MOD ATG/999/1

APPENDIX 7 (REV.WRC‑12)

Methods for the determination of the coordination area around an earth  
station in frequency bands between 100 MHz and 105 GHz

# 1 Introduction

This is an Appendix addresses the determination of the coordination area (see No. **1.171**) around a transmitting or receiving earth station that is sharing spectrum in frequency bands between 100 MHz and 105 GHz with terrestrial radiocommunication services or with earth stations operating in the opposite direction of transmission.

The coordination area represents the area surrounding an earth station sharing the same frequency band with terrestrial stations, or the area surrounding a transmitting earth station that is sharing the same bidirectionally allocated frequency band with receiving earth stations, within which the permissible level of interference may be exceeded and hence coordination is required. The coordination area is determined on the basis of known characteristics for the coordinating earth station and on conservative assumptions for the propagation path and for the system parameters for the unknown terrestrial stations (see Tables 7 and 8), or the unknown receiving earth stations (see Table 9), that are sharing the same frequency band.

## 1.1 Overview

This Appendix contains procedures and system parameters for calculating an earth station’s coordination area, including predetermined distances.

The procedures allow the determination of a distance in all azimuthal directions around a transmitting or receiving earth station beyond which the predicted path loss would be expected to exceed a specified value for all but a specified percentage of the time. This distance is called the coordination distance (see No. **1.173**). When the coordination distance is determined for each azimuth around the coordinating earth station it defines a distance contour, called the coordination contour (see No. **1.172**), that encloses the coordination area.

It is important to note that, although the determination of the coordination area is based on technical criteria, it represents a regulatory concept. Its purpose is to identify the area within which detailed evaluations of the interference potential need to be performed in order to determine whether the coordinating earth station or any of the terrestrial stations, or in the case of a bidirectional allocation any of the receiving earth stations that are sharing the same frequency band, will experience unacceptable levels of interference. Hence, the coordination area is not an exclusion zone within which the sharing of frequencies between the earth station and terrestrial stations or other earth stations is prohibited, but a means for determining the area within which more detailed calculations need to be performed. In most cases a more detailed analysis will show that sharing within the coordination area is possible since the procedure for the determination of the coordination area is based on unfavourable assumptions with regard to the interference potential.

For the determination of the coordination area, two separate cases are to be considered:

– case when the earth station is transmitting and hence capable of interfering with receiving terrestrial stations or earth stations;

– case when the earth station is receiving and hence may be the subject of interference from transmitting terrestrial stations.

Calculations are performed separately for great circle propagation mechanisms (propagation mode (1)) and, if required by the sharing scenario (see § 1.4), for scattering from hydrometeors (propagation mode (2)). The coordination contour is then determined using the greater of the two distances predicted by the propagation mode (1) and propagation mode (2) calculations for each azimuth around the coordinating earth station. Separate coordination contours are produced for each sharing scenario. Guidance and examples of the construction of coordination contours, and their component propagation mode (1) and propagation mode (2) contours, are provided in § 1.6.

To facilitate bilateral discussion it can be useful to calculate additional contours, defining smaller areas, that are based on less conservative assumptions than those used for the calculation of the coordination contour.

## 1.2 Structure of this Appendix

In this Appendix the general principles are separated from the detailed text on methods. The general principles are contained in the main body of the Appendix, while the methods are contained in a series of Annexes, enabling the user to select only those sections that are relevant for a specific sharing scenario.

Table 1 is provided to help the user to navigate through the Appendix and the Annexes; it also indicates the relevant sections that need to be explored for a specific coordination case.

TABLE 1

Cross-reference between sharing scenarios and calculation methods

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sharing scenarios of § 1.4 | | | | | | |
| Applicable sections and Annexes | § 1.4.1 Earth stations operating with geostationary space stations | § 1.4.2 Earth stations operating with non-geostationary space stations1 | § 1.4.3 Earth stations operating with both geostationary and non-geostationary space  stations | § 1.4.4 Earth stations operating in bidirectionally allocated frequency bands | § 1.4.5 Broadcasting-satellite service earth stations | § 1.4.6 Mobile (except aeronautical mobile) earth stations | § 1.4.7 Aeronautical mobile earth stations |
| § 1.3 Basic concepts | X | X | X | X | X | X | X |
| § 1.5 Propagation model concepts | X | X | X | X | See § 1.4.1, 1.4.2, 1.4.3 or 1.4.4 as applicable and § 1.6 | See § 1.4.1, 1.4.2, 1.4.3 or 1.4.4 as applicable and § 1.6 | See § 1.4.1, 1.4.2, 1.4.3 or 1.4.4 as applicable and § 1.6 |
| § 1.6 The coordination contour: concepts and construction | X | X | X | X |
| § 2.1 Earth stations operating with geostationary space stations | X |  | X |  |
| § 2.2 Earth stations operating with non-geostationary space stations |  | X | X |  |
| § 3 Determination of the coordination area between earth stations operating in bidirectionally allocated frequency bands |  |  |  | X |
| § 4 General considerations for the determination of the propagation mode (1) required distance | X | X | X | X |
| § 5 General considerations for the determination of the propagation mode (2) required distance | X |  | X |  |
| Annex 1 Determination of the required distance for propagation mode (1) | X | X | X | X |
| Annex 2 Determination of the required distance for propagation mode (2) | X |  | X |  |
| Annex 3 Antenna gain towards the horizon for an earth station operating with a geostationary space station | X |  | X |  |
| Annex 4 Antenna gain towards the horizon for earth stations operating with non‑geostationary space stations |  | X | X | X |
| Annex 5 Determination of the coordination area for a transmitting earth station with respect to receiving earth stations operating with geostationary space stations in bidirectionally allocated frequency bands |  |  |  | X |
| Annex 6 Supplementary and auxiliary contours | X | X | X | X |
| Annex 7 System parameters and predetermined coordination  distances for determination of the coordination area around an earth station | X | X | X | X |
| 1 For an earth station using a non-tracking antenna the procedure of § 2.1 is used. For an earth station using a non‑directional antenna the procedures of § 2.1.1 are used. | | | | | | | |

## 1.3 Basic concepts

Determination of the coordination area is based on the concept of the permissible interference power at the antenna terminals of a receiving terrestrial station or earth station. Hence, the attenuation required to limit the level of interference between a transmitting terrestrial station or earth station and a receiving terrestrial station or earth station to the permissible interference power for *p*% of the time is represented by the “minimum required loss”, which is the loss that needs to be equalled or exceeded by the predicted path loss for all but *p*% of the time[[1]](#footnote-1)1.

For propagation mode (1) the following equation applies:

*Lb*(*p*) = *Pt* + *Gt* + *Gr* – *Pr*(*p*)                    dB (1)

where:

*p*: maximum percentage of time for which the permissible interference power may be exceeded

*Lb*(*p* ): propagation mode (1) minimum required loss (dB) for *p*% of the time; this value must be exceeded by the propagation mode (1) predicted path loss for all but *p*% of the time

*Pt*:maximum available transmitting power level (dBW) in the reference bandwidth at the terminals of the antenna of a transmitting terrestrial station or earth station

*Pr*(*p* ): permissible interference power 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 antenna of a receiving terrestrial station or earth station that may be subject to interference, where the interfering emission originates from a single source

*Gt*: gain (dB relative to isotropic) of the antenna of the transmitting terrestrial station or earth station. For a transmitting earth station, this is the antenna gain towards the physical horizon on a given azimuth; for a transmitting terrestrial station, the maximum main beam axis antenna gain is to be used

*Gr*: gain (dB relative to isotropic) of the antenna of the receiving terrestrial or earth station that may be subject to interference. For a receiving earth station, this is the gain towards the physical horizon on a given azimuth; for a receiving terrestrial station, the maximum main beam axis antenna gain is to be used.

In the case of a receiving earth station, the permissible interference power *Pr*(*p*) is specified with respect to the actual percentage of time the receiver is in operation, rather than the total elapsed time.

For propagation mode (2), a volume scattering process is involved and a modification of the above approach is necessary. Where the coordinating earth station antenna beam intersects a rain cell, a common volume may be formed with a terrestrial station beam or an earth station beam (operating in the opposite direction of transmission in bidirectionally allocated frequency bands). In the case of a terrestrial station, the assumptions are made that the terrestrial station beamwidth is relatively large in comparison with that of the coordinating earth station (terrestrial station gain values are given in Tables 7 and 8) and that the terrestrial station is some distance from the common volume. The terrestrial station beam is therefore assumed to illuminate the whole rain cell, which is represented by a vertical cylinder filled with hydrometeors that give rise to isotropically scattered signals. This scattering process may give rise to unwanted coupling between the coordinating earth station and terrestrial stations or other earth stations operating in bidirectionally allocated frequency bands, via the common volume.

The earth station antenna gain and its beamwidth are interdependent. The size of the common volume, and the number of scattered signals arising within that volume, increases as the gain of the earth station antenna transmitting or receiving those signals decreases, the one effect compensating for the other. A term which approximates the full integral required to evaluate the volume scattering process within the earth station antenna beam is included in equation (72). Therefore in the procedure for evaluation of interference that may arise from propagation mode (2) mechanisms a simplifying assumption can be made that the path loss is independent of the earth station antenna gain[[2]](#footnote-2)2.

Hence for propagation mode (2), equation (1) reduces to:

*Lx*(*p* ) = *Pt* + *Gx* – *Pr*(*p* )                    dB (2)

where:

*Lx*(*p* ): minimum loss required for propagation mode (2)

*Gx*: maximum antenna gain (dBi) assumed for the terrestrial station. Tables 7 and 8 give values of *Gx* for the various frequency bands.

To facilitate the calculation of propagation mode (2) auxiliary contours (see Annex 6) the calculation is further modified by placing the terrestrial network antenna gain *Gx* within the iterative loop for the propagation mode (2) required loss calculations[[3]](#footnote-3)3.

Hence equation (2) further reduces to:

*L*(*p* ) = *Pt* – *Pr*(*p* )                    dB (3)

where:

*L*(*p* ): propagation mode (2) minimum required loss (dB) for *p*% of the time; this value must be exceeded by the propagation mode (2) predicted path loss for all but *p*% of the time.

For both modes of propagation, *Pt*and *Pr*(*p*) are defined for the same radio-frequency bandwidth (the reference bandwidth). Further, *Lb*(*p*), *L*(*p*) and *Pr*(*p*) are defined for the same small percentage of the time, and these values are set by the performance criteria of the receiving terrestrial station or receiving earth station that may be subject to interference.

For an earth station operating with a geostationary space station, Annex 3 provides the numerical method for determining the minimum angle between the earth station antenna main beam axis and the physical horizon as a function of azimuth, and the corresponding antenna gain. In the case of a space station in a slightly inclined geostationary orbit, the minimum elevation angle and corresponding horizon gain will depend on the maximum inclination angle to be coordinated.

For an earth station operating with non-geostationary space stations, the antenna gain of the earth station in the direction of the horizon varies as a function of time and Annex 4 provides the numerical methods for its determination.

For an earth station operating in a frequency band with a bidirectional allocation, the antenna gain to be used in determining the propagation mode (1) minimum required loss is calculated using the methods in Annex 3 or Annex 4, as appropriate.

Determination of the coordination area requires the calculation of the predicted path loss and its comparison with the minimum required loss, for every azimuth around the coordinating earth station, where:

– the predicted path loss is dependent on several factors including the length and general geometry of the interfering path (e.g. antenna pointing, horizon elevation angle), antenna directivity, radio climatic conditions, and the percentage of the time during which the predicted path loss is less than the minimum required loss; and

– the minimum required loss is based on system and interference model considerations.

The required coordination distance is the distance at which these two losses are considered to be equal for the stated percentage of time.

In determining the coordination area, the pertinent parameters of the coordinating earth station are known, but knowledge of the terrestrial stations or other earth stations sharing that frequency range is limited. Hence it is necessary to rely on assumed system parameters for the unknown terrestrial stations or the unknown receiving earth stations. Furthermore, many aspects of the interference path between the coordinating earth station and the terrestrial stations or other earth stations (e.g. antenna geometry and directivity) are unknown.

The determination of the coordination area is based on unfavourable assumptions regarding system parameter values and interference path geometry. However, in certain circumstances, to assume that all the worst-case values will occur simultaneously is unrealistic, and leads to unnecessarily large values of minimum required loss. This could lead to unnecessarily large coordination areas. For propagation mode (1), detailed analyses, supported by extensive operational experience, have shown that the requirement for the propagation mode (1) minimum required loss can be reduced because of the very small probability that the worst-case assumptions for system parameter values and interference path geometry will exist simultaneously. Therefore, a correction is applied within the calculation for the propagation mode (1) predicted path loss in the appropriate sharing scenario to allow benefit to be derived from these mitigating effects. The application of this correction factor is described in more detail in § 4.4.

This correction applies to cases of coordination with the fixed service. It is frequency, distance and path dependent. It does not apply in the case of the coordination of an earth station with mobile stations, nor with other earth stations operating in the opposite direction of transmission, nor in the case of propagation via hydrometeor scatter (propagation mode (2)).

A number of propagation models are used to cover the propagation mechanisms that exist in the full frequency range. These models predict the path loss as a monotonically increasing function of distance. Therefore, coordination distances are determined by calculating the path loss iteratively for an increasing distance until either the minimum required loss is achieved, or a maximum calculation distance limit is reached (see § 1.5.3).

The iteration method always starts at a defined value of minimum distance, *dmin* (km), and iteration is performed using a uniform step size, *s* (km), for increasing the distance. A step size of 1 km is recommended.

## 1.4 Sharing scenarios

The following subsections describe the basic assumptions made for the various earth station sharing scenarios. These subsections need to be read in conjunction with the information contained in Table 1 and § 1.6 which contains guidance on the development of a coordination contour. Except as discussed in § 1.4.5 to 1.4.7, the earth stations around which coordination areas are determined are assumed to be fixed earth stations authorized to operate at a single permanent location. In cases of earth stations that can be operated from a number of fixed locations, the coordination areas are determined for each individual location.[[4]](#footnote-4)4

### 1.4.1 Earth stations operating with geostationary space stations

For an earth station operating with a space station in the geostationary orbit, the space station appears to be stationary with respect to the Earth. However variations in gravitational forces acting on the space station and limitations in positional control mean that a geostationary space station’s orbital parameters are not constant. Movement from the space station’s nominal orbital position in an east/west direction (longitudinal tolerance) is limited under the Radio Regulations (see Nos. **22.6** to **22.18**), but movement in the north/south direction (inclination excursion) is not specified.

Relaxation in the north/south station-keeping of a geostationary space station allows its orbit to become inclined, with an inclination that increases gradually with time. Therefore the determination of the coordination area requires consideration of the range of movement of the earth station antenna. Although the direction of pointing of the earth station antenna may in practice vary with time, the earth station antenna may also be pointing in one direction for considerable periods of time. Hence the gain of the earth station antenna in the direction of the horizon is assumed to be constant. For an earth station operating with a space station in an orbit as described above, an assumption of constant horizon gain as the inclination angle increases may lead to a conservative estimation of the coordination area, the degree of conservatism increasing with increasing inclination angle.

For an earth station operating with a geostationary space station the coordination area is determined using the procedures described in § 2.1.

### 1.4.2 Earth stations operating with non-geostationary space stations

Earth stations operating with non-geostationary space stations may use a directional or a non-directional antenna. Furthermore, earth stations using a directional antenna may track the orbital path of a non-geostationary space station.

While an earth station operating with a geostationary space station is assumed to have a constant antenna gain towards the horizon, for an earth station antenna that is tracking the orbital path of a non-geostationary space station, the antenna gain towards the horizon will vary with time. Therefore, it is necessary to estimate the variation of the antenna gain with time towards the horizon for each azimuth in order to determine the coordination area. The procedure is described in § 2.2.

For an earth station operating with a non-geostationary space station, the motion of a relatively high gain tracking antenna reduces the probability of interference due to propagation mode (2) mechanisms and hence the propagation mode (2) required distances will be relatively short. The minimum coordination distance *dmin*(see § 1.5.3) will provide adequate protection in these cases. The propagation mode (2) contour is therefore taken to be identical to a circle whose radius is the minimum coordination distance. Propagation mode (2) calculations are not required in these circumstances and the coordination area is determined using the propagation mode (1) procedure in § 2.2 only.

For an earth station operating with a non-geostationary space station using a non-directional antenna, a similar situation applies, and the low gain means that propagation mode (2) required distances will be less than the minimum coordination distance. Hence, for the case of a non‑directional antenna the propagation mode (2) contour is also coincident with the circle of radius *dmin*, and the coordination area is determined using the propagation mode (1) procedures described in § 2.1.1 only.

For an earth station operating with a non-geostationary space station using a non-tracking directional antenna, the potential for interference arising from propagation mode (2) is the same as for an earth station operating with a geostationary space station. Hence, for the case of non-tracking directional antenna the coordination area is determined using both the propagation mode (1) and propagation mode (2) procedures described in § 2.1.

### 1.4.3 Earth stations operating with both geostationary and non-geostationary space stations

For earth stations that are sometimes intended to operate with geostationary space stations and at other times with non-geostationary space stations, separate coordination areas are determined for each type of operation. In such cases, the coordination area for the geostationary space station is determined using the procedures described in § 2.1 and the coordination area for the non-geostationary space station is determined using the procedure described in § 2.2. For each case, the percentage of time, *p*,is specified for all the operational time that the receiving earth station is expected to spend in reception from geostationary space stations or non-geostationary space stations, as appropriate.

### 1.4.4 Earth stations operating in bidirectionally allocated frequency bands

For earth stations operating in some frequency bands there may be allocations with equal rights to space services operating in both the Earth-to-space and space-to-Earth directions. In this case, where two earth stations are operating in opposite directions of transmission it is only necessary to establish the coordination area for the transmitting earth station, as receiving earth stations will automatically be taken into consideration. Hence, a receiving earth station operating in a bidirectionally allocated frequency band will only be involved in coordination with a transmitting earth station if it is located within the transmitting earth station’s coordination area.

