving earth station is the same as that of the transmitting earth station for which the coordination area is being determined, is a simplifying assumption which introduces generally negligible errors which, in any case, will not exceed 2 dB.

Thus the procedure given in Case 2 in Appendix 1 to Annex 1 of Recommendation ITU-R IS.847 for calculating the antenna gain in the direction of the earth-station horizon has to be carried out for each counter-azimuth α':

– for all orbital locations having elevation angles greater than 3°, using the latitude of the transmitting earth station as an approximation for the receiving earth station latitude;

– with a 0° horizon elevation angle.

Figure 1 shows an example set of curves of the minimum angular distance between points on the geostationary-satellite orbit and the horizontal plane as functions of azimuth (α) and counter-azimuth (α') with the station latitude (ζ) as a parameter. Using the earth-station antenna reference pattern of Appendix 1 to Annex 1 of Recommendation ITU-R IS.847, a plot of horizon antenna gain as a function of (α) and (α') can then be constructed. Figure 2 gives an example of such a plot.

The assumption of 0° horizon elevation angle is conservative since the increase in antenna gain due to a raised horizon would, in practice, be more than offset by any real site shielding which, for the receiving antenna site, must be assumed to be zero. It should be noted that while no site shielding can be assumed for the receiving earth station, any site shielding that may exist at the transmitting earth station is considered in the normal fashion.

An example of how the antenna gains $G_{t'}$ and G_r are to be added on a common azimuth plot is given below:

$$\begin{aligned} \alpha \quad &= 192° \\ \alpha + 180° &= 372° \;(= 360° + 12°) \\ \alpha' \quad &= 12° \end{aligned}$$

One obtains $G_{t'} + G_r$ from:

$$G_{t'} + G_r = G_{t'}(\alpha) + G_r(\alpha') \qquad \text{dB} \qquad (1)$$

for each azimuth α at a transmitting earth station to be used in equations (2) and (6) of Recommendation ITU-R IS.847. When determining $G_r(\alpha')$ using equation (33) of Recommendation ITU-R IS.847 and the equations following it, G_{max} shall be taken to be 42 dBi. (Based on information from the ITU, this is the 1σ (one standard deviation) antenna gain of a large statistical sample of notified earth station antennas, the average main beam gain of which was found to be 50 dBi.)

Figure 3 gives a more elaborate example of a coordination area determined by this method. Figure 4 shows the sum of the antenna gains $G_{t'} + G_r$ for the example of Fig. 3 on a transmitting earth station's azimuth plot.

FIGURE 1

Illustration of minimum angular distance between points on the geostationary-satellite orbit (GSO) and the horizontal plane

