

RECOMMENDATION ITU-R S.1430

**DETERMINATION OF THE COORDINATION AREA FOR EARTH STATIONS OPERATING WITH
NON-GSO SPACE STATIONS WITH RESPECT TO EARTH STATIONS OPERATING
IN THE REVERSE DIRECTION IN FREQUENCY BANDS ALLOCATED
BIDIRECTIONALLY TO THE FSS**

(Questions ITU-R 253/4, ITU-R 231/4 and ITU-R 212/1)

(2000)

The ITU Radiocommunication Assembly,

considering

- a) that some frequency bands are allocated to the FSS for use by non-GSO systems in both the Earth-to-space and the space-to-Earth direction of transmission;
- b) that these frequency bands are also available for use by GSO systems;
- c) that, therefore, there is a possibility of mutual interference between earth stations operating to space stations in both GSO and non-GSO orbits;
- d) that such potential interference may be alleviated or avoided through the coordination of such earth stations;
- e) that it is desirable to limit the number of coordinations that may have to be undertaken;
- f) 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;
- g) that Radiocommunication Study Group 1 is drawing together the results of studies from all concerned Study Groups in the development of comprehensive texts that may be used to revise RR Appendix S7;
- h) that Recommendation ITU-R P.620 contains a propagation model that is intended for coordination of earth stations,

recommends

- 1 that, in frequency bands allocated to the FSS in both the space-to-Earth and the Earth-to-space direction of transmission and utilized by both non-GSO and GSO FSS systems, a bidirectional coordination area be determined for each transmitting earth station;
- 2 that, for that purpose, Annex 1 to this Recommendation should be used.

ANNEX 1

**Determination of the coordination area for earth stations operating with non-GSO
space stations with respect to earth stations operating in the reverse direction
in frequency bands allocated bidirectionally to the FSS****1 Introduction**

This procedure has been developed for the determination of the bidirectional coordination area around an earth station operating with a non-GSO space station in frequency bands used bidirectionally by earth stations operating to non-GSO space stations and GSO earth stations.

The operation of transmitting and receiving non-GSO and GSO earth stations in bidirectionally allocated frequency bands may give rise to interference between stations of the two FSS applications. The magnitude of such interference depends on the transmission loss along the interfering path which, in turn, depends on factors such as length and general geometry of the interference path, the minimum operational elevation angle, antenna gain distribution as a function of time, radio climatic conditions and the percentage of time during which the transmission loss should be exceeded.

The described procedure allows the determination, in all azimuth directions from a transmitting earth station, of a distance beyond which the transmission loss would be expected to exceed a specified value for all but a specified percentage of the time. A distance so determined is called the coordination distance. The end points of coordination distances determined for all azimuths define a coordination contour around the earth station which contains the coordination area. For earth stations located outside the coordination area the probability of causing or experiencing significant interference is considered to be negligible.

Stations located outside the coordination area of a given planned station are eliminated from any coordination consideration. Consequently, the coordination requirements of a station may be strictly domestic, if the coordination area of the planned station lies entirely in the territory of the notifying administration or, domestic and international if the coordination area also includes the territory of another administration in which case the coordination agreement of that administration is required.

Stations located in the coordination area of a planned station need to be examined on a case-by-case basis initially, taking into account the antenna discrimination, separation distance and path profile if necessary.

Although based on technical data, the coordination area is an administrative concept. Since the coordination area is determined before any specific cases of potential interference are examined in detail, it must therefore rely on assumed parameters of the receiving earth stations, while the pertinent parameters of the transmitting earth stations are known.

Once the coordination area around an earth station has been computed, it can be stated, regarding another earth station to be operated in the reverse direction:

- if the earth station is to be located outside the coordination area, then there will be little risk of interference;
- if the earth station is to be located within the coordination area, then it will be necessary to carry out a detailed coordination.

The coordination area will normally be determined for the case where the non-GSO earth station is transmitting and hence capable of interfering with the reception of other earth stations. It may also be necessary to determine the coordination area for the case where the non-GSO earth station is receiving and hence capable of being interfered-with by emissions from other earth stations.