For a transmitting earth station operating with either geostationary or non-geostationary satellites in a bidirectionally allocated frequency band, the coordination area is determined using the procedures described in § 3.     (WRC‑03)

### 1.4.5 Broadcasting-satellite service earth stations

For earth stations in the broadcasting-satellite service operating in the unplanned bands, the coordination area is determined by extending the periphery of the specified service area within which the earth stations are operating by the coordination distance based on a typical BSS earth station. In calculating the coordination distance, no additional protection can be assumed to be available from the earth station horizon elevation angle, i.e. *Ah* = 0 dB in Annex 1, for all azimuth angles around the earth station.

### 1.4.6 Mobile (except aeronautical mobile) earth stations

For a mobile (except aeronautical mobile) earth station, the coordination area is determined by extending the periphery of the specified service area, within which the mobile (except aeronautical mobile) earth stations are operating, by the coordination distance. The coordination distance may be represented by a predetermined coordination distance (see Table 10), or it may be calculated. In calculating the coordination distance, no additional protection can be assumed to be available from the earth station horizon elevation angle, i.e. *Ah* = 0 dB in Annex 1, for all azimuths around the earth station.

### 1.4.7 Aeronautical mobile earth stations

For aeronautical mobile earth stations, the coordination area is determined by extending the periphery of the specified service area within which the aeronautical mobile earth station operates, by an appropriate predetermined coordination (see Table 10) distance for the respective services.

## 1.5 Propagation model concepts

For each mode of propagation, according to the requirements of the specific sharing scenario (see § 1.4) it is necessary to determine the predicted path loss. The determination of this predicted path loss is based on a number of propagation mechanisms.

Interference may arise through a range of propagation mechanisms whose individual dominance depends on climate, radio frequency, time percentage in question, distance and path topography. At any given point in time, one or more mechanisms may be present.The propagation mechanisms that are considered within this Appendix in the determination of the interference potential are as follows:

*–* *Diffraction*: Insofar as it relates to diffraction losses occurring over the earth station’s local physical horizon. This effect is referred to below as “site shielding”. The remainder of the path along each radial is considered to be flat and therefore free of additional diffraction losses.

*– Tropospheric scatter*: This mechanism defines the “background” interference level for paths longer than about 100 km, beyond which the diffraction field becomes very weak.

*– Surface ducting*: This is the most important short-term interference mechanism over water and in flat coastal land areas, and can give rise to high signal levels over greater distances, sometimes exceeding 500 km. Such signals can exceed the equivalent “free-space” level under certain conditions.

*– Elevated layer reflection and refraction*: The treatment of reflection and/or refraction from layers at heights of up to a few hundred metres is an important mechanism that enables signals to by-pass any diffraction losses due to the underlying terrain under favourable path geometry situations. Here again, the impact can be significant over long distances.

*– Hydrometeor scatter*: Hydrometeor scatter can be a potential source of interference between terrestrial station transmitters and earth stations because it may act isotropically, and can therefore have an impact irrespective of whether the common volume is on or off the great‑circle interference path between the coordinating earth station and terrestrial stations, or other receiving earth stations operating in bidirectionally allocated frequency bands.

In this Appendix, propagation phenomena are classified into two modes as follows:

– *Propagation mode (1)*: propagation phenomena in clear air (tropospheric scatter, ducting, layer reflection/refraction, gaseous absorption and site shielding). These phenomena are confined to propagation along the great-circle path.

– *Propagation mode (2)*: hydrometeor scatter.

### 1.5.1 Propagation mode (1)

For the determination of the propagation mode (1) required distances, the applicable frequency range has been divided into three parts:

– For VHF/UHF frequencies between 100 MHz and 790 MHz and for time percentages from 1% to 50% of an average year.

– From 790 MHz to 60 GHz and for time percentages from 0.001% to 50% of an average year.

– From 60 GHz to 105 GHz and for time percentages from 0.001% to 50% of an average year.

The variation in predicted path loss due to the horizon elevation angle around an earth station is calculated by the method described in § 1 of Annex 1, using the horizon elevation angles and distances along different radials from the earth station. For all frequencies between 100 MHz and 105 GHz, the attenuation arising from the horizon characteristics is included in the value of propagation mode (1) predicted path loss, unless its use is specifically prohibited for a particular sharing scenario (see § 1.4.5 and § 1.4.6).

In the determination of the propagation mode (1) required distance, the world is divided into four basic radio-climatic zones. These zones are defined as follows:

– Zone A1: coastal land, i.e. land adjacent to a Zone B or a Zone C area (see below), up to an altitude of 100 m relative to mean sea or water level, but limited to a maximum distance of 50 km from the nearest Zone B or Zone C area; in the absence of precise information on the 100 m contour, an approximation (e.g. 300 feet) may be used. Large inland areas of at least 7 800 km2 which contain many small lakes, or a river network, comprising more than 50% water, and where more than 90% of the land is less than 100 m above the mean water level may be included in Zone A1[[5]](#footnote-5)5.

– Zone A2: all land, other than coastal land as defined in Zone A1 above.

– Zone B: “cold” seas, oceans and large bodies of inland water situated at latitudes above 30°, with the exception of the Mediterranean Sea and the Black Sea. A “large” body of inland water is defined, for the administrative purpose of coordination, as one having an area of at least 7 800 km2, but excluding the area of rivers. Islands within such bodies of water are to be included as water within the calculation of this area if they have elevations lower than 100 m above the mean water level for more than 90% of their area. Islands that do not meet these criteria should be classified as land for the purposes of calculating the area of the water.

– Zone C: “warm” seas, oceans and large bodies of inland water situated at latitudes below 30°, as well as the Mediterranean Sea and the Black Sea.

### 1.5.2 Propagation mode (2)

For the determination of the propagation mode (2) required distance, interference arising from hydrometeor scatter can be ignored at frequencies below 1 000 MHz and above 40.5 GHz outside the minimum coordination distance (see § 1.5.3.1). Below 1 000 MHz, the level of the scattered signal is very low and above 40.5 GHz, although significant scattering occurs, the scattered signal is then highly attenuated along the path from the scatter volume to the receiving terrestrial station or earth station. Site shielding is not relevant to propagation mode (2) mechanisms as the interference path is via the main beam of the coordinating earth station antenna.

### 1.5.3 Distance limits

The effect of interference on terrestrial and space systems often needs to be assessed by considering long- and short‑term interference criteria. These criteria are generally represented by a permissible interference power not to be exceeded for more than a specified percentage of time.

The long-term interference criterion (typically associated with percentages of time ≥ 20%) allows the error performance objective (for digital systems) or noise performance objective (for analogue systems) to be met. This criterion will generally represent a low level of interference and hence require a high degree of isolation between the coordinating earth station and terrestrial stations, or other receiving earth stations operating in bidirectionally allocated bands.

The short-term criterion is a higher level of interference, typically associated with time percentages in the range 0.001% to 1% of time, which will either make the interfered-with system unavailable, or cause its specified short-term interference objectives (error rate or noise) to be exceeded.

This Appendix addresses only the protection provided by the short-term criterion. There is therefore an implicit assumption that if the short-term criterion is satisfied, then any associated long-term criteria will also be satisfied. This assumption may not remain valid at short distances because additional propagation effects (diffraction, building/terrain scattering etc.) requiring a more detailed analysis become significant. A minimum coordination distance is therefore needed to avoid this difficulty. This minimum coordination distance is always the lowest value of coordination distance used. At distances equal to or greater than the minimum coordination distance, it can be assumed that interference due to continuous (long-term) propagation effects will not exceed levels permitted by the long-term criteria.

In addition to the minimum coordination distance, it is also necessary to set an upper limit to the calculation distance. Hence the coordination distance, on any azimuth, must lie within the range between the minimum coordination distance and the maximum calculation distance.

#### 1.5.3.1 Minimum coordination distance

For the reasons stated in § 1.5.3, it is necessary to set a lower limit, *dmin*, for the coordination distance. The iterative calculation of the coordination distance starts at this minimum distance, and this distance varies according to radiometeorological factors and the frequency band (see § 4.2). This same minimum coordination distance applies both to propagation mode (1) and propagation mode (2) calculations.

#### 1.5.3.2 Maximum calculation distance

Maximum calculation distances are required for propagation modes (1) and (2). In the case of mode (1), this distance corresponds to the maximum coordination distance, *dmax*1, given in § 4.3 for each of the four radioclimatic Zones. The propagation mode (1) maximum calculation distance is therefore dependent on the mixture of radioclimatic Zones in the propagation path, as described in § 4.3.

The maximum calculation distance for propagation mode (2) is given in § 2 of Annex 2.

## 1.6 The coordination contour: concepts and construction

The coordination distance, determined for each azimuth around the coordinating earth station, defines the coordination contour that encloses the coordination area. The coordination distance lies within the range defined by the minimum coordination distance and the maximum calculation distance.

In this Appendix, the procedures determine the distance at which the minimum required loss is equal to the predicted path loss. In addition, some procedures[[6]](#footnote-6)6 require that, for any azimuth, the greater of the distances determined for propagation mode (1) and propagation mode (2) is the distance to be used in determining the coordination contour. In both these cases, the distance at which the minimum required loss is equal to the predicted path loss may or may not be within the range of valid values that define the limits for the coordination distance. Hence, the distance determined from the application of all the procedures is referred to as the required distance.

The coordination area is determined by one of the following methods:

– calculating, in all directions of azimuth from the earth station, the coordination distances and then drawing to scale on an appropriate map the coordination contour; or

*–* extending the service area in all directions by the calculated coordination distance(s); or

*–* for some services and frequency bands, extending the service area in all directions by a predetermined coordination distance.

Where a coordination contour includes the potential interference effects arising from both propagation mode (1) and propagation mode (2), the required distance used for any azimuth is the greater of the propagation mode (1) and propagation mode (2) required distances.

The sharing scenarios and the various procedures contained in this Appendix are based on different assumptions. Hence, the coordination area developed for one sharing scenario is likely to be based on different sharing considerations, interference paths and operational constraints than the coordination area developed under a different sharing scenario. Separate coordination areas are therefore required for each sharing scenario described in § 1.4, and each coordination area is specific to the radiocommunication services covered by the sharing scenario under which it was developed. Further, the coordination area developed for one sharing scenario cannot be used to determine the extent of any impact on the radiocommunication services covered by a different sharing scenario. Thus, a coordinating earth station operating in a bidirectionally allocated frequency band that is also allocated to terrestrial services will have two separate coordination areas:

*–* one coordination area for determining those administrations with terrestrial services that may be affected by the operation of the coordinating earth station; and

*–* one coordination area for determining those administrations with receiving earth stations that may be affected by the operation of the coordinating (transmitting) earth station.

This means that the establishment of the coordination area for an earth station will generally require the determination of several individual coordination areas, each drawn on a separate map. For example, an earth station which transmits to a geostationary space station in the band 10.7-11.7 GHz will need to develop the following coordination areas with respect to:

– analogue terrestrial services which receive in the same band; this will comprise the potential effects arising from both propagation mode (1) and propagation mode (2) interference paths;

– an earth station operating with a geostationary space station which receives in the same band; this will comprise the potential effects arising from both propagation mode (1) and propagation mode (2) interference paths;

– an earth station operating with a non-geostationary space station which receives in the same band; this will comprise the potential effects arising from propagation mode (1) interference paths.

In addition, separate coordination contours are produced if the earth station both transmits and receives in bands shared with terrestrial services. However, for earth stations in bidirectionally allocated frequency bands, the coordination contours with respect to other earth stations are only produced for a transmitting earth station (see § 1.4.4).

Examples of coordination contours for each of the sharing scenarios in § 1.4 is provided in Fig. 1. It will be noticed that for some of the sharing scenarios there is a commonality to the construction of the coordination contour (shown by a solid line) that encompasses each coordination area. For those sharing scenarios where both propagation mode (1) and propagation mode (2) interference paths need to be taken into consideration, the parts of the propagation mode (1) contour and that part of the propagation mode (2) contour located within the overall coordination contour may be drawn using dashed lines.

In addition to the coordination contour, supplementary contours and auxiliary contours (see Annex 6) may be drawn to facilitate more detailed sharing discussions. Supplementary contours are based on the coordinating earth station sharing frequency bands with other radiocommunication services, or other types of radio systems in the same service, that have less onerous sharing criteria than the radio system used for developing the coordination area. These supplementary contours may be developed by the same method used to determine the coordination contour, or by other methods as agreed on a bilateral basis between administrations. For example, the Time Variant Gain method described in § 4 of Annex 6 can be used to generate supplementary contours for earth stations operating with non-geostationary space stations. Auxiliary contours are based on less conservative assumptions, with regard to the interference path and operational constraints, for the unknown terrestrial stations, or earth stations. Auxiliary contours are developed separately for propagation mode (1) and propagation mode (2) interference paths. In this context, the contours from which the coordination contour was developed are called main contours, and the auxiliary contours for propagation mode (1) and propagation mode (2) are referenced to the appropriate main contour. The various assumptions used for developing auxiliary contours to the propagation mode (1) contour, or the propagation mode (2) contour, can also be applied to supplementary contours. Hence, auxiliary contours may be drawn for both a main or a supplementary contour.



Supplementary contours are always drawn on a separate map as they apply to other types of radio system within the same radiocommunication service, or to radio systems in different radiocommunication services. However, as auxiliary contours apply to the various assumptions used in developing the main, or supplementary, contour they are always drawn on the same map that contains the corresponding main, or supplementary, contour.

While the use of supplementary or auxiliary contours allows less conservative assumptions with regard to the interference path and operational constraints to be taken into consideration, earth stations may transmit or receive a variety of classes of emissions. Hence, the earth station parameters to be used in the determination of the coordination contour, and any supplementary or auxiliary contours, are those which lead to the greatest distances for each earth station antenna beam and each allocated frequency band which the coordinating earth station shares with other radiocommunication systems.

# 2 Determination of the earth station coordination area with respect to terrestrial stations

This section contains the procedures for determining the coordination area for the case of earth stations sharing frequency bands with terrestrial stations. These procedures cover the cases for earth stations operating with space stations in the geostationary orbit, or in non-geostationary orbits, and are described in the following subsections.

For earth stations operating with space stations in non-geostationary orbits, consideration has to be given to the potential time-varying nature of the earth station’s antenna gain towards the horizon.

## 2.1 Earth stations operating with geostationary space stations

For an earth station operating with a geostationary space station, the value of *Gt* and *Gr* towards the horizon is considered to be constant with time. The percentage of time associated with *Lb* in equation (1) is the same as the time percentage, *p*, associated with *Pr*(*p*). When determining the coordination area between a coordinating earth station operating with a geostationary space station and terrestrial systems, the coordination distance on any azimuth is the greater of the propagation mode (1) and propagation mode (2) required distances. The required distances for propagation mode (1) and propagation mode (2) are determined using the procedures described in § 2.1.1 and § 2.1.2 respectively, after taking into consideration the following discussion on station-keeping.

When the north/south station-keeping of a geostationary space station is relaxed, the orbit of the space station becomes inclined with an inclination that increases gradually with time. This movement of the space station from its nominal position may require small corresponding adjustments in the elevation angle of the earth station antenna beam. Hence, to avoid considering the time variation in antenna gain in the direction of the horizon, the coordination area of an earth station operating with a space station in a slightly inclined geostationary orbit is determined for the minimum angle of elevation and the associated azimuth at which the space station is visible to the earth station (see Annex 3).

### 2.1.1 Determination of the coordinating earth station’s propagation mode (1) contour

Determination of the propagation mode (1) contour is based on great circle propagation mechanisms and it is assumed, for the interference path, that all the terrestrial stations are pointing directly at the coordinating earth station’s location. The required distance, on each azimuth, for propagation mode (1) is that distance which will result in a value of propagation mode (1) predicted path loss that is equal to the propagation mode (1) minimum required loss, *Lb*(*p*) (dB), as defined in § 1.3.

*Lb*(*p* ) = *Pt* + *Ge* + *Gx* – *Pr*(*p* )                    dB (4)

where:

*Pt* and *Pr*(*p*): as defined in § 1.3

*Ge*: gain of the coordinating earth station antenna (dBi) towards the horizon at the horizon elevation angle and azimuth under consideration

*Gx*: maximum antenna gain (dBi) assumed for the terrestrial station. Tables 7 and 8 give values for *Gx* for the various frequency bands.

The propagation mode (1) required distance is determined using the procedures described in § 4, and the detailed methods in Annex 1. Specific guidance relevant to the application of the procedures is provided in § 4.4.

### 2.1.2 Determination of the coordinating earth station’s propagation mode (2) contour

The required distance for hydrometeor scatter is that distance that will result in a propagation mode (2) predicted path loss equal to the propagation mode (2) minimum required loss *L*(*p*), as defined in equation (3). This propagation mode (2) required distance is determined using the guidance in § 5, and the detailed methods in Annex 2.

For an earth station operating with a geostationary space station having a slightly inclined orbit, the rain-scatter coordination contours for each of the satellite’s two most extreme orbit positions are determined individually, using the relevant elevation angles and their associated azimuths to the satellite. The rain scatter area is the total area contained within the two resulting overlapping coordination contours.

## 2.2 Earth stations operating with non-geostationary space stations

For an earth station that operates with non-geostationary space stations and whose antennas track the space stations, the antenna gain in the direction of the horizon on any azimuth varies with time. The method used to determine the coordination contour is the time invariant gain (TIG) method.

This method uses fixed values of antenna gain based on the maximum assumed variation in horizon antenna gain on each azimuth under consideration. In considering the horizon gain of the antenna for either a transmitting or a receiving earth station, only the horizon antenna gain values during the operational time are to be considered. The horizon antenna gain may be determined using Annex 4. Reference or measured antenna radiation patterns may be used as described in Annex 3. The values of horizon antenna gain defined below are used for each azimuth when applying equation (4) to determine the propagation mode (1) required distances:

*Ge* = *Gmax* for (*Gmax* – *Gmin*) ≤ 20 dB

*Ge* = *Gmin* + 20 for 20 dB  < (*Gmax* – *Gmin*) < 30 dB (5)

*Ge* = *Gmax* – 10 for (*Gmax* – *Gmin*) ≥ 30 dB

where:

*Ge*: gain of the coordinating earth station antenna (dBi) towards the horizon at the horizon elevation angle and azimuth under consideration in equation (4)

*Gmax, Gmin*: maximum and minimum values of the horizon antenna gain (dBi), respectively, on the azimuth under consideration.

The maximum and minimum values of the horizon antenna gain, on the azimuth under consideration, are derived from the antenna pattern and the maximum and minimum angular separation of the antenna main beam axis from the direction of the physical horizon at the azimuth under consideration.