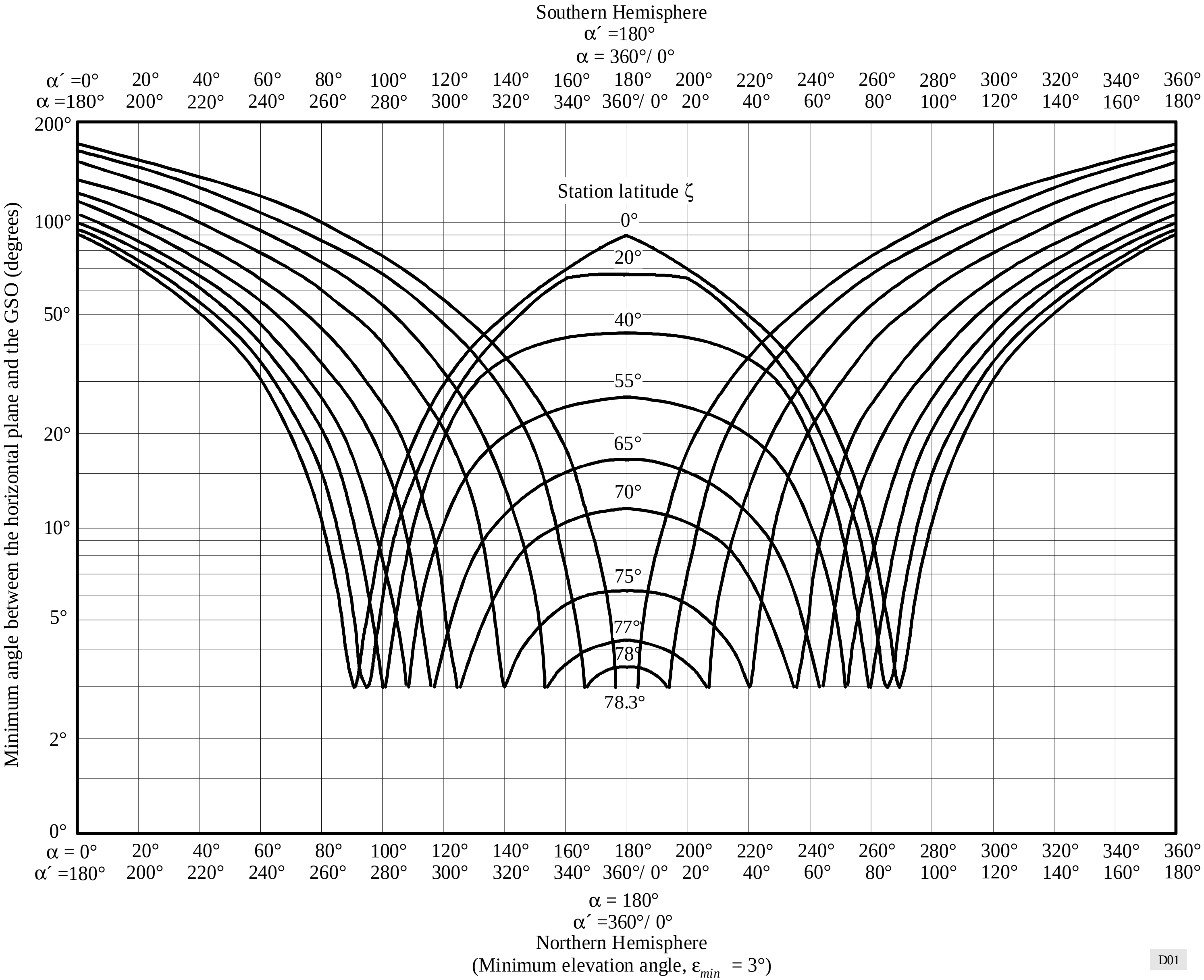
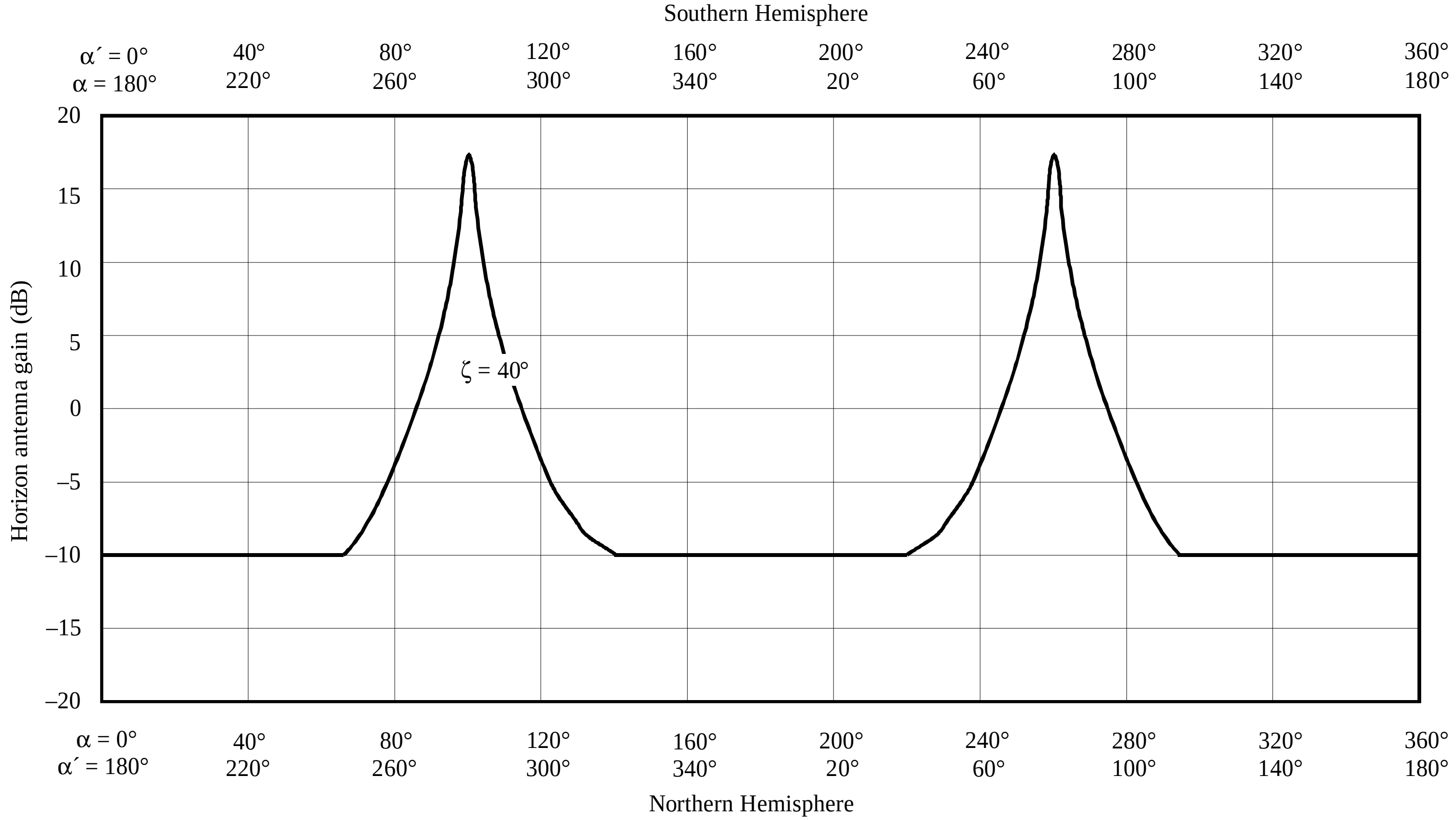