The procedure in this Annex describes the case in which the non-GSO earth station is transmitting. The methodologies apply equally to the case in which the non-GSO earth station is receiving. For the calculation of the coordination area of transmitting earth station the necessary parameters can be found in Recommendation ITU-R SM.1448. For a receiving earth station the methodologies can be used on bilateral basis only, since the parameters of the transmitting earth station with respect to which the coordination area is established will have to be provided by the responsible administration.

The coordination area of an earth station operating with a GSO space station in a slightly inclined GSO orbit should be determined for the minimum angle of elevation and the associated azimuth at which the space station is visible to the earth station.

2 General considerations

2.1 Concept of minimum permissible transmission loss

The determination of the coordination distance, as the distance from a non-GSO earth station beyond which interference from or to a GSO earth station may be considered negligible, is based on the premise that the attenuation of an unwanted signal is, or can be represented by, a monotonically increasing function of distance.

The amount of attenuation required between an interfering transmitter and an interfered-with receiver is given by the minimum permissible transmission loss for $p\%$ of the time, a value of transmission loss which should be exceeded by the actual or predicted transmission loss for all but $p\%$ of time: (when p is a small percentage of time, in the range 0.001% to 1.0%, it is referred to as short-term; if $p \geq 20\%$, it is referred to as long-term):

$$L(p) = P_t - P_r(p) \quad \text{dB} \quad (1)$$

where:

P_t : maximum available transmitting power level (dBW) in the reference bandwidth at the input to the antenna of an interfering earth station

$P_r(p)$: threshold interference level of an interfering emission (dBW) in the reference bandwidth to be exceeded for no more than $p\%$ of the time at the terminals of the receiving antenna of an interfered-with station, the interfering emission originating from a single source.

P_t and $P_r(p)$ are defined for the same radio-frequency bandwidth (the reference bandwidth) and $L(p)$ and $P_r(p)$ for the same percentage of the time, as dictated by the performance criteria of the interfered-with system.

The coordination distance can then be determined using a suitable propagation model. The ITU-R has developed propagation models suitable for the determination of the coordination area of earth stations operating with the non-GSO networks.

2.2 The concept of minimum permissible basic transmission loss

The transmission loss is defined in terms of separable parameters, vis-à-vis basic transmission loss (i.e. attenuation between isotropic antennas) and the effective antenna gains at both ends of an interference path. The minimum permissible basic transmission loss may then be expressed as:

$$L_b(p) = P_t + G_t + G_r - P_r(p) \quad \text{dB} \quad (2)$$

where:

$L_b(p)$: minimum permissible basic transmission loss (dB) for $p\%$ of time; this value must be exceeded by the actual or predicted basic transmission loss for all but $p\%$ of time

G_t : gain of the transmitting antenna of the interfering station towards the physical horizon on a given azimuth (dBi). If the interfering station is an earth station operating to non-GSO space station, then G_t is a time-varying function

G_r : gain of the receiving antenna of the interfered-with station towards the physical horizon at a given azimuth (dBi). If the interfered-with station is an earth station operating to non-GSO space station, then G_r is a time-varying function.

2.3 Determination of the threshold interference level $P_r(p)$ of an interfering emission

The threshold interference level (dBW) of the interfering emission in the reference bandwidth, to be exceeded for no more than $p\%$ of time at the receiving antenna terminals of a station subject to interference, from each source of interference, is given by the general formula below:

$$P_r(p) = 10 \log(k T_e B) + N_L + 10 \log(10^{M_s/10} - 1) - W \quad \text{dBW} \quad (3)$$

where:

- k : Boltzmann's constant (1.38×10^{-23} J/K)
- T_e : thermal noise temperature of the receiving system (K), at the terminal of the receiving antenna (see Note 1)
- N_L : link noise contribution (see Note 2)
- B : reference bandwidth (Hz), i.e. the bandwidth in the interfered-with system over which the power of the interfering emission can be averaged
- p : percentage of time during which the interference from one source may exceed the threshold value; since the entries of interference are not likely to occur simultaneously: $p = p_0/n$
- p_0 : percentage of time during which the interference from all sources may exceed the threshold value
- n : number of equivalent equal level, equal probability entries of interference, assumed to be uncorrelated for small percentages of time
- M_s : link performance margin (dB) (see Note 3)
- W : equivalence factor (dB) relating interference from interfering emissions to that caused, alternatively, by the introduction of additional thermal noise of equal power in the reference bandwidth (see Note 4).