Where a single value of minimum elevation angle for the main beam axis of the earth station antenna is specified for all azimuths, the minimum and maximum values of the horizon gain can be determined, for each azimuth under consideration, from the antenna pattern and the horizon elevation angle at that azimuth. The plot of the horizon elevation angle against azimuth is called the horizon profile of the earth station.

Additional constraints may be included in the determination of the maximum and minimum values of the horizon antenna gain where an earth station is operating with a constellation of non-geostationary satellites at a latitude for which no satellite is visible at the earth station’s specified minimum elevation angle over a range of azimuths. Over this range of azimuth angles, the minimum elevation angle of the earth station antenna main beam axis is given by the minimum elevation angle at which any satellite of the constellation is visible at that azimuth. The azimuthal dependence of this minimum satellite visibility elevation angle may be determined from consideration of the orbital altitude and inclination of the satellites in the constellation, without recourse to simulation, using the procedure in § 1.1 of Annex 4. In this case, the horizon antenna gain to be used in the method depends on the profile of the composite minimum elevation angle. This minimum composite elevation angle at any azimuth is the greater of the minimum satellite visibility elevation angle, at the azimuth under consideration, and the specified minimum elevation angle for the earth station which is independent of the azimuth.

Thus, at each azimuth under consideration, the maximum horizon antenna gain will be determined from the minimum value of the angular separation between the earth station horizon profile at this azimuth and the profile of the minimum composite elevation angle. Similarly, the minimum horizon antenna gain will be determined from the maximum value of the angular separation from the earth station horizon profile at this azimuth to the profile of the minimum composite elevation angle. The procedure for calculating the minimum and maximum angular separations from the profile of the minimum composite elevation angle is given in § 1.2 of Annex 4.

The propagation mode (1) required distance is then determined using the procedures described in § 4, and the detailed methods in Annex 1. Specific guidance relevant to the application of the propagation calculations is provided in § 4.4.

# 3 Determination of the coordination area between earth stations operating in bidirectionally allocated frequency bands

This section describes the procedures to be used for determination of the coordination area for an earth station transmitting in a frequency band allocated to space services in both Earth-to-space and space-to-Earth directions.

There are various coordination scenarios, involving only non-time-varying antenna gains, or only time-varying antenna gains (both earth stations operate with non-geostationary space stations) or, one time-varying antenna gain and one non-time-varying antenna gain.

The following subsections describe the methods for the determination of coordination area which are specific to each of these bidirectional cases. The procedures applicable to the coordination scenario where both earth stations operate with geostationary space stations are given in § 3.1. The other bidirectional coordination scenarios are considered in § 3.2, where particular attention is given to the approaches for using the horizon antenna gain of the receiving earth station for each of the possible coordination scenarios in the appropriate procedure of § 2.

Table 9 provides the parameters that are to be used in the determination of the coordination area. Table 9 also indicates whether, in each band, the receiving earth stations operate with geostationary or non-geostationary space stations. In some bands, receiving earth stations may operate with both geostationary and non-geostationary space stations. Table 2 indicates the number of coordination contours which need to be drawn for each coordination scenario and the section(s) containing the applicable calculation methods. Once drawn, each coordination contour must be appropriately labelled.

TABLE 2

Coordination contours required for each bidirectional scenario

| Coordinating earth station operating to a space station in the | Unknown receiving earth station operating with a space station in the | Section containing the method to determine  *Gt* and *Gr* | Contours required | |
| --- | --- | --- | --- | --- |
|  | No. | Details |
|  | Geostationary orbit | § 3.1 | 1 | A coordination contour comprising both propagation mode (1) and propagation mode (2) contours |
| Geostationary orbit | Non-geostationary orbit | § 3.2.1 | 1 | A propagation mode (1) coordination contour |
|  | Geostationary or non-geostationary orbits1 | § 3.1.1 and 3.2.1 | 2 | Two separate coordination contours, one for the geostationary orbit (propagation mode (1) and mode (2) contours) and one for the non-geostationary orbit (propagation mode (1) contour) |
|  | Geostationary orbit | § 3.2.2 | 1 | A propagation mode (1) coordination contour |
| Non-geostationary orbit | Non-geostationary orbit | § 3.2.3 | 1 | A propagation mode (1) coordination contour |
|  | Geostationary or non-geostationary orbits1 | § 3.2.2 and 3.2.3 | 2 | Two separate propagation mode (1) coordination contours, one for the geostationary orbit and one for the non-geostationary orbit |
| 1 In this case, the bidirectional frequency band may contain allocations in the Earth-to-space direction for space stations in both the geostationary orbit and non-geostationary orbits. Hence, the coordinating administration will not know whether the unknown receiving earth stations are operating with space stations in the geostationary orbit or non-geostationary orbit. | | | | |

## 3.1 Coordinating and unknown earth stations operating with geostationary space stations

When both the coordinating and the unknown earth stations operate with space stations in the geostationary orbit, it is necessary to develop a coordination contour comprising both propagation mode (1) and propagation mode (2) contours, using the procedures described in § 3.1.1 and 3.1.2, respectively.

### 3.1.1 Determination of the coordinating earth station’s propagation mode (1) contour

The procedure for the determination of the propagation mode (1) contour in this case differs from that described in § 2.2 in two ways. First, the parameters to be used for the unknown receiving earth station are those in Table 9. Second, and more significantly, the knowledge that both earth stations operate with geostationary satellites can be used to calculate the worst-case value of the horizon antenna gain of the receiving earth station towards the transmitting earth station for each azimuth at the transmitting earth station. The propagation mode (1) required distance is that distance which will result in a value of propagation mode (1) predicted path loss which is equal to the propagation mode (1) minimum required loss, *Lb*(*p* ) (dB), as defined in § 1.3, and repeated here for convenience.

*Lb*(*p* ) = *Pt* + *Gt* + *Gr* – *Pr*(*p* )                    dB (6)

where:

*Pt*and *Pr*(*p* ): as defined in § 1.3

*Gt*: gain of the coordinating (transmitting) earth station antenna (dBi) towards the horizon at the horizon elevation angle and the azimuth under consideration

*Gr*: the horizon antenna gain of the unknown receiving earth station towards the transmitting earth station on the specific azimuth from the coordinating earth station. Values are determined by the procedure in § 2.1 of Annex 5, based on parameters from Table 9.

To facilitate the determination of the values of *Gr* to be used at an azimuth from the transmitting earth station, several simplifying approximations must be made:

− that the horizon elevation of the receiving earth station is zero degrees on all azimuths;

− that the receiving earth station operates with a space station that has zero degrees orbital inclination and may be located anywhere on the geostationary orbit that is above the minimum elevation angle, given in Table 9, for the location of the receiving earth station;

− that the latitude of the receiving earth station is the same as that of the transmitting earth station;

− that plane geometry can be used to interrelate the azimuth angles at the respective earth stations, rather than using the great circle path.

The first three assumptions provide the basis for determining the horizon antenna gain of the receiving earth station on any azimuth. The assumption of 0° horizon elevation angle is conservative since the increase in horizon antenna gain due to a raised horizon would, in practice, be more than offset by any real site shielding[[7]](#footnote-7)7. The last two assumptions in the list simplify the calculation of the sum of *Gt* and *Gr* along any azimuth. Since the propagation mode (1) required distances are small, in global geometric terms these approximations may introduce a small error in the determination of the horizon antenna gain of the receiving earth station antenna that, in any case, will not exceed 2 dB. Because of the assumption of plane geometry, for a given azimuth at the transmitting earth station the appropriate value of the horizon antenna gain of the receiving earth station is the value on the reciprocal (i.e. 180°, see § 2.1 of Annex 5) azimuth at the receiving earth station.

The propagation mode (1) required distance is then determined using the procedures described in § 4, and the detailed methods in Annex 1. Specific guidance relevant to the application of the propagation calculations is provided in § 4.4.

### 3.1.2 Determination of the coordinating earth station’s propagation mode (2) contour

The procedure for the determination of the propagation mode (2) contour for a transmitting earth station operating with a geostationary space station uses the same simplifying approximations as made in § 3.1.1, but it is based on a geometrical construction that avoids the requirement for a complex propagation model (see § 3 of Annex 5). Auxiliary contours cannot be used in this method, as the calculations are not based on the propagation mode (2) required loss.

The propagation mode (2) contour is determined using the elevation angle and the azimuth from the coordinating transmitting earth station to the space station, together with the following two considerations:

– the minimum coordination distance (see § 4.2), which will be the required distance for some azimuths; and

– a worst-case required distance determined by the hydrometeor scatter geometry for a receiving earth station located in either of two 6° azimuth sectors. Within these sectors, the receiving earth station is assumed to be operating at the minimum elevation angle to a space station in the geostationary orbit and its main beam intersects the beam for the coordinating transmitting earth station at the point where the latter beam passes through the rain height, *hR*. Although the scattering can occur anywhere between the coordinating earth station and this point, the intersection of the two beams at this point represents the worst-case interference scenario. Hence, it results in the worst-case distance requirement for receiving earth stations located in the two azimuth sectors.

For an earth station operating with a space station in an inclined orbit, the lowest expected operational antenna elevation angle and its associated azimuth are used in the calculations.

The propagation mode (2) contour is determined using the method in § 3 of Annex 5.

## 3.2 Coordinating or unknown earth stations operating with non-geostationary space stations

To determine the coordination area, the method described in § 2.2 is used. For the cases where a coordinating (transmitting) earth station operates with non-geostationary space stations, the following procedures assume that the earth station antenna is tracking the space station, otherwise see § 1.4.2. Table 9 provides values of horizon antenna gain to be used in the calculations.

One or more of the following three procedures may be needed to determine the required propagation mode (1) coordination contours of Table 2. Propagation mode (2) contours are not required for any of the cases where either of the earth stations operates with space stations in non‑geostationary orbits.

### 3.2.1 A coordinating earth station operating with a geostationary space station with respect to unknown earth stations operating with non-geostationary space stations

When the coordinating earth station operates with a space station in the geostationary orbit and the unknown earth stations operate with space stations in non-geostationary orbits, the propagation mode (1) coordination area is determined using the procedures described in § 2.1.1. The only modification needed is to use the horizon antenna gain, *Gr*, of the unknown receiving earth station in place of the terrestrial station gain, *Gx*. The appropriate values for this gain and the appropriate system parameters are contained in Table 9.

### 3.2.2 A coordinating earth station operating with non-geostationary space stations with respect to unknown earth stations operating with geostationary space stations

When the coordinating earth station operates to space stations in non-geostationary orbits and the unknown earth stations operate with space stations in the geostationary orbit, the horizon antenna gain, *Gr*, for the unknown receiving earth station is determined in accordance with the simplifying approximations of § 3.1.1, as elaborated in § 2.1 of Annex 5, and the parameters of Table 9. Determination of the propagation mode (1) coordination area then follows the procedure of § 2.2 by using the appropriate horizon gain of the receiving earth station at each azimuth under consideration and the appropriate system parameters from Table 9.

### 3.2.3 Coordinating and unknown earth stations operating with non-geostationary space stations

When the coordinating earth station operates with space stations in non-geostationary orbits and the unknown earth stations operate with space stations in non-geostationary orbits, the propagation mode (1) coordination area is determined using the procedure described in § 2.2. The only modification is to use the horizon antenna gain, *Gr*, of the unknown receiving earth station in place of the terrestrial station antenna gain. The appropriate values for this gain and the appropriate system parameters are given in Table 9.

# 4 General considerations for the determination of the propagation mode (1) required distance

For the determination of the propagation mode (1) required distances, the applicable frequency range has been divided into three parts. The propagation calculations for the VHF/UHF frequencies between 100 MHz and 790 MHz are based upon propagation mode (1) predicted path loss curves. From 790 MHz to 60 GHz the propagation modelling uses tropospheric scatter, ducting and layer reflection/refraction models. At higher frequencies up to 105 GHz, the model is based on a free-space loss and a conservative assumption for gaseous absorption. The possible range of time percentages is different in the different propagation models.

After taking site shielding (see § 1 of Annex 1) into consideration, for the coordinating earth station only, the following methods are used to determine the propagation mode (1) required distances:

– For frequencies between 100 MHz and 790 MHz, the method described in § 2 of Annex 1.

– For frequencies between 790 MHz and 60 GHz, the method described in § 3 of Annex 1.

– For frequencies between 60 GHz and 105 GHz, the method described in § 4 of Annex 1.

The three methods referred to above rely on a value of propagation mode (1) minimum required loss, determined according to the appropriate system parameters in Tables 7, 8 and 9.

## 4.1 Radio-climatic information

For the calculation of the propagation mode (1) required distance, the world has been classified in terms of a radio-meteorological parameter representing clear-air anomalous propagation conditions. The percentage of time β*e*for which these clear-air anomalous propagation conditions exist, is latitude dependent and is given by:

  

with:

  

where ζ is the latitude of the earth station’s location (degrees).

For frequencies between 790 MHz and 60 GHz, the path centre sea level surface refractivity, *N*0, is used in the propagation mode (1) calculations. This can be calculated using:

 (11)

## 4.2 Minimum coordination distance for propagation modes (1) and (2)

The minimum coordination distance can be calculated in two steps. First calculate distance *dx* using:

                    km (12)

where β*e* is given in § 4.1.

Then calculate the minimum coordination distance at any frequency, *f* (GHz) in the range 100 MHz to 105 GHz using:



The distance from which all iterative calculations start (for both propagation mode (1) and propagation mode (2)), is the minimum coordination distance, *dmin*, as given in equations (13) to (18).

## 4.3 Maximum coordination distance for propagation mode (1)

In the iterative calculation described in Annex 1, it is necessary to set an upper limit, *dmax*1, to the propagation mode (1) coordination distance.

For frequencies less than or equal to 60 GHz and propagation paths entirely within a single Zone, the distance shall not exceed the maximum coordination distance given in Table 3 for that Zone.

For mixed paths, the required distance can comprise one or more contributions from Zones A1, A2, B and C. The aggregate distance for any one zone must not exceed the value given in Table 3. The overall required distance must not exceed the value in Table 3 for the zone in the mixed path having the largest Table 3 value. Thus, a path comprising both Zones A1 and A2 must not exceed 500 km.

TABLE 3

Maximum coordination distances for propagation mode (1)   
for frequencies below 60 GHz

|  |  |
| --- | --- |
| Zone | *dmax*1  (km) |
| A1 | 500 |
| A2 | 375 |
| B | 900 |
| C | 1 200 |

For frequencies above 60 GHz, the maximum coordination distance, *dmax*1, is given by:

 (19)

where *p* is defined in § 1.3.

## 4.4 Guidance on application of propagation mode (1) procedures

As explained in § 1.3, for those cases where earth stations are sharing with terrestrial stations, it is appropriate to apply a correction factor, *Ci* (dB), to the worst‑case assumptions on system parameters and interference path geometry. This correction factor takes into account the fact that the assumption that all the worst-case values will occur simultaneously is unrealistic when determining the propagation mode (1) required distances.

The characteristics of terrestrial systems depend on the frequency band, and the value of the correction factor to be applied follows the frequency dependence given in equation (20). At frequencies between 100 MHz and 400 MHz, and between 60 GHz and 105 GHz, sharing between earth stations and terrestrial systems is a recent development and there is little established practical experience, or opportunity to analyse operational systems. Hence, the value of the correction factor is 0 dB in these bands. Between 400 MHz and 790 MHz and between 4.2 GHz and 60 GHz, the value of the correction factor is reduced in proportion to the logarithm of the frequency, as indicated in equation (20).

The value of the nominal correction to be used at any frequency *f* (GHz) is therefore given by:

 (20)

where:

*X*:15 dB for a transmitting earth station and 25 dB for a receiving earth station.

In principle, the value of the nominal correction factor, *X*(*f* ), is distance and path independent. However, there are a number of issues relating to interference potential at the shorter distances, and it is not appropriate to apply the full nominal correction at these distances. The correction factor *Ci* is therefore applied proportionally with distance along the azimuth under consideration, starting with 0 dB at *dmin*, such that the full value of *X*(*f* ) is achieved at a nominal distance of 375 km from the earth station.

Hence, the correction is applied using the correction constant *Z*(*f* ) (dB/km) where:

                    dB/km (21)

The correction factor *Ci* (dB) is calculated in equations (28b) and (52) from the correction constant *Z*(*f* ) (dB/km).

At distances greater than 375 km, the correction factor *Ci* to be applied is the value of *Ci* at 375 km distance.

In addition, the correction factor is applied to its highest value only on land paths. The correction factor is 0 dB for wholly sea paths. A proportion of the correction factor is applied on mixed paths. The amount of correction to be applied to a particular path is determined by the path description parameters used for the propagation mode (1) calculation (correction factors *Ci* and *C*2*i* in § 2 and § 3 respectively of Annex 1). As the correction factor is distance dependent, it is applied automatically within the iterative calculation used to determine the propagation mode (1) required distance (see Annex 1).

The correction factor does not apply to the bidirectional case and therefore in the determination of the bidirectional coordination contour:

                   dB/km

For the determination of propagation mode (1) auxiliary contours, the propagation mode (1) minimum required loss *Lb*(*p* ) for *p*% of time in equation (1) (see § 1.3) is replaced by:

*Lbq*(*p*) = *Lb*(*p*) + *Q*                   dB (22)

where:

*Q*: auxiliary contour value (dB).

Note that auxiliary contour values are assumed to be negative (i.e. −5, −10, −15, −20 dB, etc.).

# 5 General considerations for the determination of the propagation mode (2) required distance

The determination of the contour for scattering from hydrometeors (e.g. rain scatter) is predicted on a path geometry that is substantially different from that of the great-circle propagation mechanisms. Hydrometeor scatter can occur where the beams of the earth station and the terrestrial station intersect (partially or completely) at, or below, the rain height *hR*(see § 3 of Annex 2). It is assumed that at heights above this rain height the effect of scattering will be suppressed by additional attenuation, and it will not, therefore, contribute significantly to the interference potential. For the determination of the propagation mode (2) contour, it is assumed that the main beam of any terrestrial station exactly intersects the main beam of the coordinating earth station. The mitigating effects of partial beam intersections can be determined using propagation mode (2) auxiliary contours.