FIGURE 2

Example of full-arc horizon antenna gain for 0° horizon elevation angle at 40° latitude



(Minimum main beam elevation angle = 3°)

Assumed earth station reference radiation diagram $G(\theta) = 29 - 25 \log \theta$ (dB)

$\alpha' = (\alpha + 180°)$ modulo (360°)

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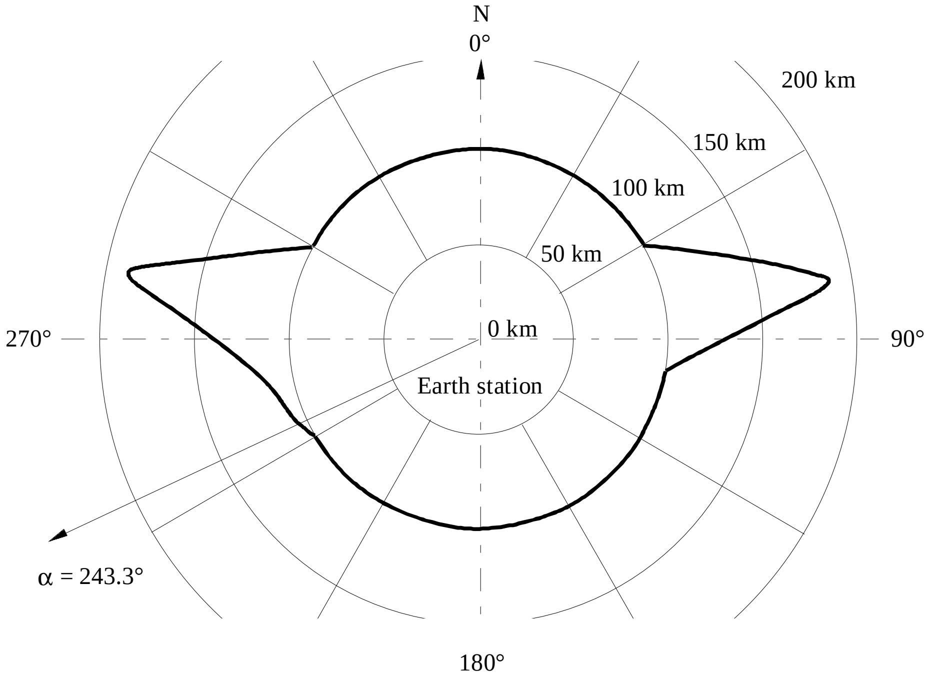
FIGURE 3