NOTE 1 – The following earth station receiving system noise temperatures should be used since the location and precise characteristics of the station are unknown:

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

NOTE 2 – The factor N_L is the noise contribution to the link. In the case of a satellite transponder, it includes the up-link noise, intermodulation, etc. In the absence of specific interference data, it is assumed $N_L = 1$ dB for fixed-satellite links.

NOTE 3 – M_s is the factor by which the link noise under clear-sky conditions would have to be raised to produce the specified minimum performance. It is the dB sum of two margins M_0 (the natural performance margin) and ΔM (the operational excess margin). The natural performance margin M_0 is the dB difference between the two C/N values that would just produce the specified nominal (long term) and the specified minimum (short term) performances, respectively. The excess margin ΔM is the dB difference between the actual clear-sky C/N and the value which would produce the nominal specified performance; it may be equal to 0 dB. Thus, M_s is the real fade margin but it is also the margin by which the clear-sky noise floor could be raised (e.g. as the result of interfering emissions) to produce minimum performance conditions.

In analogue systems of the FSS, M_0 is given by $M_0 = 10 \log (50\,000/10\,000) = 7$ dB. Since this is sufficient to deal with fading at least below about 17 GHz, ΔM is taken as 0 dB, and $M_s = 7$ dB. For frequencies above about 17 GHz, ΔM may have to assume some value greater than 0 dB.

In digital systems of the FSS, M_0 can be as little as 1 dB for practical satellite circuits. In real satellite circuits, due to the presence of FEC codes, the BER versus C/N curve is very steep. In addition, at BER as low as 1×10^{-5} , the modem's decoder can lose synchronization to the incoming bit stream as the modem FEC algorithm begins to break down. Especially for very low bit rates, the recovery time could be significantly large. Thus, a degradation in C/N as small as 1.0 dB, when the BER is 1×10^{-7} , could result in degraded performance and/or downtime to the end-user anywhere from

a few seconds to several minutes. The low value of M_0 , i.e. 1 dB, is not likely to be sufficient to deal with fading on real links, hence, M_s is to be estimated directly from the expected fading depth for the real percentages of the time of concern. Practical values for M_s are therefore:

F (GHz)	M_s (dB)
< 10	2
10-17	4
> 17	6

NOTE 4 – The factor W (dB) is the level of the radio-frequency thermal noise power relative to the received power of an interfering emission which, in the place of the former and contained in the same (reference) bandwidth, would produce the same interference (e.g. an increase in the voice or video channel noise power, or in the BER). The factor W generally depends on the characteristics of both the wanted and the interfering signals. The factor W is positive when the interfering emissions would cause more degradation than thermal noise. When the wanted signal is digital, W is usually equal to or less than 0 dB, regardless of the characteristics of the interfering signal.

3 Determination of the antenna gain of the non-GSO earth station

For an earth station operating with non-GSO satellites, the antenna gain varies as functions of the time. The statistics of the horizon gain of the antenna of an earth station operating to a non-GSO space station can either be provided by administrations or derived based on computer simulations.

Using computer simulations, a procedure for calculating the time-varying gain of the transmitting or the receiving antenna of an earth station operating to a non-GSO space station is as follows:

- Simulate the non-GSO satellite constellation over a sufficiently long period (e.g. one repetition cycle of the constellation) with a time step appropriate for the orbit altitude to have a valid representation of the antenna gain variations.
- At each time step, record the earth station azimuth and elevation angles of all satellites which are visible at the earth station and are above the minimum operational elevation angle. Criteria in addition to elevation angle could be used to avoid certain geometries, e.g. geostationary orbit arc avoidance.
- Use the actual earth station antenna pattern or a formula giving a good approximation of it to calculate the gain towards the horizon at each azimuth and elevation angle around the earth station.
- For each azimuth on the horizon around the earth station, calculate the percentage of time each gain value occurs. The probability distribution function (pdf) of the horizon antenna gain varies over the range G_{min} to G_{max} . It is recommended that increments of s dB are used between G_{min} and G_{max} , i.e. $G = \{G_{min}, G_{min} + s, G_{min} + 2s, \dots, G_{max}\}$. A value of $s = 0.1$ to 0.5 dB is recommended.
- Derive the gain cumulative distribution function (cdf) by integrating the gain density function; this cdf gives the percentage of time that the gain is less than or equal to a specific value.