Since, to a first approximation, microwave energy is scattered isotropically by rain, interference can be considered to propagate equally at all azimuths around the common volume centred at the beam intersection (see § 1.3). Generally, the beam intersection will not lie on the great‑circle path between the two stations. A common volume can therefore result from terrestrial stations located anywhere around the earth station, including locations behind the earth station.

The propagation mode (2) contour is a circle with a radius equal to the propagation mode (2) required distance. Unlike the case for propagation mode (1), the propagation mode (2) contour is not centred on the earth station’s physical location, instead it is centred on a point on the earth’s surface immediately below the centre of the common volume.

A common volume can exist, with equal probability, at any point along the earth station beam between the earth station’s location and the point at which the beam reaches the rain height. To provide appropriate protection for/from terrestrial stations[[8]](#footnote-8)8, the centre of the common volume is assumed to be half way between the earth station and the point at which its beam intersects the rain height. The distance between the projection of this point on to the Earth's surface and the location of the earth station is known as Δ*d* (see § 4 of Annex 2). The centre of the propagation mode (2) contour is therefore Δ*d* (km) from the earth station on the azimuth of the earth station’s main beam axis.

## 5.1 The required distance for propagation mode (2)

Propagation mode (2) required distances are measured along a radial originating at the centre of the rain scatter common volume. The calculation requires iteration for distance, starting at the same minimum distance as that defined for propagation mode (1) until either the required propagation mode (2) minimum required loss, or a latitude-dependent propagation mode (2) maximum calculation distance, is achieved. The propagation mode (2) calculations use the method described in Annex 2. The calculations only need to be performed in the frequency range 1 000 MHz to 40.5 GHz. Outside this frequency range, rain scatter interference can be neglected and the propagation mode (2) required distance is set to the minimum coordination distance given by equations (13) to (18).

ANNEX 1

Determination of the required distance for propagation mode (1)

# 1 Adjustments for earth station horizon elevation angle and distance

For propagation mode (1), the required distance depends on the characteristics of the physical horizon around the earth station. The horizon is characterized by the horizon distance *dh* (see below), and the horizon elevation angle ε*h*. The horizon elevation angle is defined here as the angle (degrees), viewed from the centre of the earth station antenna, between the horizontal plane and a ray that grazes the physical horizon in the direction concerned. The value of ε*h* is positive when the physical horizon is above the horizontal plane and negative when it is below.

It is necessary to determine horizon elevation angles and distances for all azimuths around an earth station. In practice it will generally suffice to do this in azimuth increments of 5°. However, every attempt should be made to identify, and take into consideration, minimum horizon elevation angles that may occur between those azimuths examined in 5° increments.

For the purposes of the determination of the propagation mode (1) required distance it is useful to separate the propagation effects related to the local horizon around the earth station which, on some or all azimuths, may be determined by nearby hills or mountains, from the propagation effects on the remainder of the path. This is achieved by referencing the propagation model to a 0° horizon elevation angle for the coordinating earth station, and then to include a specific term *Ah* to deal with the known horizon characteristics of the earth station being coordinated. Where appropriate, *Ah* modifies the value of the path loss, on each azimuth, from which the propagation mode (1) required distance is derived.

There are two situations in which the level of attenuation for the propagation mode (1) path loss with respect to the reference 0° case can change:

– The first is where the coordinating earth station has a positive horizon elevation angle (on a particular azimuth). In this case, it will benefit from additional diffraction propagation losses over the horizon (generally referred to as site shielding). As a result, the attenuation *Ah* is positive and the value of the required path loss is reduced, with respect to the reference 0° horizon elevation angle case (see equations (27a) and (27b)).

– The second situation is where the coordinating earth station is at a location above the local foreground, and has a negative (downward) horizon elevation angle on a particular azimuth. In this case, a measure of additional protection is necessary because the path angular distance along the radial is reduced and hence the path loss for a given distance will be lower than for the zero degree elevation angle case. It is convenient to deal with this effect as part of the site shielding calculation. As a result, the attenuation *Ah* will be negative and the value of the required path loss is increased, with respect to the reference 0° horizon elevation angle case.

The contribution made by the attenuation arising from the coordinating earth station’s horizon characteristics to the propagation mode (1) minimum required loss modifies the value of path loss that then needs to be determined in the three propagation mode (1) models. The attenuation *Ah* is calculated for each azimuth around the coordinating earth station as follows.

The distance of the horizon, *dh*, from the earth station’s location, is determined by:

|  |
| --- |
|  |

The contribution made by the horizon distance, *dh*, to the total site shielding attenuation is given by *Ad* (dB) for each azimuth using:

                    dB (23)

where *f* is the frequency (GHz) throughout this Annex.

The total site shielding attenuation along each azimuth from the coordinating earth station is given by:

The value of *Ah* must be limited to satisfy the conditions:

−10 ≤ *Ah* ≤ (30 + ε*h*) (25)

In equations (23), (24) and (25) the value of ε*h* must always be expressed in degrees. The limits defined in equation (25) are specified because protection outside these limits may not be realized in practical situations.

# 2 Frequencies between 100 MHz and 790 MHz

The propagation model given in this section is limited toan average annual time percentage, *p*, in the range 1% to 50%.

An iterative process is used to determine the propagation mode (1) required distance. First, equation (27) is evaluated. Then, commencing at the minimum coordination distance, *dmin*, given by the method described in § 1.5.3 of the main body of this Appendix, equations (28) to (31) are iterated for distances *di* (where *i* = 0, 1, 2,...) incremented in steps of *s* (km) as described in § 1.3 of the main body of this Appendix. In each iteration, *di* is the distance considered. This process is continued until either of the following expressions becomes true:

 (26a)

or:

 (26b)

The required distance, *d*1, or the auxiliary contour distance, *dq*, are then given by the distance for the last iteration: i.e.

*d*1 = *di* (26c)

or:

*dq* = *di* (26d)

As the eventual mix of zones along a path is unknown, all paths are treated as if they are potential land and sea paths. Parallel calculations are undertaken, the first assuming the path is all land and a second assuming it is all sea. A non-linear interpolation is then performed, the output of which depends upon the current mix of land and sea losses in the distance, *di*. Where the current mix along the path includes sections of both warm sea and cold sea zones, all the sea along that path is assumed to be warm sea.

For the main or supplementary contour:

*L*1(*p* ) = *Lb*(*p* ) – *Ah* (27a)

For an auxiliary contour:

*L*1*q*(*p* ) = *Lbq*(*p* ) – *Ah* (27b)

where:

*Lb*(*p* ) (dB) and *Lbq*(*p* ) (dB): minimum required loss required for *p*% of the time for the main or supplementary contour and the auxiliary contour with value *Q* (dB), respectively (see equation (22)).

Iterative calculations

At the start of each iteration calculate the current distance for *i* = 0, 1, 2,…:

*di* = *dmin* + *i* · *s* (28a)

The correction factor, *Ci* (dB), (see § 4.4 of the main body of this Appendix) for the distance, *di*, is given by:

 (28b)

where *Z*(*f*) is given by equation (21) in § 4.4 of the main body of this Appendix.

At distances greater than 375 km, the value of the correction factor (*Ci* in equation (28b)) to be applied is the value of *Ci* at the 375 km distance.

The loss, *Lbl*(*p* ), where it is assumed that the path is wholly land (Zones A1 or A2), is evaluated successively using:

 (29)

The loss, *Lbs*(*p* ), where it is assumed that the path is wholly cold sea (Zone B) or warm sea (Zone C), is evaluated successively using:

|  |  |
| --- | --- |
|  | (30a)  (30b) |

The predicted path loss at the distance considered is then given by:

 (31)

where:

*dtm* (km): longest continuous land (inland + coastal) distance, i.e. Zone A1 + Zone A2 along the current path.

# 3 Frequencies between 790 MHz and 60 GHz

The propagation model given in this section is limited toan average annual time percentage (*p* ) in the range 0.001% to 50%.

An iterative process is used to determine the propagation mode (1) required distance. First, equations (33) to (42) are evaluated. Then, commencing at the minimum coordination distance, *dmin*, equations (43) to (53) are iterated for distances *di*, where *i* = 0, 1, 2, ..., incremented in steps of *s* (km) as described in § 1.3 of the main body of this Appendix. For each iteration, *di* is the distance considered. This process is continued until either of the following expressions becomes true:

 (32a)

or:

 (32b)

The required distance, *d*1, or the auxiliary contour distance, *dq*, is then given by the current distance for the last iteration, i.e.:

*d*1 =*di* (32c)

or:

*dq* =*di* (32d)

Specific attenuation due to gaseous absorption

Calculate the specific attenuation (dB/km) due to dry air:

The specific attenuation due to water vapour is given as a function of ρ (the water vapour density (g/m3)) by the following equation:

 (34)

Calculate the specific attenuation (dB/km) due to water vapour for the troposcatter propagation model using a water vapour density of 3.0 g/m3:

γ*wt* = γ*w* (3.0) (35a)

Calculate the specific attenuation (dB/km) due to water vapour for the ducting propagation model using a water vapour density of 7.5 g/m3 for paths over land, Zones A1 and A2, using:

γ*wdl* = γ*w* (7.5) (35b)

Calculate the specific attenuation (dB/km) due to water vapour for the ducting propagation model using a water vapour density of 10.0 g/m3 for paths over sea, Zones B and C, using:

γ*wds* = γ*w* (10.0) (35c)

Note that the value of 10 g/m3 is used for both Zones B and C in view of the lack of data on the variability of water vapour density on a global basis, particularly the minimum values.

Calculate the frequency-dependent ducting specific attenuation (dB/km):

 (36)

For the ducting model

Calculate the reduction in attenuation arising from direct coupling into over-sea ducts (dB):

 (37)

where *dc* (km) is the distance from a land based earth station to the coast in the direction being considered.

*dc* is zero in other circumstances.

Calculate the minimum loss to be achieved within the iterative calculations:

 (38)

For the main or supplementary contour:

 (39a)

For an auxiliary contour:

 (39b)

where:

*Lb*(*p* ) (dB) and *Lbq*(*p* ) (dB):   minimum required loss required for *p*% of the time for the main or supplementary contour and the auxiliary contour with value *Q* (dB) respectively (see equation (22)).

For the tropospheric scatter model

Calculate the frequency-dependent part of the losses (dB):

 (40)

Calculate the non-distance-dependent part of the losses (dB):

 (41)

where:

ε*h*: earth station horizon elevation angle (degrees)

*N*0: path centre sea level surface refractivity (see equation (11), § 4.1 in the main body of this Appendix).

Calculate the minimum required value for the distance dependent losses (dB):

For the main, or supplementary, contour:

 (42a)

For an auxiliary contour:

 (42b)

where:

*Lb*(*p* ) (dB) and *Lbq*(*p* ) (dB): minimum required loss required for *p*% of the time for the main or supplementary contour and the auxiliary contour of value *Q* (dB) respectively (see equation (22)).

Iterative calculations

At the start of each iteration, calculate the distance considered for *i* = 0, 1, 2,...:

 (43)

Calculate the specific attenuation due to gaseous absorption (dB/km):

 (44)

where:

*dt* (km): current aggregate land distance, Zone A1 + Zone A2, along the current path.

Calculate the following zone-dependent parameters:

 (45)

where:

*dlm* (km): longest continuous inland distance, Zone A2, along the path considered;

 (46)

where:

*dtm* (km): longest continuous land (i.e. inland + coastal) distance, Zone A1 + Zone A2 along the path considered.

μ1 shall be limited to μ1 ≤ 1.

 (47)

σ shall be limited to σ ≥ −3.4.

 (48)

μ2 shall be limited to μ2 ≤ 1.

where ζ*r* is given in equations (9) and (10), § 4.1 in the main body of this Appendix.

Calculate the path-dependent incidence of ducting, β, and a related parameter, Γ1 used to calculate the time dependency of the path loss:

 (50)

where β*e* is given in equations (7) and (8), § 4.1 in the main body of this Appendix.

 (51)

Calculate the correction factor, *C*2*i* (dB) (see § 4.4 in the main body of this Appendix) using:

 (52)

where *Z*(*f*) is calculated using equation (21) in § 4.4 in the main body of this Appendix.

At distances greater than 375 km the value of the correction factor *C*2*i* in equation (52) to be applied is the value of *C*2*i* at the 375 km distance.

Calculate the distance-dependent part of the losses (dB) for ducting:

 (53)

and for tropospheric scatter:

 (54)

For the determination of distances for auxiliary contours, *C*2*i =*0 dB.

# 4 Frequencies between 60 GHz and 105 GHz

This propagation model is valid for average annual percentage time (*p* ) in the range from 0.001% to 50%.

An iterative process is used to determine the propagation mode (1) required distance. First, equations (55) to (59) are evaluated. Then commencing at the minimum coordination distance, *dmin*, equations (60) and (61) are iterated for distances *di*, where *i* = 0, 1, 2,..., incremented in steps of *s* (km) as described in § 1.3 of the main body of this Appendix. For each iteration, *di* is the distance considered.

This process is continued until either of the following expressions becomes true:

 (54a)

or:

 (54b)

The required distance, *d*1, or the auxiliary contour distance *dq* are then given by the current distance for the last iteration: i.e.

*d*1 = *di* (54c)

or:

*dq* = *di* (54d)

Calculate the specific attenuation (dB/km) for dry air in the frequency range 60 GHz to 105 GHz using:

Calculate the specific attenuation (dB/km) for an atmospheric water vapour density of 3 g/m3 using:

 (56)

Calculate a conservative estimate of the specific attenuation (dB/km) for gaseous absorption using:

γ*gm* = γ*om* + γ*wm*                    dB/km (57)

For the required frequency and the value of earth station site shielding, *Ah* (dB), as calculated using the method described in § 1 of this Annex, calculate the minimum loss to be achieved in the iterative calculations:

*L*7(*p* )  = 92.5 + 20 log (*f*) + *Ah*                    dB (58)

For the main or supplementary contour:

*L*8(*p* ) = *Lb*(*p* ) – *L*7                                       dB (59a)

For an auxiliary contour:

                                 dB (59b)

where:

*Lb*(*p* ) (dB) and *Lbq*(*p* ) (dB):   minimum required loss required for *p*% of the time for the main or supplementary contour and the auxiliary contour of value *Q* (dB) respectively (see equation (22)).

Iterative calculations

At the start of each iteration calculate the distance for *i* = 0, 1, 2, ...:

 (60)

Calculate the distance-dependent losses for the distance:

 (61)

For frequencies above 60 GHz, the correction factor (see § 4.4 in the main body of this Appendix) is 0 dB. Therefore, no correction term has been added to equation (61).

ANNEX 2

Determination of the required distance for propagation mode (2)

# 1 Overview

The algorithm given below allows propagation mode (2) path loss, *Lr*(*p* ) (dB), to be obtained as a monotonic function of rainfall rate, *R*(*p* ) (mm/h), and with the hydrometeor scatter distance, *ri* (km), as a parameter. The model is valid for average annual time percentage (*p* ) in the range 0.001% to 10%. The procedure to determine the hydrometeor scatter contour is as follows:

a) The value of *R*(*p* ), is determined for the appropriate rain climatic Zones A to Q.

b) Values of *Lr*(*p* ), are then calculated for incremental values of *ri*, starting at the minimum coordination distance *dmin*, in steps of *s* (km), as described in § 1.3 of the main body of this Appendix. The correct value of *ri* is that for which the corresponding value of *Lr*(*p* ) equals or exceeds the propagation mode (2) minimum required loss *L*(*p* ). This value of *ri* is the propagation mode (2) required distance and is denoted *dr*.

c) If the iterative calculation results in *ri* equalling or exceeding the appropriate maximum calculation distance (*dmax*2) given in § 2, then the calculation is terminated and *dr* is assumed to be equal to *dmax*2. Hence the iteration stops when either of the following expressions becomes true:

*Lr*(*p* ) ≥ *L*(*p* ) (62a)

or:

*ri* ≥ *dmax*2 (62b)

d) The contour for propagation mode (2) is a circle of radius *dr* (km) centred on a point along the azimuth of the earth station antenna main beam at a horizontal distance of Δ*d* (km) from the earth station.

# 2 Maximum calculation distance

As discussed in § 1.5.3 of the main body of this Appendix, it is necessary to set upper limits to the maximum distance used in the iterative calculation of the required distance. The maximum calculation distance to be used for propagation mode (2) (*dmax*2) is latitude dependent and is given in the following equation:

                    km

where *hR* is defined in equations (74) and (75).

# 3 Calculation of the propagation mode (2) contour

Determine *R*(*p* ), the rainfall rate (mm/h) exceeded on average for *p*% of a year. The world has been divided into a number of rain climatic zones (see Figs. 2, 3 and 4) which show different precipitation characteristics.

ap7a2-02e





The curves shown in Fig. 5 represent consolidated rainfall-rate distributions, each applicable to several of these rain climatic zones.

Determine which rain climatic zone is applicable to the location of the earth station:

– For 0.001% < *p* < 0.3% and the applicable rain climatic zone:

Determine *R*(*p* ) either from Fig. 5 or from equations (63) to (67).

– For *p* ≥ 0.3%:

Use equation (68) with values of *R*(0.3%) and *pc* obtained from Table 4.



Rain climatic Zones A, B

 mm/h (63)

Rain climatic Zones C, D, E

 mm/h (64)

Rain climatic Zones F, G, H, J, K

 mm/h (65)

Rain climatic Zones L, M

 mm/h (66)

Rain climatic Zones N, P, Q

 mm/h (67)

TABLE 4

Values of *R* and *pc* for the different rain climatic zones

|  |  |  |
| --- | --- | --- |
| Rain climatic zone | *R* (0.3%)  (mm/h) | *pc* (%) |
| A, B | 1.5 | 2 |
| C, D, E | 3.5 | 3 |
| F, G, H, J, K | 7.0 | 5 |
| L, M | 9.0 | 7.5 |
| N, P, Q | 25.0 | 10 |
| where:  *pc* (%): reference time percentage above which the rainfall rate *R*(*p*) can be assumed to be zero. | | |

 (68)

Determine the specific attenuation (dB/km) due to rain using values of *k* and α from Table 5 in equation (70). Values of *k* and α at frequencies other than those in Table 5 can be obtained by interpolation using a logarithmic scale for frequency, a logarithmic scale for *k* and a linear scale for α.