Example of a bidirectional great-circle coordination area



Assumptions for the transmitting earth station:

f = 17 GHz
$P_{t'}$ = 40 dB(W/MHz)
ζ = 40° N
Elevation angle to satellite = 20°
Azimuth to satellite = 243.3°
Radio climatic zone = A2
Horizon elevation angle = 0°

Calculation result:

P_r (p)	= –141.1 dB(W/MHz)	Equation (3) of Recommendation ITU-R IS.847
p	= 0.003%	Table 2 of Recommendation ITU-R IS.847
L_1	= 38.7 = $G_{t'} + G_r$	Equations (6) and (7) of Recommendation ITU-R IS.847
$G_{t'} + G_r$	= see Fig. 4	For $G_e = 42 + \Delta G$ of equation (6) of Recommendation ITU-R IS.847
β_{dz}	= 0.19102 dB/km	Equation (12) of Recommendation ITU-R IS.847
β_o	= 0.00903 dB/km	Equation (13) of Recommendation ITU-R IS.847
β_{vz}	= 0.03631 dB/km	Equation (14) of Recommendation ITU-R IS.847
d_1	= L_1/0.24636	From equation (10) of Recommendation ITU-R IS.847

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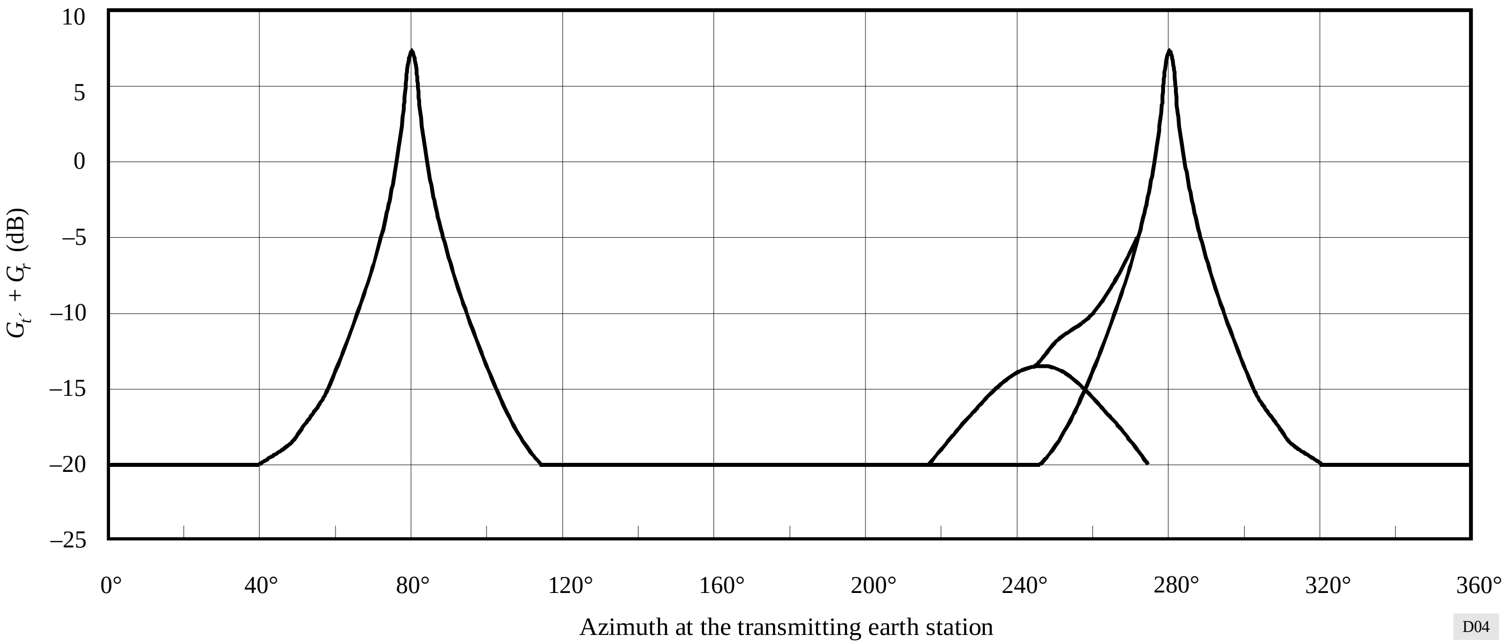
FIGURE 4