The following equations should be used in the above algorithmic approach to describe the geometry of the boresight of the antenna of the earth station operating to a non-GSO space station as a function of time.

For a spherical Earth and a circular orbit, the elevation angle (ε_t) to a non-GSO satellite as seen from the earth station operating to a non-GSO space station is given by:

$$\varepsilon_t = \arcsin \left\{ \left(r_s \cos(\psi) - r_g \right) / \left(r_s^2 + r_g^2 - 2r_s r_g \cos(\psi) \right)^{0.5} \right\} \quad (4)$$

where:

$$\cos(\psi) = \cos(\xi_t) [\cos(\dot{\theta}t + \lambda_g - \lambda_s) \cos(\omega + f) + \sin(\dot{\theta}t + \lambda_g - \lambda_s) \cos(i_s) \sin(\omega + f)] + \sin(\xi_g) \sin(i_s) \sin(\omega + f)$$

$$\dot{\theta}t = \omega_e - \dot{\Omega}$$

ω_e : Earth rotation rate = 0.004178 (degrees/s)

$\dot{\Omega}$: rate of precession of the nodes of the non-GSO satellite (degrees/s)

ψ : angle between the vectors from the Earth's centre to the non-GSO satellite and from the Earth's centre to the non-GSO earth station (degrees)

r_s : distance from the Earth's centre to the non-GSO satellite (km)

r_g : distance from the Earth's centre to the non-GSO earth station (km)

λ_s : longitude of ascending node of the non-GSO satellite orbit at time $t = 0$ (degrees)

i_s : operational inclination angle of the non-GSO satellite orbit (degrees)

ω : argument of perigee of the non-GSO satellite orbit at time t (degrees)

f : true anomaly of the non-GSO satellite in its orbit at time t (degrees)

λ_g, ξ_g : longitude and latitude of the non-GSO earth station (degrees)

t : time (s).

The satellite vector from the Earth's centre as a function of time is given by:

$$r_s = r_s \begin{bmatrix} x \\ y \\ z \end{bmatrix} = r_s \begin{bmatrix} \sin(\dot{\theta}t - \lambda_s) \cos(i_s) \sin(\omega + f) + \cos(\dot{\theta}t - \lambda_s) \cos(\omega + f) \\ \cos(\dot{\theta}t - \lambda_s) \cos(i_s) \sin(\omega + f) - \sin(\dot{\theta}t - \lambda_s) \cos(\omega + f) \\ \sin(i_s) \sin(\omega + f) \end{bmatrix} \quad (5)$$

The sub-satellite longitude, λ_t and latitude, ξ_t as functions of time are:

$$\lambda_t = \arctan(y/x) \quad \xi_t = \arcsin(z) \quad (6)$$

The azimuth, α_s , of the non-GSO satellite as seen from the earth station operating to non-GSO space station is:

$$\alpha_s = \left\{ \frac{\cos(\xi_t) \sin(\delta)}{\sin(\xi_g) \cos(\xi_t) \cos(\delta) - \cos(\xi_g) \sin(\xi_t)} \right\} \quad (7)$$

where:

$$\delta = \lambda_g - \lambda_t \quad (8)$$

The angle $\varphi(\alpha_s)$ (between the boresight of the antenna and the horizon direction) corresponding to a pertinent azimuth α_s , expressed as a function of the boresight azimuth and elevation angles (α_s, ε_t) and the azimuth and elevation angles (α_0, ε_0) in the pertinent direction, is given by:

$$\varphi(\alpha_s) = \arccos \left\{ \cos(\alpha_s - \alpha_0) \cos(\varepsilon_t) \cos(\varepsilon_0) + \sin(\varepsilon_t) \sin(\varepsilon_0) \right\} \quad (9)$$

when $\varepsilon_0 = 0^\circ$:

$$\varphi(\alpha_s) = \arccos \left\{ \cos(\alpha_s - \alpha_0) \cos(\varepsilon_t) \right\} \quad (10)$$

Appendix 1 to Annex 1 shows examples of calculating the horizon antenna gain of a non-GSO earth station.