TABLE 5

Values of *k* and α for vertical polarization as a function of the frequency

|  |  |  |
| --- | --- | --- |
| Frequency (GHz) | *k* | α |
| 1 | 0.0000352 | 0.880 |
| 4 | 0.000591 | 1.075 |
| 6 | 0.00155 | 1.265 |
| 8 | 0.00395 | 1.31 |
| 10 | 0.00887 | 1.264 |
| 12 | 0.0168 | 1.20 |
| 14 | 0.029 | 1.15 |
| 18 | 0.055 | 1.09 |
| 20 | 0.0691 | 1.065 |
| 22.4 | 0.090 | 1.05 |
| 25 | 0.113 | 1.03 |
| 28 | 0.150 | 1.01 |
| 30 | 0.167 | 1.00 |
| 35 | 0.233 | 0.963 |
| 40 | 0.310 | 0.929 |
| 40.5 | 0.318 | 0.926 |

Let:

*R* = *R*(*p* ) (69)

Then the specific attenuation (dB/km) due to rain is given by:

 (70)

Calculate the effective diameter of the rain cell:

 (71)

Then, calculate the effective scatter transfer function:

 (72)

Calculate the additional attenuation outside the common volume:

 (73)

Determine the rain height above ground, *hR* (km):

For North America and Europe west of 60° E longitude:

*hR* = 3.2 – 0.075 (ζ – 35)                    for  35 ≤ ζ ≤ 70 (74)

where:

ζ: latitude of the coordinating earth station.

For all other areas of the world:

 

Determine the specific attenuation due to water vapour absorption (a water vapour density of 7.5 g/m3 is used):

 (76)

## 3.1 Iterative calculations

Evaluate equations (77) to (82) inclusive for increasing values of *ri*, where *ri* is the current distance considered (km) between the region of maximum scattering and the possible location of a terrestrial station and *i* = 0, 1, 2,... Continue this process until either of the conditions given in equations (62a) and (62b) is true. Then the rain-scatter required distance *dr* is the current value of *ri*.

 (77)

Determine the loss above the rain height, *Lar* (dB), applicable to scatter coupling:

 

Calculate the additional attenuation for the departure from Rayleigh scattering:

 

Calculate the effective path length for oxygen absorption:

|  |  |
| --- | --- |
|  |  |

Calculate the effective path length for water vapour absorption:

|  |  |
| --- | --- |
|  |  |

Determine the propagation mode (2) path loss, *Lr* (dB):

 (82)

where:

γ*o*: as given in equation (33)

*Gx*: terrestrial network antenna gain in Tables 7 or 8.

# 4 Construction of the propagation mode (2) contour

In order to determine the centre of the circular propagation mode (2) contour, it is necessary to calculate the horizontal distance to this point from the earth station, along the azimuth of the earth station antenna main beam axis. The distance, Δ*d* (km), to the centre of the propagation mode (2) contour is given by:

 (83)

where:

ε*s*: earth station antenna main beam axis elevation angle

and

Δ*d*: shall be limited to the distance (*dr* – 50) km.

The propagation mode (2) required distance, *dr*, must lie within the range between the minimum coordination distance, *dmin*, and the propagation mode (2) maximum calculation distance, *dmax*2.

Draw the propagation mode (2) contour as a circle of radius *dr* (km) around the centre determined above. The propagation mode (2) contour is the locus of points on this circle. However, if any part of the propagation mode (2) contour falls within the contour defined by the minimum coordination distance, this arc of the propagation mode (2) contour is taken to be identical to the contour based on the minimum coordination distance and the propagation mode (2) contour is then no longer circular.

ANNEX 3

Antenna gain towards the horizon for an earth station  
operating with a geostationary space station

# 1 General

The gain component of the earth station antenna in the direction of the physical horizon around an earth station is a function of the angular separation between the antenna main beam axis and the horizon in the direction under consideration. When the earth station is used to transmit to a space station in a slightly inclined orbit, all possible pointing directions of the antenna main beam axis need to be considered. For earth station coordination, knowledge of φ(α), the minimum possible value of the angular separation that will occur during the operation of the space station, is required for each azimuth.

When a geostationary space station maintains its location close to its nominal orbital position, the earth station’s main beam axis elevation angle, ε*s*, and the azimuth angle, α*s*, to the space station from the earth station’s latitude, ζ, are uniquely related. Figure 6 shows the possible location arcs of positions of a space station on the geostationary orbit in a rectangular azimuth/elevation plot. It shows arcs corresponding to a set of earth station latitudes and the intersecting arcs correspond to points on the orbit with a fixed difference in longitude East or West of the earth station. Figure 6 also shows a portion of the horizon profile ε*h*(α). The off-axis angle φ(α) between the horizon profile at an azimuth of 190° and a space station located 28° W of an earth station at 43° N latitude is indicated by the great-circle arc shown dashed on Fig. 6.



When the north/south station-keeping of a geostationary satellite is relaxed, the orbit of the satellite becomes inclined, with an inclination that increases gradually with time. As viewed from the Earth, the position of the satellite traces a figure eight during each 24-hour period. Figure 7 shows the variations in the trajectories of a set of satellites, each with 10° inclination, spaced by 3° along the geostationary orbit from 28° W to 44° E, with respect to an earth station at 43° N latitude. Figure  7 also shows, with a dashed curve, the great-circle arc corresponding to the minimum off-axis angle φ(α) between a point on the trajectory of one of the satellites and the horizon profile at an azimuth of 110°.



For a transmitting earth station operating in a frequency band that is also allocated for bidirectional use by receiving earth stations operating with geostationary space stations, refer to § 2.1 of Annex 5.

# 2 Determination of the angular separation φ()

For the determination of the off-axis angle φ(α), two cases are distinguished. These depend on whether the orbit of the space station has no inclination, or is slightly inclined. The following equations may be used in both of these cases:

 (84)

 (85)

 (86)

 (87)

 (88)

 (89)

where:

ζ: latitude of the earth station (positive for north; negative for south)

δ: difference in longitude between the earth station and a space station

*i*: latitude of a sub-satellite point (positive for north; negative for south)

ψ*s*(*i*, δ): great-circle arc between the earth station and a sub-satellite point

α*s*(*i*, δ): space station azimuth as seen from the earth station

ε*s*(*i*, δ): space station elevation angle as seen from the earth station

φλα, *i*, δ): angle between the main beam and the horizon direction corresponding to the azimuth, α, under consideration when the main beam is steered towards a space station with a sub-satellite point at latitude, *i*, and longitude difference, δ

α: azimuth of the direction under consideration

ε*h*: elevation angle of the horizon at the azimuth under consideration, α

φ(α): angle to be used for horizon gain calculation at the azimuth under consideration, α

*K*: orbit radius/Earth radius, which for the geostationary orbit is assumed to be 6.62.

All arcs mentioned above are in degrees.

*Case 1:* Single space station, no orbital inclination

For a space station operating with no orbital inclination at an orbital position with difference in longitude δ0, equations (84) to (89) may be applied directly using *i* = 0 to determine φ(α) for each azimuth α. Thus:

φ() = φ, 0, 0) (90)

where:

δ0: difference in longitude between the earth station and the space station.

*Case 2:* Single space station, slightly inclined orbit

For a space station operating in a slightly inclined orbit on a portion of the geostationary arc with a nominal longitude difference of δ0, the maximum orbital inclination over its lifetime, *is*, must be considered. Equations (84) to (89) may be applied to develop the minimum off-axis angle to each of four arcs in azimuth/elevation that bound the trajectory of the space station in angle and elevation. The bounding arcs correspond to the maximum and minimum latitudes of the sub-satellite points and the extremes of the difference in longitude between the earth and space stations when the space station is operating at its maximum inclination.

The determination of the minimum off-axis angles in equations (91) to (95) may be made by taking increments along a bounding contour. The step size in inclination *i* or longitude δ should be between 0.5° and 1.0° and the end points of the respective ranges should be included in the calculation.

The horizon profile ε*h*(α) used in the determination of φ(α) is specified at increments in azimuth α that do not exceed 5°.

Thus:

 (91)

with:

 (92)

 (93)

 (94)

 (95)

 (96)

where:

*is*: maximum operational inclination angle of the satellite orbit

δ*s*: maximum longitude change from nominal value of the sub-satellite point of a satellite with orbital inclination *is*.

# 3 Determination of antenna gain

The relationship φ(α) is used to derive a function for the horizon antenna gain (dBi), *G*(φ) as a function of the azimuth , by using the actual earth station antenna pattern, or a formula giving a good approximation. For example, in cases where the ratio between the antenna diameter and the wavelength is equal to or greater than 35, the following equation is used:

 (97)



                    degrees



Where a better representation of the actual antenna pattern is available, it may be used.

In cases where *D*/ is not given, it may be estimated from the expression:



where:

*Gamax*: main beam axis antenna gain (dBi)

*D*: antenna diameter (m)

λ: wavelength (m)

*G*1: gain of the first side lobe (dBi).

ANNEX 4

Antenna gain toward the horizon for an earth station operating with  
non‑geostationary space stations

This Annex presents methods which may be used to determine the antenna gain towards the horizon for an earth station operating to non-geostationary satellites using the TIG method described in § 2.2 of the main body of this Appendix.

# 1 Determination of the horizon antenna gain

In its simplest implementation, the TIG method depends on the minimum elevation angle of the beam axis of the earth station antenna (ε*sys*), which is a system parameter that has the same value on all azimuths from the earth station. If the horizon elevation angle at an azimuth under consideration is ε*h* (degrees), the minimum separation angle from the horizon at this azimuth to any possible pointing angle for the main beam axis of the antenna (φ*min*) is equal to the difference between these two angles (ε*sys* − ε*h*), but it is not less than zero degrees. The maximum separation angle from the horizon at this azimuth to any possible pointing angle for the main beam axis of the antenna (φ*max*) is equal to the difference between the sum of these two angles and 180° (180 − ε*sys* − ε*h*). The maximum and minimum values of horizon gain for the azimuth under consideration are obtained from the gain pattern of the earth station antenna at these off-axis angles. Where no pattern is available the pattern of § 3 of Annex 3 may be used.

Additional constraints may be included in the determination of the maximum and minimum values of horizon antenna gain where an earth station operates with a constellation of non-geostationary satellites that are not in near-polar orbit. In this case, depending on the latitude of the earth station, there may be portions of the hemisphere above the horizontal plane at the earth station in which no satellite will appear. To include these visibility limitations within this method, it is first necessary to determine, for a closely spaced set of azimuth angles around the earth station, the minimum elevation angle at which a satellite may be visible. This minimum satellite visibility elevation angle (εν) may be determined from consideration of the visibility of the edge of the shell formed by all possible orbits having the orbital inclination and altitude of the satellites in the constellation.

The lowest elevation angle towards which the main-beam axis of the earth station antenna will point on any azimuth is the minimum composite elevation angle (ε*c*), which is equal to the greater of the minimum satellite visibility elevation angle (εν) and the minimum elevation angle of the earth station (ε*sys*). After the minimum composite elevation angle has been determined for all azimuths by the procedure of § 1.1 of this Annex, the resulting profile of the minimum composite elevation angles can be used, in the procedure of § 1.2 of this Annex, to determine the maximum and minimum values of horizon gain at any azimuth.

Further information and an example of this method may be found in the latest version of Recommendation ITU‑R SM.1448.

## 1.1 Determination of satellite visibility limits

The visibility limits of a constellation of satellites can be determined from the inclination angle of the most inclined satellite and the altitude of the lowest satellite in the constellation. For this determination, six cases may be distinguished, but not all of these may be applicable for a given constellation and a given earth station latitude. The azimuth and the corresponding lower limit on the elevation angle are developed by a parametric method using a set of points on the edge of the orbital shell of the constellation. The approach is to develop this relationship for azimuths to the east of a station in the northern hemisphere. Elevation angles for azimuths to the west of the station and for all azimuths for stations in the southern hemisphere are obtained by symmetry. The following equations, which are applicable to circular orbits only, may be used for the complete determination of the horizon antenna gain in all practical cases:

 (98)

 (99)

 (100)

with:

 (101)

where:

*is*: orbital inclination of the satellites in the constellation assumed to be positive and between 0° and 90°

ζ*e*: modulus of the latitude of the earth station

δ: difference in longitude from the earth station to a point on the edge of the orbital shell of the constellation

ψ(δ): great-circle arc between the earth station and a point on the surface of the Earth directly below the point on the edge of the orbital shell of the constellation

α(δ): azimuth from the earth station to a point on the edge of the orbital shell

α0(δ): principal azimuth, an azimuth between 0° and 180°, from an earth station to a point on the edge of the orbital shell

εν(δ): elevation angle from the earth station to a point on the edge of the orbital shell

*K*1: orbit radius/Earth radius for the lowest altitude satellite in the constellation (Earth radius = 6 378.14 km)

ψ*m* = arccos (1/*K*1).

All arcs mentioned above are in degrees.

For any latitude on the surface of the Earth, the azimuth for which the minimum elevation angle to a satellite can be greater than zero, and the corresponding elevation angles, may be determined by implementing the calculations under the following case(s). No more than two of these cases will be applicable for any latitude. For situations not specifically addressed in the following cases, no satellite is visible at elevation angles at or below 90° on any azimuth.

*Case 1:* For: ζ*e* ≤ *is* – ψ*m*

For this case, a satellite may be visible to the horizon for all azimuths about the earth station (εν = 0).

*Case 2:*For: *is* – ψ*m* < ζ*e* ≤ arcsin (sin *is* cos ψ*m*)

For this case, the azimuth angles and elevation are developed parametrically by choosing a set of values of δuniformly spaced on the interval 0 to δ1, and applying equations (98) to (101). For this purpose the spacing between values is not to exceed 1.0°, and the end points are to be included.



At any principal azimuth (α0(δ)) that is not included in the set, the minimum elevation angle is zero (εν = 0), except for azimuths where Case 6 additionally applies.

*Case 3:*For: arcsin (sin *is* cos ψ*m*) < ζ*e* < *is* and ζ*e* < 180° − ψ*m* − *is*

For this case, the azimuth angles and elevation are developed parametrically by choosing a set of values of δuniformly spaced on the interval 0 to δ2, and applying equations (98) to (101). For this purpose the spacing between values is not to exceed 1.0°, and the end points are to be included.



At any principal azimuth (α0(δ)) that is not included in the set, the minimum elevation angle is zero (εν = 0), except for azimuths where Case 6 additionally applies.

***Case 4:*** For: *is* ≤ ζ*e* < *is* + ψ*m* and ζ*e* < 180° – *is* – ψ*m*

For this case, the minimum elevation angle is given explicitly in terms of the principal azimuth angle α0, as follows:



where:



Note that a minimum elevation angle of 90° in this formulation indicates that no satellite is visible at elevation angles at or below 90° on these azimuths. Furthermore, within the range of principal azimuths where the minimum elevation angle is zero, Case 6 may additionally apply.

*Case 5:* For 180° – *is* – ψ*m* ≤ ζ*e* ≤ 90°

For this case, a satellite may be visible to the horizon for all azimuths about the earth station (εν = 0).

***Case 6:*** Forζ*e* < ψ*m* – *is*

This case may occur additionally with Case 2, Case 3 or Case 4 and a satellite may be visible only above a minimum elevation angle for other principal azimuths.

For this case, the other principal azimuths and the corresponding elevation angles are developed parametrically by choosing a set of values of δ, uniformly spaced on the interval 0 to δ3, and applying equations (98) to (101) with *is* replaced by −*is*. For this purpose the spacing between values is not to exceed 1.0° and the end points are to be included.



## 1.2 Determination of minimum and maximum horizon gain from the minimum visible elevation angle profile

The horizon gain of the earth station antenna is determined from the profile of values of the minimum composite elevation angle (ε*c*). At any azimuth, the minimum composite elevation angle is the greater of the minimum satellite visibility elevation angle at that azimuth (εν) and the minimum elevation angle for the earth station (ε*sys*). The following procedure may be used to determine the maximum and minimum values of horizon antenna gain for each azimuth under consideration.

The following equation may be used to determine the angular separation between the horizon profile, at an azimuth angle α and horizon elevation angle ε*h*, and a point on the profile of the minimum composite elevation angle, where the minimum composite elevation angle is ε*c* at an azimuth angle of α*c*:

 (102)

where:

α: azimuth of the direction under consideration

ε*h* (α): elevation angle of the horizon at the azimuth under consideration, α

ε*c* (α*c*): minimum composite elevation angle at the azimuth, α*c*

α*c*: azimuth corresponding to ε*c*.

The minimum value of the separation angle φ*min*, for the azimuth under consideration, is determined by finding the minimum value of φ(α, α*c*) for any azimuth α*c*, and the maximum value, φ*max*, is determined by finding the maximum value of φ(α, α*c*) for any azimuth α*c*. The azimuth angles (α) are usually taken in increments of 5°; however, to accurately determine the minimum separation angle, the values of the minimum composite elevation angle, ε*c*, need to be determined for a spacing of 1° or less in the azimuth α*c*. Where the procedures in § 1.1 of this Annex do not provide a profile of minimum composite elevation angle with a close enough spacing in azimuth angles, linear interpolation may be used to develop the necessary intermediate values. The maximum and minimum horizon antenna gains, *Gmax* and *Gmin*, to be used in the equations of § 2.2 of the main body of this Appendix for the azimuth under consideration are obtained by applying the off-axis angles, φ*min* and φ*max*, respectively, in the earth station antenna pattern. If the earth station antenna pattern is not known then the antenna pattern in § 3 of Annex 3 is used. In many cases, φ*max* will be large enough on all azimuths so that *Gmin* will be equal to the minimum gain of the antenna pattern at all azimuths.

ANNEX 5

Determination of the coordination area for a transmitting earth station   
with respect to receiving earth stations operating with   
geostationary space stations in bidirectionally   
allocated frequency bands

# 1 Introduction

The propagation mode (1) coordination area of a transmitting earth station with respect to unknown receiving earth stations operating with geostationary space stations requires the determination of the horizon gain of the antenna of the receiving earth station at each azimuth of the transmitting earth station. Different methods then need to be applied to determine the coordination area of the coordinating earth station, depending on whether it operates with geostationary or non‑geostationary space stations. When both the coordinating earth station and the unknown receiving earth stations operate with geostationary space stations, it is also necessary to determine a propagation mode (2) coordination contour.