Composite horizon antenna gain $G_{t'} + G_r$ for the example of Fig. 3



4. Determination of the bidirectional rain scatter area

The bidirectional rain scatter area for a transmitting earth station is determined as follows:

Step 1: Determine the elevation angle ε_s and the azimuth α_s to the satellite with which the earth station is to operate. For an earth station operating with an inclined-orbit satellite, use the lowest expected operational antenna elevation angle and the associated azimuth.

Step 2: Determine the "beam intersection distance" d_s (km) from the earth station to the point at which the beam axis attains the 0° isotherm altitude h_{FR} from:

$$d_s = 8\,500 \left(\sqrt{\tan^2 \varepsilon_s + h_{FR} / 4\,250} - \tan \varepsilon_s \right) \qquad \text{km} \tag{2}$$

$$h_{FR} = \begin{cases} 5 - 0.075(\zeta - 23) & \text{km} \quad \text{for} \quad \zeta > 23° \\ 5 & \text{km} \quad \text{for} \quad 0° \le \zeta \le 23° \end{cases} \text{Northern Hemisphere}$$

$$\begin{cases} 5 & \text{km} \quad \text{for} \quad 0° \ge \zeta \ge -21° \\ 5 + 0.1(\zeta + 21) & \text{km} \quad \text{for} \quad -71° < \zeta \le -21° \\ 0 & \text{km} \quad \text{for} \quad \zeta \le -71° \end{cases} \text{Southern Hemisphere} \tag{3}$$

Step 3: Mark the distance d_s on the azimuth α_s from the earth station location, on a map of appropriate scale. This point is the geographic location of the beam intersection point and is the reference point around which the bidirectional rain scatter contour is constructed.

Step 4: Determine the maximum visibility distance d_{max} for the beam intersection point from:

$$d_{max} = 130.4 \sqrt{h_{FR}} \text{ km or 100 km} \tag{4}$$

whichever is the greater,

and the reference azimuth α_r from:

$$\alpha_r = \cos^{-1} (0.2069 \tan \zeta) \tag{5}$$

where ζ is the latitude of the beam intersection point (also assumed to be equal to that of the transmitting earth station).

For North latitudes above 78.3° and for South latitudes below –71°, the rain scatter contour is a circle of radius 100 km (d_{max} = 100 km).

Step 5: From the beam intersection point, mark on the map the distance d_{max} in the two azimuths α_r and 360° – α_r.

Step 6: Draw on the map from both of the two maximum distance marks of Step 5 equal distance arcs of width 3° clockwise and counter-clockwise with the location of the beam penetration point as centre. These two arcs, each having a total width of 6°, are the first boundary elements of the bidirectional rain scatter area.