4 Determination of the horizon antenna gain for unknown station

4.1 Determination of G_r of a GSO earth station

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 equation (2), the horizon antenna gains of the transmitting and receiving antennas must be added for each azimuth. This allows the transmitting antenna gain to be directly plotted versus its azimuth, but a given azimuth at the transmitting antenna's location 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 non-GSO earth station must be added a value of G_r which is found for the azimuth $\alpha' = (\alpha + 180^\circ)$.

The determination of the antenna gain G_r of the receiving earth station recognizes that:

- The main beam is not directed towards the physical horizon but towards a satellite at some, perhaps a large, elevation angle.
- The direction of the main beam is constrained by the possible locations of GSO satellites.

Hence, to determine G_r of a GSO earth station, in the absence of any knowledge regarding the location of a receiving earth station, the procedure described in Appendix 2 to Annex 1 is used.

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 2 to Annex 1 for calculating the antenna gain in the direction of the earth-station horizon has to be carried out for each counter-azimuth α' at a 0° horizon elevation angle.

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:

$$\alpha = 192^\circ$$

$$\alpha + 180^\circ = 372^\circ = 360^\circ + 12^\circ$$

$$\alpha' = 12^\circ$$

One obtains $G_t + G_r$ from:

$$G_t + G_r = G_t(\alpha) + G_r(\alpha') \quad \text{dB} \quad (11)$$

for each azimuth α at a transmitting earth station to be used in equation (2). When determining $G_r(\alpha')$ using equation (28) of Appendix 2 of Annex 1 and the equations following it, G_{max} shall be taken to be 42 dBi.

4.2 Determination of G_r for a non-GSO earth station

When the unknown earth station operates to non-GSO space stations the antenna gain in the direction of the horizon on any azimuth would normally be expected to vary with time. By definition, it is impossible to have any knowledge of the statistics of the gain variations of the unknown station, and a simplifying assumption must therefore be made.

In the time-invariant gain method, the actual value of the horizon antenna gain is based on the maximum assumed variation in horizon antenna gain on each azimuth. The values of horizon antenna gain defined below should be used for each required azimuth:

$$G_e = G_{max} \quad \text{for} \quad (G_{max} - G_{min}) \leq 20 \quad \text{dB}$$

$$G_e = G_{min} + 20 \quad \text{for} \quad 20 \text{ dB} < (G_{max} - G_{min}) < 30 \quad \text{dB}$$

$$G_e = G_{max} - 10 \quad \text{for} \quad (G_{max} - G_{min}) \geq 30 \quad \text{dB}$$

where:

G_e : horizon antenna gain of the unknown earth station (dBi) for a particular azimuth use G_t or G_r as appropriate for a transmitting or receiving earth station in the equation

G_{max}, G_{min} : maximum and minimum values of horizon antenna gain (dBi), respectively, on the azimuth under consideration.

Representative system characteristics of the unknown earth station are required to derive G_{min} and G_{max} .

5 Determination of coordination areas

Having assembled characteristics for the known and unknown earth stations, one of the two methods described in § 5.1 and 5.2 may be applied to determine the coordination area for the earth station.

The method in § 5.1 makes certain approximations to avoid the need to convolve the statistics of transmission loss and antenna gain. These approximations result in identical or smaller coordination distances than would be given by a full convolution. The truncation of the transmission loss model at values less than 100% will introduce small or negligible errors. The advantage of this method is that the algorithms required are straightforward and the need to derive distribution functions of transmission loss is avoided. The simplicity of this method helps to ensure the repeatability of results between different software implementations. This method is less sensitive to errors stemming from the sizes of the bins used in the gain and loss distributions.