The coordination area of a transmitting earth station, with respect to unknown receiving earth stations that operate to non-geostationary space stations, can be determined by minor modifications to the methods applicable to the determination of coordination area of transmitting earth stations with respect to terrestrial stations. (See § 3.2.1 and § 3.2.3 of the main body of the Appendix.)

# 2 Determination of the bidirectional coordination contour for propagation mode (1)

For a transmitting earth station operating in a frequency band that is also allocated for bidirectional use by receiving earth stations operating with geostationary space stations, further development of the procedures in Annex 3 is needed. It is necessary to determine the horizon gain of the unknown receiving earth station, the horizon gain to be used at each azimuth at the coordinating (transmitting) earth station, for the determination of the bidirectional coordination area.

## 2.1 Calculation of horizon gain for unknown receiving earth stations operating with geostationary space stations

The value of *Gr*, the horizon gain of the receiving earth station, for each azimuth, α, at the transmitting earth station is found by the following steps:

*Step 1*: The receiving earth station may be operating with any satellite in the geostationary orbit above a minimum elevation angle, ε*min*, contained in Table 9. The maximum difference in longitude (δ*b* (degrees)) between the receiving earth station and its associated space station occurs at this minimum elevation angle, ε*min*, and is given by:

 (103)

where:

ζ: latitude of the receiving earth station, which is assumed to be the same as the transmitting earth station

*K*: ratio of the radius of the satellite orbit to the radius of the Earth, equal to 6.62.

*Step 2*: For each azimuth, α, at the transmitting earth station:

– determine the azimuth α*r* from the receiving earth station to the transmitting earth station:





– for each azimuth α*r*, determine the minimum angular separation, ϕ(α*r*), between the receiving earth station main beam axis and the horizon at this azimuth using Case 1 in § 2 of Annex 3. For this evaluation, ϕ(α*r*) is the minimum value of ϕ(α*r*, 0, δ0), where the values of δ0 are between −δ*b* and +δ*b* in steps of 1° or less, making sure to include the end points.

The minimum angular separation, φ(α*r)*, may be used with the gain pattern in § 3 of Annex 3 to determine the horizon gain for this azimuth, α, unless a different gain pattern is referenced in Table 9.

Figure 8 shows plots of the minimum angular separation between the horizon at zero degrees elevation on an azimuth α*r* and a satellite on the geostationary orbit at an elevation above 3°. Plots are shown for a set of values of the station latitude, ζ, which is assumed to be the same for both transmitting and receiving earth stations. Figure 8 also provides a scale showing the corresponding azimuth, α, of the transmitting earth station.

Further information and an example may be found in the latest version of Recommendation ITU‑R SM.1448.



# 3 Determination of the bidirectional rain scatter contour

The procedure for the determination of the bidirectional rain scatter area, as described in § 3.1.2 of the main body of this Appendix, is as follows:

The horizontal distance *ds* (km) from the coordinating earth station to the point at which the main beam axis attains the rain height *hR* is calculated by:

                    km (104)

where the rain height, *hR*,can be determined from equations (74) or (75) in Annex 2 and ε*s* is the minimum elevation angle of the transmitting earth station.

The maximum calculation distance, *demax*, to be used in the determination of the propagation mode (2) contour, for the case of a coordinating earth station operating in bidirectionally allocated frequency bands, is dependent on the rain height. It is the greater distance determined from:

**                    km             or 

where the minimum coordination distance, *dmin*, is given in § 4.2 of the main body of this Appendix.

The point, at the distance *ds* from the earth station, on the azimuth α*s* of the coordinating earth station’s main beam axis, is the geographic point immediately below the main beam axis intersection with the rain height, and is the reference point from which the maximum calculation distance *demax* is determined (see Fig. 9).

If the maximum calculation distance, *demax*, is greater than the minimum coordination distance, *dmin*, then calculate the maximum latitude at which a receiving earth station may operate with a geostationary satellite with a minimum elevation angle ε*min*:

 (105)

where:

ε*min*: given in Table 9

*K*: ratio of the radius of the satellite orbit to the radius of the Earth, equal to 6.62.

If the coordinating earth station latitude in the northern hemisphere is greater than ζ*max*, or if the coordinating earth station latitude in the southern hemisphere is less than −ζ*max* or −71°, then the rain scatter contour is a circle of radius *dmin*, centred on the transmitting earth station.

For all other cases, the coordination area is developed by the following procedure:

*Step 1*: The unknown receiving earth station is assumed to be operating with a satellite at the minimum elevation angle ε*min*. It is also assumed that the receiving earth station is relatively close to the coordinating earth station in geometric terms and hence a plane geometry approximation can be applied within the coordination area. If the receiving earth station’s main beam axis passes through the intersection of the coordinating earth station’s main beam axis with the rain height, the azimuths from the point on the ground immediately below this intersection to the possible locations of a receiving earth station are given by:



and



where ζ is the latitude of the transmitting earth station.

*Step 2*: Mark on a map of an appropriate scale the coordinating earth station’s location and draw from this location a line of distance, *ds*, along the azimuth, α*s*, to the point below the coordinating earth station’s main beam axis intersection with the rain height.

*Step 3*: From the main beam axis intersection point in Step 2, mark on the map the distance, *demax*, along the two azimuths, α*w*2 and α*w*1, and on each azimuth at the distance, *demax*, draw two equal distance arcs of width 3° clockwise and counter-clockwise. The two arcs, each having a total width of 6°, are the first boundary elements of the bidirectional rain scatter area.

*Step 4*: Mark a circle of radius equal to the minimum coordination distance, *dmin*, around the coordinating earth station’s location, and then draw straight lines from the northern edges of the two arc segments tangential to the northern rim of the circle, and from the southern edges of the two arc segments tangential to the southern rim of the circle.

The area bounded by the two 6° wide arcs, the four straight lines, and the circular 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 9 illustrates the construction of the bidirectional rain scatter area for a coordinating earth station. (The resulting rain scatter area contains the possible loci of all receiving earth station locations from which a beam path towards the geostationary-satellite orbit will intersect the main beam of the transmitting earth station antenna.)



ANNEX 6

Supplementary and auxiliary contours

# 1 Introduction

The material found in this Annex is intended to assist administrations in bilateral discussions.

# 2 Supplementary contours

The coordination area is determined with respect to the type of terrestrial station (or, in a frequency band with a bidirectional space allocation, an earth station operating in the opposite direction of transmission) that would yield the largest coordination distances. Therefore, in the case of terrestrial services, fixed stations using tropospheric scatter have been assumed to be operating in frequency bands that may typically be used by such radiocommunication systems; and fixed stations operating in line-of-sight configurations and using analogue modulation have been assumed to be operating in other frequency bands. However, other radiocommunication systems (e.g. other terrestrial stations), that typically have lower antenna gains, or otherwise less stringent system parameters, than those on which the coordination area is based, may also operate in the same frequency range. Therefore, it is possible for the administration seeking coordination to identify a supplementary contour using either the methods in § 2 or 3 of the main body of this Appendix, where they are applicable, or other agreed methods. Subject to bilateral agreement between administrations, these supplementary contours can assume the role of the coordination contour for an alternative type of radio system in the same service or another radiocommunication service.

When a supplementary contour is to be developed for other types of systems, for example digital fixed systems, the necessary system parameters may be found in one of the adjacent columns in Tables 7, 8 and 9. If no suitable system parameters are available then the value of the permissible interference power (*Pr*(*p* )) may be calculated using equation (127) of § 2 in Annex 7.

In addition, supplementary contours may be prepared by the administration seeking coordination in order to define smaller areas, based on more detailed methods, for consideration when agreed bilaterally between the concerned administrations. These contours can be a useful aid for the rapid exclusion of terrestrial stations or earth stations from further consideration. For earth stations operating with non‑geostationary space stations, supplementary contours may be generated using the method in § 4 of this Annex.

Supplementary contours may comprise propagation mode (1) interference paths and, depending on the sharing scenario, propagation mode (2) interference paths. In addition, the propagation mode (1) element of a supplementary contour may, if appropriate for the radiocommunication service, utilize the same level of correction factor (see § 4.4 of the main body of this Appendix) that was applied in the determination of the coordination contour. However, all parts of each supplementary contour must fall on or between the contour defined by the minimum coordination distance and the corresponding propagation mode (1) or propagation mode (2) main contour.

# 3 Auxiliary contours

Practical experience has shown that, in many cases, the separation distance required for the coordinating earth station, on any azimuth, can in fact be substantially less than the coordination distance, since the worst-case assumptions do not apply to every terrestrial station or earth station. There are two main mechanisms that contribute to such a difference between the separation distance and the coordination distance:

– the terrestrial station antenna gain (or e.i.r.p.), or receiving earth station antenna gain, in the direction of the coordinating earth station is less than that assumed in calculating the coordination contour;

– appropriate allowance can be made, for example, for the effects of site shielding not included in the coordination distance calculations.

Auxiliary contours must use the same method as that used to determine the corresponding main or supplementary contour. In addition, all parts of each auxiliary contour must fall on or between the contour defined by the minimum coordination distance and the corresponding main or supplementary contour. Auxiliary contours may assist in eliminating from detailed coordination terrestrial stations or earth stations that are located in the coordination area and hence have been identified as potentially affected by the coordinating earth station. Any terrestrial station or earth station that lies outside an auxiliary contour and has an antenna gain towards the coordinating earth station that is less than the gain represented by the relevant auxiliary contour need not be considered further as a significant source, or subject, of interference.

## 3.1 Auxiliary contours for propagation mode (1)

Propagation mode (1) auxiliary contours are calculated with values for the propagation mode (1) minimum required loss in equation (22) in § 4.4 of the main body of this Appendix that are progressively reduced by, for example, 5, 10, 15, 20 dB, etc., below the value derived from the parameters assumed in Tables 7, 8 and 9 for the corresponding main or supplementary propagation mode (1) contour, until the minimum coordination distance is reached. Propagation mode (1) auxiliary contour distances are calculated without the correction factor (see § 4.4 of the main body of this Appendix), and hence could be larger, on any azimuth, than the corresponding main, or supplementary, propagation mode (1) distance. To prevent this, in those cases where a correction factor applies to the main or supplementary contour, the maximum propagation mode (1) auxiliary contour distance on any azimuth is limited to the corresponding main or supplementary propagation mode (1) distance. In effect this means that the correction factor will limit the possible range of auxiliary contour values so that only those auxiliary contours with values greater than the applied correction factor will be shown within the main or supplementary contour (see Fig. 10). For example, if the value of correction factor applicable to the propagation mode (1) main or supplementary contour is 10 dB, then the first auxiliary contour drawn would be for a reduction in minimum required loss of 5 dB and hence the auxiliary contour value would be −15 dB (by convention, auxiliary contours are shown as negative quantities as they represent a reduction in the terrestrial, or receiving earth station, antenna gain, or the terrestrial station e.i.r.p.).



Propagation mode (2) interference effects may still need to be considered even if propagation mode (1) interference effects have been eliminated from detailed coordination, as the propagation models are based on different interference mechanisms.

## 3.2 Auxiliary contours for propagation mode (2)

The propagation mode (2) contour around an earth station is calculated assuming the main beams of the coordinating earth station and the terrestrial station intersect exactly (see § 1.3 of the main body of this Appendix). However, it is unlikely that these antenna main beams will intersect exactly. It is therefore possible to generate propagation mode (2) auxiliary contours that take account of any offset in the pointing of the terrestrial station antenna beam from the direction of the coordinating earth station. This offset would result in partial beam intersections and hence a reduced interference potential. These propagation mode (2) auxiliary contours are calculated according to the method described in § 3.2.1 of this Annex.

Propagation mode (2) auxiliary contours are not generated for different values of antenna gain or e.i.r.p. but for different values of beam avoidance angle. Hence, if there is a need to consider both a lower value of antenna gain, or e.i.r.p., for the terrestrial station and propagation mode (2) auxiliary contours, it is first essential to consider the impact of the reduction in antenna gain, or e.i.r.p., on the propagation mode (2) contour. This is achieved by generating a supplementary contour (see § 2) corresponding to the lower value of antenna gain or e.i.r.p. for the terrestrial station, which is drawn on a separate map. Auxiliary mode (2) contours can then be generated inside this propagation mode (2) supplementary contour for different values of the beam avoidance angle. Hence, propagation mode (2) auxiliary contours may be most frequently applied in conjunction with a supplementary contour rather than with the coordination contour.

The correction factor discussed in § 1.3 of the main body of this Appendix does not apply to propagation mode (2) interference paths and hence is also not applicable to propagation mode (2) auxiliary contours. In addition propagation mode (2) auxiliary contours cannot be developed for the bidirectional case.

Propagation mode (2) auxiliary contours are prepared for appropriate values of terrestrial station main beam avoidance angle (see Fig. 11). When the antenna characteristics of the terrestrial stations are known, the appropriate antenna pattern[[9]](#footnote-9)9 should be used when determining the propagation mode (2) auxiliary contours. If this is not available, the reference antenna pattern given in § 3.2.3 may be used.



### 3.2.1 Determination of auxiliary contours for propagation mode (2)

Propagation mode (2) auxiliary contours allow the azimuthal offset of a terrestrial station antenna beam from the coordinating earth station’s location to be taken into consideration. Figure 12 shows the hydrometeor scatter region projected on to the horizontal plane. In this Figure, the earth station and the terrestrial station are located at the points A and B, respectively, where the terrestrial station is on a radial defined by the angle ω from the point C at the centre of the propagation mode (2) main, or supplementary, contour. Point C is also the centre of the auxiliary contour.



The shaded area in Fig. 12 represents the critical region, along the earth station’s main beam axis, between the earth station and the rain height. Within this critical region a common volume can be formed between the earth station beam and the beam of any terrestrial stations within the propagation mode (2) main, or supplementary, contour. This critical region’s length is *b* and its maximum horizontal extent is at point M. Intersection of this critical region by the terrestrial station main beam axis would result in significant hydrometeor scatter interference via main lobe-to-main lobe coupling.

For a given point within the propagation mode (2) main, or supplementary, contour, the angle subtended by the critical region is termed the critical angle, ψ. The protection angle, υ, represents the angle of the terrestrial station main beam axis away from the critical region. The beam avoidance angle between the terrestrial station’s main beam axis and the earth station’s location is φ. It is the sum of the two angles ψ and υ and it is this quantity that has a fixed value for a specific auxiliary contour. Each auxiliary contour is generated by varying the angle, ω, and deriving the distance, *rb*, from point C to the auxiliary contour. As the angle ω increases from 0° to 360°, the angles ψ and υ change, but their sum remains the same.

The algorithm in § 3.2.2 of this Annex can be used to calculate the auxiliary propagation mode (2) contour for a given value of beam avoidance angle ϕ.

The method is based on iteratively decrementing the distance, *rb*, between terrestrial station and the centre of the common volume, and starting at the main contour distance *dr*, until either the shortest value of *rb* is found for which the required minimum loss is achieved, or the minimum coordination distance is reached. For each value of *rb*, the critical angle ψ is determined and then the protection angle υ is calculated. The terrestrial station antenna gain corresponding to υ and the current distance *rb* are used to obtain the propagation mode (2) path loss in equation (82) in Annex 2.

The above process is repeated for each angle ω, to generate a complete auxiliary contour for a given value of beam avoidance angle ϕ. For some combinations of beam avoidance angle and angle ω, an auxiliary contour may coincide with the main, or supplementary, propagation mode (2) contour.

### 3.2.2 The step-by-step algorithm

Auxiliary propagation mode (2) contours are constructed by calculating distances along radials from the centre of the circular mode (2) main, or supplementary, contour, which is the point C, at the distance *b*/2 from the earth station along the azimuth of its main beam axis. The distance *b*/2 is equal to Δ*d*, where Δ*d* is given by equation (83) in Annex 2.

For the selected value of beam avoidance angle, ϕ, generate the auxiliary contour for values of angle, ω, ranging from 0° to 180° in steps of 1°, as follows:

a) Set *rb* to the main, or supplementary, mode (2) contour distance *dr* calculated as described in § 3.1 of Annex 2.

b) Compute ψ from:

 (106)

 (107)

 (108)

c) If ψ > ϕ then the auxiliary mode (2) contour coincides with the main or supplementary mode (2) contour for the current value of ω, and the calculation for that value of ω is completed, and go to step j). Otherwise proceed through the following steps d) to i) until one of the terminating conditions described in step f) and step i) is satisfied.

d) Decrement *rb* by subtracting 0.2 km from its value.

e) Recalculate the critical angle ψ using equations (106), (107) and (108).

f) If (0.5 *b* sin ω/sin ψ2) < *dmin*, the auxiliary mode (2) contour coincides with the minimum coordination distance *dmin* and the calculation for the current value of ω is completed – go to step j). Otherwise, proceed to step g).

g) Compute the protection angle υ = φ − ψ.

h) Calculate *G*(υ), the terrestrial station antenna gain at the angle υ relative to the beam axis, using the reference antenna pattern given in this Annex.

i) In equation (82) in Annex 2, use the gain calculated in step h) in place of *Gx* and the value considered of *rb* in place of *ri*, and calculate the corresponding propagation mode (2) path loss *Lr*. If *Lr* < *L*(*p* ), then increment *rb* by adding 0.2 km to its value and take this as the distance for the current radial. Otherwise, repeat from step d).

j) Once the value of *rb* has been found for the current value of angle ω, calculate the angle θ*d* from the location of the earth station, and if appropriate the distance, *d*, to that contour point using:

 (109)

 (110)

An auxiliary propagation mode (2) contour is symmetrical about the earth station main beam axis. Thus, values of *d* and θ*d* corresponding to the values of ω from 181° to 359° can be found by noting that results for a given value of ωare the same as for (−ω) or (360° − ω).

The step size for incrementing *rb* used above, 0.2 km, is suitable for most situations. It controls the granularity of the result when viewed as a set of *rb* values. For low values of earth station beam elevation, the granularity becomes more noticeable in the values of *d* and θ*d*, and a smaller step size may be used.