Step 7: Mark a circle of 100 km radius around the earth station location and draw straight lines from the northern edges of the two arc segments tangential to the northern rim of the 100 km radius circle, and from the southern edges of the two arc segments tangential to the southern rim of the 100 km radius circle.

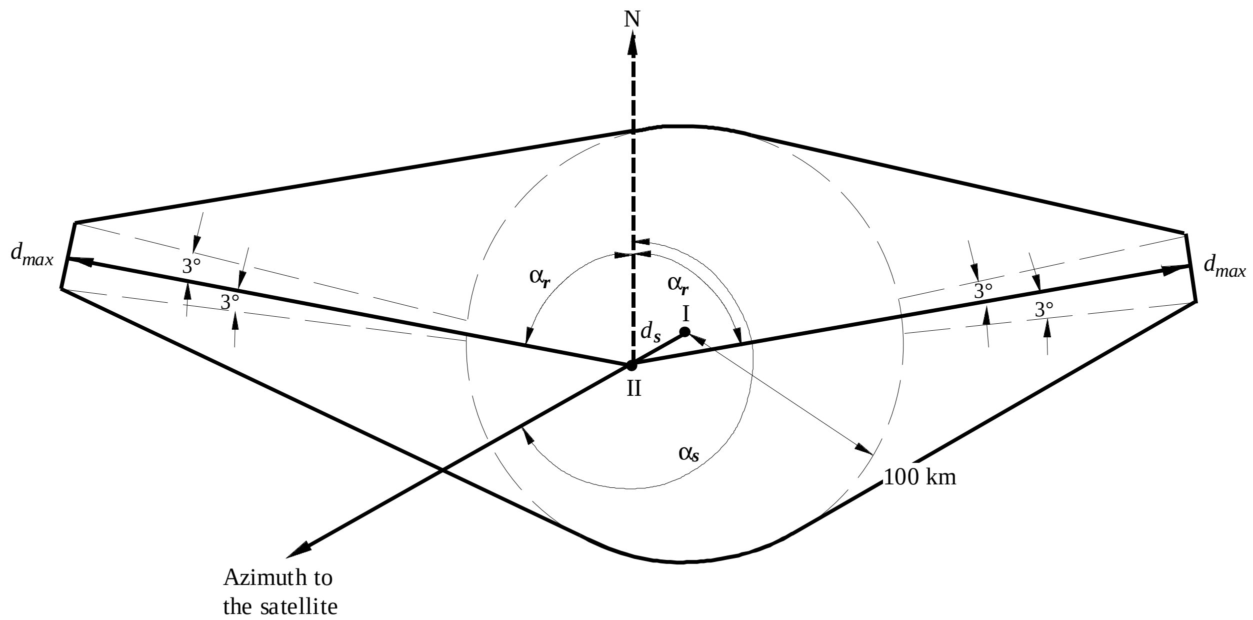
The area bounded by the two 6° wide arcs, the four straight lines, and the 100 km radius circle sections (of which there is always at least one) between the two northern and the two southern tangent points with the straight lines, constitutes the bidirectional rain scatter area.

Figure 5 illustrates the construction of the bidirectional rain scatter area. (The resulting rain scatter area contains the loci of all receiving earth station locations for which directions towards the geostationary-satellite orbit intersect the beam axis of the transmitting earth station antenna. The boundaries of the area are established by stipulating a minimum beam intersection avoidance angle of 3°.)

FIGURE 5

Example of the bidirectional rain scatter area

(Not to scale)



I: location of the transmitting earth station

II: point where the earth station antenna beam axis penetrates the altitude h_{FR}

Assumptions:

ζ = 40° N

ε_s = 8°

α_s = 253.6

Results:

d_s = 26.2 km from equation (2)

h_{FR} = 3.725 km from equation (3)

d_{max} = 251.7 km from equation (4)

α_r = 80.0° from equation (5)

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