The method in § 5.2 is based on a conceptually more accurate principal though it is more complex to implement. The potential accuracy may not be achieved in practice for two principal reasons. Firstly, the current propagation model of Recommendation ITU-R P.620 is valid for percentage-times only below 50% and above 0.001%: it is therefore necessary to approximate some parts of the transmission loss distribution function, with consequent loss of accuracy. Secondly, the discrete convolution and the subsequent search for the required coordination distance require finite values of iteration step-size and convergence criteria. As in the method of § 5.1, the use of too large iteration step-size will result in an overestimate or underestimate of the required coordination distance. However the greater complexity of the method of § 5.2 may encourage the use of large step sizes and convergence criteria to reduce computer run-times. The smaller values given in § 5.2 are recommended.

Practical implementations have shown that the two methods give comparable results, with the method in § 5.1 yielding slightly smaller coordination distances.

5.1 Determination of the coordination distance using method 1

The coordination distance for a specific propagation model is that distance d (km), which will result in a value of available basic transmission loss which is equal to the minimum permissible basic transmission loss as defined in § 2.2.

The methodology used here requires knowledge of the statistics of the time-varying horizon antenna gain of the earth station operating to a non-GSO space station, but does not require a derivation of the distribution function of the transmission loss.

The solution to equation (2) of the minimum permissible basic transmission loss which is given below is based on the case for a transmitting earth station operating to a non-GSO space station. A similar procedure can be adopted for a receiving non-GSO earth station where the antenna gain G_r varies with time.

The minimum permissible basic transmission loss equation can be re-written as follows:

$$L_b(p') - G_t(p_i) = P_t + G_r - P_r(p) \quad \text{dB} \quad (12)$$

where:

P_t , $P_r(p)$ and G_r are as defined in equations (1) and (2) where p is the percentage of time at which the interference level allowed to exceed the interference threshold $P_r(p)$;

p_i and p' are defined by the following probabilities:

$$p(G_t \geq G_{ti}) = p_i$$

$$p(L_b \leq L_{bi}) = p'$$

$G_t(p_i)$ is the time-varying transmitting antenna gain (dBi) towards the physical horizon in a given azimuth of the interfering earth station that is operating to a non-GSO space station.

Under the assumption that the path loss, L_b , and the antenna gain, G_t , are independent variables, the total percentage of time, p , that $\{L_b - G_t\}$ is allowed to be less than or equal to $\{P_t + G_r - P_r(p)\}$ is equal to the product of p' and p_i :

$$p(L_b - G_t \leq L_{bi} - G_{ti}) = p' p_i$$

For each pair of p' and p_i values that satisfy $p = p' p_i$ there exists a family of values L_b and G_t that satisfy equation (12). By using the cdf of the antenna gain G_t , for each azimuth, a value G_{ti} is selected such that G_t exceeds G_{ti} for only $p_i\%$ of time. At each such step the values of G_{ti} and p_i are fixed. Then equation (12) can be rewritten as follows:

$$L_{bi}(p') = P_t + G_{ti}(p_i) + G_r - P_r(p) \quad \text{dB}$$

The $L_{bi}(p')$ calculations are repeated for all G_{ti} gain levels as described in the implementation steps below. From the values of $L_{bi}(p')$ and associated distances, the distance corresponding to the maximum value is selected as the coordination distance at the specified azimuth.

The coordination distance is determined as described in the following steps:

Step 1: Compute the cdf of the horizon antenna gain of the earth station operating to non-GSO space station at a specific azimuth as described in § 3. This function may also be provided by administrations.

Step 2: From the cdf of the horizon antenna gain, determine the minimum gain value, G_{tmin} , and the maximum gain value, G_{tmax} . Choose a gain increment s dB and divide this gain range into a number of gain levels $\{G_{tmin}, G_{tmin} + s, G_{tmin} + 2s, \dots, G_{tmax}\}$. A value of $s = 0.1$ to 0.5 dB is recommended.

Step 3: Determine the percentage of time, p_i , associated with each gain level G_{ti} . This p_i represents the percentage of time the horizon antenna gain is greater than or equal to G_{ti} .

Step 4: Determine the percentage of time p' of the minimum required transmission loss associated with each p_i :

$$p' = p/p_i \quad \text{if} \quad p/p_i \leq Z\%$$

$$p' = Z\% \quad \text{if} \quad p/p_i > Z\%$$

where the recommended value for Z is $Z = 20\%$, and p' is defined over the range $0 \leq p' \leq 100\%$. If p' is greater than 100% then it should be ignored.