### 3.2.3 Reference radiation patterns for line-of-sight radio-relay system antennas

The reference radiation pattern for line-of-sight radio-relay system antennas in this section is used for the unknown terrestrial station antenna in the propagation mode (2) auxiliary contour calculations when the actual antenna pattern is not available.

a)In cases where the ratio between the antenna diameter and the wavelength is greater than 100, the following equation is used:

 for 0 <  φ  <  φ*m* (111)

 for φ*m* ≤  φ  <  φ*r* (112)

 for φ*r* ≤  φ  <  48° (113)

 for 48° ≤  φ  ≤  180° (114)

 (115)

 (116)

 (117)

b)In cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100, the following equation is used:

 for 0 < φ < φ*m* (118)

 for φ*m* ≤ φ < 100 (119)

 for 100  ≤ φ < 48° (120)

 for 48° ≤ φ ≤ 180° (121)

c)In cases where only the maximum antenna gain is known, *D*/λ can be estimated from the following expression:

 (122)

where:

*Gamax*: main beam axis antenna gain (dBi)

*D*: antenna diameter (m)

λ: wavelength (m)

*G*1: gain of the first side lobe (dBi).

# 4 Determination of a supplementary contour using the time-variant gain (TVG) method

The TVG method requires the cumulative distribution of the time-varying horizon antenna gain of an earth station operating with a non-geostationary space station. In comparison to the TIG method, the TVG method usually produces smaller distances, but requires greater effort in determining the cumulative distribution of the horizon gain of the earth station antenna for each azimuth to be considered.

The TVG method closely approximates the convolution of the distribution of the horizon gain of the earth station antenna and the propagation mode (1) path loss. This method may produce slightly smaller distances than those obtained by an ideal convolution. An ideal convolution cannot be implemented due to the limitations of the current model for propagation mode (1). The propagation mode (1) required distance, at the azimuth under consideration, is taken as the largest distance developed from a set of calculations, each of which is based on equation (4) of the main body of this Appendix. For convenience, in these calculations, this equation may be rewritten for the *n*-th calculation in the following form:

                    dB (123)

with the constraint:



where:

*Pt*, *Pr*(*p* ): as defined in equations in § 1.3 of the main body of this Appendix where *p*  is the percentage of time associated with permissible interference power *Pr*(*p* )

*Gx*: maximum antenna gain assumed for the terrestrial station (dBi). Tables 7 and 8 give values for *Gx* for the various frequency bands

*Ge*(*pn*): the horizon gain of the coordinating earth station antenna (dBi) that is exceeded for *pn*%of the time on the azimuth under consideration

*Lb*(*pv*): the propagation mode (1) minimum required loss (dB) for *pv*% of the time; this loss must be exceeded by the propagation mode (1) predicted path loss for all but *pv*% of the time.

The values of the percentages of time, *pn*, to be used in equation (123) are determined in the context of the cumulative distribution of the horizon antenna gain. This distribution needs to be developed for a predetermined set of values of horizon antenna gain spanning the range from the minimum to the maximum values for the azimuth under consideration. The notation *Ge*(*pn*) denotes the value of horizon antenna gain for which the complement of the cumulative distribution of the horizon antenna gain has the value corresponding to the percentage of time *pn*. The *pn* value is the percentage of time that the horizon antenna gain exceeds the *n*-th horizon antenna gain value. The procedure in § 4.1 may be used to develop this distribution.

For each value of *pn*, the value of horizon antenna gain for this time percentage, *Ge*(*pn*), is used in equation (123) to determine a propagation mode (1) minimum required loss. The propagation mode (1) predicted path loss is to exceed this propagation mode (1) required loss for no more than *pv*% of the time, as specified by the constraint associated with equation (123). A series of propagation mode (1) distances are then determined using the procedures described in § 4 of the main body of this Appendix.

The propagation mode (1) required distance is then the maximum distance in the series of propagation mode (1) distances that are obtained for any value of *pn*, subject to the constraint associated with equation (123). A detailed description of the method for using equation (123) to determine the propagation mode (1) required distance is provided in § 4.2.

Further information, including examples, may be found in the latest version of Recommendation ITU‑R SM.1448.

## 4.1 Determination of the horizon antenna gain distribution for the TVG method

The TVG method for the determination of an earth station’s supplementary contour requires the determination of the horizon antenna gain statistics for all azimuths (in suitable increments, e.g. 5°) around the earth station. In considering the horizon antenna gain of the antenna for either a transmitting or a receiving earth station, only the horizon antenna gain values during the operational time are to be considered. In developing the cumulative distributions of horizon antenna gain, the percentages of time are percentages of operational time. Thus, there may be periods of time for which no horizon antenna gain is specified.

The determination of the horizon antenna gain distribution requires both earth station and orbital information including whether or not station keeping is used to maintain a single orbital path (repeating/non-repeating ground track system). The cumulative distribution of the time-varying horizon gain of a transmitting or a receiving earth station antenna operating with non-geostationary space stations is calculated as follows:

*Step 1*: Simulate the constellation of non-geostationary space stations over a sufficiently long period, with a time step appropriate for orbit altitude, to obtain a valid representation of the antenna gain variations. For repeating ground track constellations, simulate the orbital path for each satellite visible from the earth station over a period of the ground track. For non-repeating ground track constellations, simulate the orbit of each satellite in the constellation over a period long enough to get a stable representation of the distribution.

*Step 2*: At each time step, determine the azimuth and elevation angle of each satellite that is both visible at the earth station and above the minimum elevation angle at which the earth station operates. In addition to the minimum elevation angle, other criteria could be used to avoid certain geometric configurations, e.g. geostationary orbit arc avoidance (no transmission between an earth station and a non-geostationary satellite that is within *X*° from the geostationary orbit arc).

*Step 3*: At each step, and for each satellite in communication with the earth station, 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.

*Step 4*: Choose a gain increment *g*(dB)and partition the gain range by a number of gain levels between *Gmin* and *Gmax*, i.e. *G* = {*Gmin*, *Gmin* + *g*, *Gmin* + 2*g*,..., *Gmax*}.

These gain levels determine a set of gain intervals so that the *n*-th gain interval (*n* = 1, 2, 3, …) includes gain values equal to, or greater than, *Gmin* + (*n* *–* 2)g and less than *Gmin* + (*n* *–* 1)*g*.

A value of *g* = 0.1 to 0.5 dB is recommended.

For each azimuth on the horizon around the earth station, accumulate the time that the horizon gain takes a value in each gain interval of width *g* (dB).

*Step 5*: The probability density function (pdf) on each azimuth is determined by dividing the time in each gain interval by the total simulation time.

*Step 6*: Determine the cumulative distribution function (cdf) of horizon antenna gain at each azimuth by accumulating the gain density function at that azimuth. The value of the required cdf at any specific gain value is the percentage of time that the gain is less than, or equal to, that gain value.

## 4.2 Determination of the supplementary contour distance using the TVG method

This calculation is based on a cumulative distribution of the horizon gain of the earth station antenna for each azimuth to be considered (in suitable angular increments e.g. 5°). Appropriate distributions for this purpose may be developed by the method in § 4.1. The process for calculating the supplementary contour distance for each azimuth is described in the following procedure.

*Step 1*: From the complementary cumulative distribution of the horizon antenna gain, for the azimuth under consideration, determine the percentage of time *pn* that the horizon gain exceeds the level *Gen*, where:

 (124)

with:

*Gmin*: minimum value of horizon gain, and

*g*: gain increment.

*Step 2*: For each percentage *pn* that is equal to or greater than 2*p*%, the percentage of time to be used in determining the propagation mode (1) path loss is *p*ν.

                  for  *pn*  ≥  2*p*% (125)

For each percentage of time, determine the distance, *dn* (km), for which the propagation mode (1) predicted path loss is equal to the propagation mode (1) minimum required loss, using the propagation model in accordance with § 4 of the main body of this Appendix and the equation:

                    dB (126)

The values of *p*ν must be within the range of percentage of time of the propagation mode (1) model (see § 1.5.1 of the main body of this Appendix).

*Step 3*: The propagation mode (1) required distance for the azimuth under consideration is the largest of the distances, *dn* (km), calculated in Step 2, except when this largest distance is attained for the smallest value of *pn* that is equal to or greater than 2*p* in accordance with equation (125) in Annex 6. In such cases, the propagation mode (1) required distance for the azimuth under consideration is the distance determined from equation (126) in Annex 6 with *Gen* = *Gmax* and *pv* = 50% where *Gmax* is the maximum value of horizon antenna gain.

*Step 4*: The propagation mode (1) supplementary contour distance for the azimuth under consideration is the required distance as determined in Step 3, except that the distance must be between the minimum coordination distance, *dmin*, and the maximum coordination distance, *dmax*1. These limits are given in § 4.2 and § 4.3 of the main body of this Appendix, respectively.

ANNEX 7

System parameters and predetermined coordination distances for determination of the coordination area around an earth station

# 1 Introduction

Tables 7 to 9 contain the system parameter values required by the methods in the main body of this Appendix to determine the coordination area around an earth station when the band is shared with terrestrial radiocommunication services or other earth stations operating in the opposite direction of transmission.

Table 7 is limited to those system parameter values required for the case of a transmitting earth station sharing with terrestrial services; Table 8 is limited to those parameter values required for the case of a receiving earth station sharing with terrestrial services; Table 9 is limited to those parameter values required for the case of a transmitting earth station which is sharing in a bidirectionally allocated band with other earth stations operating in the opposite direction of transmission.

These system parameter tables include primary allocations to the space and terrestrial services in Article **5** in all bands between 100 MHz and 105 GHz. Some of the columns have incomplete information. In some cases, this is because there is no requirement to calculate coordination distances as pre-determined coordination distances apply. In other cases, the service allocations are new and the systems may not be introduced for some years. Hence, the system parameters are the subject of ongoing development within the Radiocommunication Study Groups.

Parameters specific to the earth station, for which coordination is being sought, are provided to the Radiocommunication Bureau in the format specified in Appendix **4** as part of the notification and coordination procedures.

The row in each table entitled “method to be used” directs the user to the appropriate section of the main body of this Appendix which describes the methods to be followed for the determination of the coordination area.

Note that the earth station for which the coordination area is to be determined is identified by the service designation given in the first row of each table.

When a supplementary contour is to be developed, for example for digital fixed systems, the necessary system parameters may be found in one of the adjacent columns in Tables 7, 8 and 9. If no suitable system parameters are available, then the value of the permissible interference power (*Pr*(*p* )) may be calculated using equation (127) in § 2.

The predetermined coordination distances specified in Table 10 are used for transmitting and receiving earth stations, in cases defined by the corresponding frequency sharing situation.

# 2 Calculation of the permissible interference power of an interfering emission

Tables 7, 8 and 9 contain values for the parameters which are required for the calculation of the permissible interference power of the interfering emission (dBW), in the reference bandwidth, to be exceeded for no more than *p*% of the time at the receiving antenna terminal of a station subject to interference, from a single source of interference, using the general formula:

                     dBW (127)

where:

*k*: Boltzmann's constant (1.38 × 10−23 J/K)

*Te*: thermal noise temperature of the receiving system (K), at the terminal of the receiving antenna (see § 2.1 of this Annex)

*NL*: link noise contribution (see § 2.2 of this Annex)

*B*: reference bandwidth (Hz), i.e. the bandwidth in the receiving station that is subject to the interference and over which the power of the interfering emission can be averaged

*p*: percentage of the time during which the interference from one source may exceed the permissible interference power value; since the entries of interference are not likely to occur simultaneously, *p* = *p*0/*n*

*p*0: percentage of the 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 the time

*Ms*: link performance margin (dB) (see § 2.3 of this Annex)

*W*: a thermal noise equivalence factor (dB) for interfering emissions in the reference bandwidth; it is positive when the interfering emissions would cause more degradation than thermal noise (see § 2.4 of this Annex).

In certain cases, an administration may have reason to believe that, for its receiving earth station, a departure from the values associated with the earth station, as listed in Table 8, may be justified. Attention is drawn to the fact that for specific systems the bandwidths *B* or, for example in the case of demand assignment systems, the percentages of the time *p* and *p*0 may have to be changed from the values given in Table 8.

## 2.1 Calculation of the noise temperature of the receiving system

The noise temperature (K) of the receiving system, referred to the output terminals of the receiving antenna, may be determined (unless specifically given in Table 7) from:

                    K (128)

where:

*Ta*: noise temperature (K) contributed by the receiving antenna

*ℓt*1: numerical loss in the transmission line (e.g. a waveguide) between the antenna terminal and the receiver front end

*Tr*: noise temperature (K) of the receiver front end, including all successive stages at the front end input.

For radio-relay receivers and where the waveguide loss of a receiving earth station is not known, a value of *ℓt*1 = 1.0 is used.

In case of determination of the coordination contours between two earth stations operating in the opposite direction of transmission, the following earth station receiving system noise temperatures should be used if the value is not provided in Table 9. This assumption is necessary because the receiving earth station takes the place of a receiving terrestrial station in the calculations.

TABLE 6

|  |  |
| --- | --- |
| Frequency range  (GHz) | *Te*  (K) |
| *f* < 10 | 75 |
| 10 < *f* < 17 | 150 |
| *f* > 17 | 300 |

## 2.2 Determination of the factor *NL*

The factor *N****L*** is the noise contribution to the link. In the case of a satellite transponder, it includes the uplink noise, intermodulation, etc. In the absence of table entries, it is assumed:

*NL* = 1 dB for fixed‑satellite links

   = 0 dB for terrestrial links

## 2.3 Determination of the factor *Ms*

The factor *Ms* is the factor by which the link noise under clear-sky conditions would have to be raised in order to equal the permissible interference power.

## 2.4 Determination of the factor *W*

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 bit error ratio). The factor *W* generally depends on the characteristics of both the wanted and the interfering signals.

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 Horizon antenna gain for a receiving earth station with respect to a transmitting earth station

For the determination of the coordination area of a transmitting earth station with respect to a receiving earth station in a bidirectionally allocated band, it is necessary to calculate the horizon antenna gain of the unknown earth station. In cases where the unknown receiving earth stations operate with geostationary satellites, Table 9 provides the necessary receiving earth station parameters for the calculation procedure, which is described in § 2.1 of Annex 5.

In the case where the unknown receiving earth station operates with non-geostationary satellites, the horizon antenna gain to be used for all azimuths is provided in Table 9. The tabulated values were determined by using the method described in § 2.2 of the main body of this Appendix, which uses the maximum and minimum values of horizon antenna gain. For this purpose the maximum horizon antenna gain is the gain of the antenna for an off-axis angle equal to the minimum operating elevation angle. The minimum horizon antenna gain is the gain at large off-axis angles, usually more than 36° or 48°.

In determining the TIG horizon antenna gain entries in Table 9, the difference between the maximum and minimum horizon antenna gain did not exceed 30 dB. Consequently, the TIG horizon antenna gain was taken as the lesser of the maximum horizon antenna gain or 20 dB more than the minimum horizon antenna gain. For the purpose of determining the TIG horizon antenna gain, the reference antenna pattern of § 3 of Annex 3 was used, except in cases noted in the Tables where a different pattern was deemed to be more appropriate.

TABLE 7a     (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a transmitting earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Transmitting space radiocommunication  service designation | | Mobile-satellite, space operation | Earth  exploration-satellite, meteorological  satellite | | Space  operation | Space research, space  operation | Mobile- satellite | Space operation | | Mobile- satellite, radio- determination- satellite | Mobile- satellite | | Space operation, space  research | | Mobile- satellite | | Space research, space  operation, Earth exploration-satellite | |
| Frequency bands (MHz) | | 148.0-149.9 | 401-403 | | 433.75-434.25 | 449.75-450.25 | 806-840 | 1 427-1 429 | | 1 610-1 626.5 | 1 668.4-1 675 | | 1 750-1 850 | | 1 980-2 025 | | 2 025-2 110 2 110-2 120 (Deep space) | |
| Receiving terrestrial  service designations | | Fixed, mobile | Meteorological aids | | Amateur, radiolocation fixed, mobile | Fixed, mobile, radio- location | Fixed, mobile broadcasting, aeronautical radionavigation | Fixed, mobile | | Aeronautical radionavigation | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | |
| Method to be used | | § 2.1, § 2.2 | § 2.1, § 2.2 | | § 2.1, § 2.2 | § 2.1, § 2.2 | § 1.4.6 | § 2.1, § 2.2 | | § 1.4.6 | § 1.4.6 | | § 2.1, § 2.2 | | § 1.4.6 | | § 2.1, § 2.2 | |
| Modulation at terrestrial station 1 | | A | A | N |  | A and N | A and N | A | N |  | A | N | A | N | A | N | A | |
| Terrestrial station interference parameters and criteria | *p*0 (%) | 1.0 |  |  |  | 0.01 | 0.01 | 0.01 | 0.01 |  | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |  | 0.01 | |
| *N* | 1 |  |  |  | 2 | 2 | 2 | 2 |  | 2 | 2 | 2 | 2 | 2 |  | 2 | |
| *p* (%) | 1.0 |  |  |  | 0.005 | 0.005 | 0.005 | 0.005 |  | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |  | 0.005 | |
| *NL* (dB) | – |  |  |  | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |  | 0 | |
| *Ms* (dB) | – |  |  |  | 20 | 20 | 33 | 33 |  | 33 | 33 | 33 | 33 | 26 2 |  | 26 2 | |
| *W* (dB) | – |  |  |  | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 |  | 0 | |
| Terrestrial station parameters | *Gx* (dBi) 3 | 8 |  |  |  | 16 | 16 | 33 | 33 |  | 35 | 35 | 35 | 35 | 49 2 |  | 49 2 | |
| *Te* (K) | – |  |  |  | 750 | 750 | 750 | 750 |  | 750 | 750 | 750 | 750 | 500 2 |  | 500 2 | |
| Reference bandwidth | *B* (Hz) | 4 × 103 |  |  |  | 12.5 × 103 | 12.5 × 103 | 4 × 103 | 106 |  | 4 × 103 | 106 | 4 × 103 | 106 | 4 × 103 |  | 4 × 103 | |
| Permissible interference power | *Pr*(*p*) (dBW) in *B* | −153 |  |  |  | −139 | −139 | −131 | −107 |  | −131 | −107 | −131 | −107 | −140 |  | −140 | |
| 1 A: analogue modulation; N: digital modulation.  2 The parameters for the terrestrial station associated with transhorizon systems have been used. Line-of-sight radio-relay parameters associated with the frequency band 1 668.4-1 675 MHz may also be used to determine a supplementary contour.     (WRC‑03)  3 Feeder losses are not included. | | | | | | | | | | | | | | | | | |

TABLE 7b    (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a transmitting earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Transmitting space radiocommunication  service designation | | Fixed-satellite, mobile-satellite | Aero-nautical mobile-satellite (R) service | Aero-nautical mobile-satellite (R) service | Fixed- satellite | Fixed- satellite | Fixed- satellite | Fixed- satellite | | Space  operation, space  research | | Fixed-satellite, mobile-satellite, meteorological- satellite | | Fixed- satellite | | Fixed- satellite | | Fixed- satellite | Fixed- satellite 3 | Fixed- satellite | Fixed- satellite 3 |
| Frequency bands (GHz) | | 2.655-2.690 | 5.030-5.091 | 5.030-5.091 | 5.091-5.150 | 5.091-5.150 | 5.725-5.850 | 5.725-7.075 | | 7.100-7.235 5 | | 7.900-8.400 | | 10.7-11.7 | | 12.5-14.8 | | 13.75-14.3 | 15.43-15.65 | 17.7-18.4 | 19.3-19.7 |
| Receiving terrestrial service designations | | Fixed, mobile | Aeronautical radio- navigation | Aeronautical mobile (R) | Aeronautical radio- navigation | Aeronautical mobile (R) | Radiolocation | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | | Radiolocation radionavigation (land only) | Aeronautical radionavigation | Fixed, mobile | Fixed, mobile |
| Method to be used | | § 2.1 | § 2.1, § 2.2 | § 2.1, § 2.2 |  |  | § 2.1 | § 2.1 | | § 2.1, § 2.2 | | § 2.1 | | § 2.1 | | § 2.1, § 2.2 | | § 2.1 |  | § 2.1, § 2.2 | § 2.2 |
| Modulation at terrestrial station 1 | | A |  |  |  |  |  | A | N | A | N | A | N | A | N | A | N | − |  | N | N |
| Terrestrial station interference parameters and criteria | *p0* (%) | 0.01 |  |  |  |  |  | 0.01 | 0.005 | 0.01 | 0.005 | 0.01 | 0.005 | 0.01 | 0.005 | 0.01 | 0.005 | 0.01 |  | 0.005 | 0.005 |
| *n* | 2 |  |  |  |  |  | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |  | 2 | 2 |
| *p* (%) | 0.005 |  |  |  |  |  | 0.005 | 0.0025 | 0.005 | 0.0025 | 0.005 | 0.0025 | 0.005 | 0.0025 | 0.005 | 0.0025 | 0.01 |  | 0.0025 | 0.0025 |
| *NL* (dB) | 0 |  |  |  |  |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 |
| *Ms* (dB) | 26 2 |  |  |  |  |  | 33 | 37 | 33 | 37 | 33 | 37 | 33 | 40 | 33 | 40 | 1 |  | 25 | 25 |
| *W* (dB) | 0 |  |  |  |  |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 |
| Terrestrial station parameters | *Gx* (dBi) 4 | 49 2 | 6 | 10 | 6 | 6 |  | 46 | 46 | 46 | 46 | 46 | 46 | 50 | 50 | 52 | 52 | 36 |  | 48 | 48 |
| *Te* (K) | 500 2 |  |  |  |  |  | 750 | 750 | 750 | 750 | 750 | 750 | 1 500 | 1 100 | 1 500 | 1 100 | 2 636 |  | 1 100 | 1 100 |
| Reference bandwidth | *B* (Hz) | 4 × 103 | 150 × 103 | 37.5 × 103 | 150 × 103 | 106 |  | 4 × 103 | 106 | 4 × 103 | 106 | 4 × 103 | 106 | 4 × 103 | 106 | 4 × 103 | 106 | 107 |  | 106 | 106 |
| Permissible interference power | *Pr*( *p*) (dBW) in *B* | −140 | −160 | −157 | −160 | −143 |  | −131 | −103 | −131 | −103 | −131 | −103 | −128 | −98 | −128 | −98 | −131 |  | −113 | −113 |

1 A: analogue modulation; N: digital modulation.

2 The parameters for the terrestrial station associated with transhorizon systems have been used. Line-of-sight radio-relay parameters associated with the frequency band 5 725‑7 075 MHz may also be used to determine a supplementary contour with the exception that *Gx* = 37 dBi.

3 Feeder links of non-geostationary-satellite systems in the mobile‑satellite service.

4 Feeder losses are not included.

5 Actual frequency bands are 7 100-7 155 MHz and 7 190-7 235 MHz for space operation service and 7 145-7 235 MHz for the space research service.

TABLE 7c    (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a transmitting earth station

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Transmitting space radiocommunication service designation | | Fixed- satellite | Fixed- satellite 2 | Fixed- satellite 3 | Space  research | Earth  exploration-satellite, space research | Fixed-satellite, mobile-satellite, radionavigation-satellite | Fixed- satellite 2 | |
| Frequency bands (GHz) | | 24.65-25.25 27.0-29.5 | 28.6-29.1 | 29.1-29.5 | 34.2-34.7 | 40.0-40.5 | 42.5-47 47.2-50.2 50.4-51.4 | 47.2-50.2 | |
| Receiving terrestrial  service designations | | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile, radiolocation | Fixed, mobile | Fixed, mobile, radionavigation | Fixed, mobile | |
| Method to be used | | § 2.1 | § 2.2 | § 2.2 |  | § 2.1, § 2.2 | § 2.1, § 2.2 | § 2.2 | |
| Modulation at terrestrial station 1 | | N | N | N |  | N | N | N | |
| Terrestrial station interference parameters and criteria | *p*0 (%) | 0.005 | 0.005 | 0.005 |  | 0.005 | 0.005 | 0.001 | |
| *n* | 1 | 2 | 1 |  | 1 | 1 | 1 | |
| *p* (%) | 0.005 | 0.0025 | 0.005 |  | 0.005 | 0.005 | 0.001 | |
| *NL* (dB) | 0 | 0 | 0 |  | 0 | 0 | 0 | |
| *Ms* (dB) | 25 | 25 | 25 |  | 25 | 25 | 25 | |
| *W* (dB) | 0 | 0 | 0 |  | 0 | 0 | 0 | |
| Terrestrial station parameters | *Gx* (dBi) 4 | 50 | 50 | 50 |  | 42 | 42 | 46 | |
| *Te* (K) | 2 000 | 2 000 | 2 000 |  | 2 600 | 2 600 | 2 000 | |
| Reference bandwidth | *B* (Hz) | 106 | 106 | 106 |  | 106 | 106 | 106 | |
| Permissible interference power | *Pr*( *p*) (dBW) in *B* | −111 | −111 | −111 |  | −110 | −110 | −111 | |
| 1 A: analogue modulation; N: digital modulation.  2 Non-geostationary satellites in the fixed-satellite service.  3 Feeder links to non-geostationary-satellite systems in the mobile-satellite service.  4 Feeder losses are not included. | | | | | | | | |

TABLE 8a     (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a receiving earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Receiving space radiocommunication service designation | | | Space operation, space research | Meteorological- satellite, mobile-satellite | | Space research | Space research, space operation | Space operation | Mobile-satellite | Meteorological-satellite | Mobile-satellite | Space research | Space operation | Meteorological- satellite | Broadcasting- satellite | Mobile-satellite | Broadcasting- satellite (DAB) | Mobile-satellite, land-mobile satellite, maritime mobile-satellite |
| Frequency bands (MHz) | | | 137-138 | 137-138 | | 143.6-143.65 | 174-184 | 163-167 272-273 5 | 335.4-399.9 | 400.15-401 | 400.15-401 | 400.15-401 | 401-402 | 460-470 | 620-790 | 856-890 | 1 452-1492 | 1 518-1 530 1 555-1 559 2 160-2 200 1 |
| Transmitting terrestrial  service designations | | | Fixed, mobile | Fixed, mobile | | Fixed, mobile, radio-location | Fixed, mobile, broadcasting | Fixed, mobile | Fixed, mobile | Meteorological aids | Meteorological aids | Meteorological aids | Meteorological aids, fixed, mobile | Fixed, mobile | Fixed, mobile, broadcasting | Fixed, mobile, broad casting | Fixed, mobile, broadcasting | Fixed, mobile |
| Method to be used | | | § 2.1 | § 2.1 | | § 2.1 | § 2.1 | § 2.1 | § 1.4.6 | § 1.4.6 | § 1.4.6 | – | § 2.1 | § 2.1 | § 1.4.5 | § 1.4.6 | § 1.4.5 | § 1.4.6 |
| Modulation at earth station 2 | | | N |  | | N |  | N |  |  |  | N | N |  |  |  | N | N |
| Earth station interference parameters and criteria | *p*0 (%) |  | 0.1 | |  | 0.1 |  | 1.0 |  | 0.012 |  | 0.1 | 0.1 | 0.012 |  |  |  | 10 |
| *n* |  | 2 | |  | 2 |  | 1 |  | 1 |  | 2 | 2 | 1 |  |  |  | 1 |
| *p* (%) |  | 0.05 | |  | 0.05 |  | 1.0 |  | 0.012 |  | 0.05 | 0.05 | 0.012 |  |  |  | 10 |
| *NL* (dB) |  | 0 | |  | 0 |  | 0 |  | 0 |  | 0 | 0 |  |  |  |  | 0 |
| *Ms* (dB) |  | 1 | |  | 1 |  | 1 |  | 4.3 |  | 1 | 1 |  |  |  |  | 1 |
| *W* (dB) |  | 0 | |  | 0 |  | 0 |  | 0 |  | 0 | 0 |  |  |  |  | 0 |
| Terrestrial station parameters | *E* (dBW) in *B* 3 | A | – | |  | – |  | 15 |  |  |  | – | – | 5 |  |  | 38 | 37 4 |
| N | – | |  | – |  | 15 |  |  |  | – | – | 5 |  |  | 38 | 37 |
| *Pt* (dBW)  in *B* | A | – | |  | – |  | –1 |  |  |  | – | – | –11 |  |  | 3 | 0 |
| N | – | |  | – |  | –1 |  |  |  | – | – | –11 |  |  | 3 | 0 |
| *Gx* (dBi) |  | – | |  | – |  | 16 |  |  |  | – | – | 16 |  |  | 35 | 37 |
| Reference bandwidth | *B* (Hz) |  | 1 | |  | 1 |  | 103 |  | 177.5 × 103 |  | 1 | 1 | 85 |  |  | 25 × 103 | 4 × 103 |
| Permissible interference power | *Pr*( *p*) (dBW) in *B* |  | −199 | |  | −199 |  | −173 |  | −148 |  | −208 | −208 | −178 |  |  |  | −176 |
| 1 In the band 2 160-2 200 MHz, the terrestrial station parameters of line-of-sight radio-relay systems have been used. If an administration believes that, in this band transhorizon systems need to be considered, the parameters associated with the frequency band 2 500-2 690 MHz may be used to determine the coordination area.  2 A: analogue modulation; N: digital modulation.  3 *E* is defined as the equivalent isotropically radiated power of the interfering terrestrial station in the reference bandwidth.  4 This value is reduced from the nominal value of 50 dBW for the purposes of determination of coordination area, recognizing the low probability of high power emissions falling fully within the relatively narrow bandwidth of the earth station.  5 The fixed-service parameters provided in the column for 163-167 MHz and 272-273 MHz are only applicable to the band 163-167 MHz. | | | | | | | | | | | | | | | | | | | |

TABLE 8b    (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a receiving earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Receiving space radiocommunication service designation | | | | Space operation (GSO and non-GSO) | Meteorological- satellite (non-GSO) | Meteorological- satellite (GSO) | Space research near-Earth (non-GSO and  GSO) | | Space research deep space (non-GSO) | Space operation (non-GSO and GSO) | Earth exploration- satellite (GSO) | Broadcasting- satellite | Mobile-satellite, radio- determination- satellite | Fixed-satellite, broadcasting satellite | | Fixed-satellite | |
|  | | | |  |  |  | Unmanned | Manned |  |  |  |  |  |  | |  | |
| Frequency bands (GHz) | | | | 1.525-1.535 | 1.670-1.710 | 1.670-1.710 | 1.700-1.710 2.200-2.290 | | 2.290-2.300 | 2.200-2.290 | 2.200-2.290 | 2.310-2.360 | 2.4835-2.500 6 | 2.500-2.690 | | 3.400-4.200 | |
| Transmitting terrestrial  service designations | | | | Fixed | Fixed, mobile, meteorological aids | Fixed, mobile, meteorological  aids | Fixed, mobile | | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile, radiolocation | Fixed, mobile, radiolocation | Fixed, mobile radiolocation | | Fixed, mobile | |
| Method to be used | | | | § 2.1, § 2.2 | § 2.2 and 1 | § 2.1 and 1 | § 2.1, § 2.2 | | § 2.2 | § 2.1, § 2.2 | § 2.1 | § 1.4.5 | § 1.4.6 | § 1.4.5 and § 2.1 | | § 2.1 | |
| Modulation at earth station 2 | | | | N | N | N | N | | N | N | N |  | N | A | N | A | N |
| Earth station interference parameters and criteria | | *p*0 (%) | | 1.0 | 0.006 | 0.011 | 0.1 | 0.001 | 0.001 | 1.0 | 1.0 |  | 10 | 0.03 | 0.003 | 0.03 | 0.005 |
| *n* | | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 2 |  | 1 | 3 | 3 | 3 | 3 |
| *p* (%) | | 1.0 | 0.002 | 0.0055 | 0.05 | 0.001 | 0.001 | 0.5 | 0.5 |  | 10 | 0.01 | 0.001 | 0.01 | 0.0017 |
| *NL* (dB) | | 0 | 0 | 0 | 0 | | 0 | 0 |  |  | 0 | 1 | 1 | 1 | 1 |
| *Ms* (dB) | | 1 | 2.8 | 0.9 | 1 | | 0.5 | 1 |  |  | 1 | 7 | 2 | 7 | 2 |
| *W* (dB) | | 0 | 0 | 0 | 0 | | 0 | 0 |  |  | 0 | 4 | 0 | 4 | 0 |
| Terrestrial station parameters | | *E* (dBW) in *B* 3 | A | 50 | 92 4 | 92 4 | −27 4, 5 | | −27 5 | 72 | 72 4 |  | 37 | 72 4 | 72 4 | 55 | 55 |
| N | 37 | – | – | –27 | | −27 | 76 | 76 |  | 37 | 76 | 76 | 42 | 42 |
| *Pt* (dBW)  in *B* | A | 13 | 40 4 | 40 4 | −71 4, 5 | | −71 5 | 28 | 28 4 |  | 0 | 28 4 | 28 4 | 13 | 13 |
| N | 0 | – | – | −71 | | −71 | 32 | 32 |  | 0 | 32 | 32 | 0 | 0 |
| *Gx* (dBi) | | 37 | 52 | 52 | 44 | | 44 | 44 | 44 |  | 37 | 44 | 44 | 42 | 42 |
| Reference bandwidth | | *B* (Hz) | | 103 | 106 | 4 × 103 | 1 | | 1 | 106 | 106 |  | 4 × 103 | 106 | 106 | 106 | 106 |
| Permissible interference power | | *Pr*( *p*) (dBW) in *B* | | −184 | −142 | −177 | −216 | | −222 | −154 | −154 |  | −176 |  |  |  |  |
| 1 See Table 10.  2 A: analogue modulation; N: digital modulation.  3 *E* is defined as the equivalent isotropically radiated power of the interfering terrestrial station in the reference bandwidth.  4 In this band, the parameters for the terrestrial stations associated with transhorizon systems have been used. If an administration believes that transhorizon systems do not need to be considered, the line-of-sight radio-relay parameters associated with the frequency band 3.4‑4.2 GHz may be used to determine the coordination area, with the exception that *E* = 50 dBW for analogue terrestrial stations; and *Gx* = 37 dBi. However, for the space research service only, noting footnote 5 when transhorizon systems are not considered, *E* = 20 dBW and *Pt* = −17 dBW for analogue terrestrial stations, *E* = −23 dBW and *Pt* = −60 dBW for digital terrestrial stations; and *Gx* = 37 dBi.  5 These values are estimated for 1 Hz bandwidth and are 30 dB below the total power assumed for emission.  6 In the band 2.4835-2.5 GHz the terrestrial station parameters of line-of-sight radio-relay systems have been used. If an administration believes that, in this band, transhorizon systems need to be considered, the parameters associated with the frequency band 2 500-2 690 MHz may be used to determine the coordination area. | | | | | | | | | | | | | | | | | |

TABLE 8c    (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a receiving earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Receiving space radiocommunication service designation | | | Fixed-satellite | | Fixed-satellite, radio- determination satellite | Fixed-satellite | Fixed- satellite | | Meteorological-satellite7, 8 | Meteorological-satellite9 | Earth exploration- satellite7 | Earth exploration- satellite9 | Space research10 | | Fixed-satellite | | Broadcasting-satellite | | Fixed- satellite9 | Broadcasting-satellite | Fixed-satellite7 |
|  | | |  | |  |  |  | |  |  |  |  | Deep space |  |  | |  | |  |  |  |
| Frequency bands (GHz) | | | 4.500-4.800 | | 5.150-5.216 | 6.700-7.075 | 7.250-7.750 | | 7.450-7.550 | 7.750-7.900 | 8.025-8.400 | 8.025-8.400 | 8.400-8.450 | 8.450-8.500 | 10.7-12.75 | | 12.5-12.7512 | | 15.4-15.7 | 17.7-17.8 | 17.7-18.8 19.3-19.7 |
| Transmitting terrestrial  service designations | | | Fixed, mobile | | Aeronautical radionavigation | Fixed, mobile | Fixed, mobile | | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile | | Fixed, mobile | | Fixed, mobile | | Aeronau-tical radio-navigation | Fixed | Fixed, mobile |
| Method to be used | | | § 2.1 | | § 2.1 | § 2.2 | § 2.1 | | § 2.1, § 2.2 | § 2.2 | § 2.1 | § 2.2 | § 2.2 | | § 2.1, § 2.2 | | § 1.4.5 | |  | § 1.4.5 | § 2.1 |
| Modulation at earth  station1 | | | A | N |  | N | A | N | N | N | N | N | N | N | A | N | A | N | – |  | N |
| Earth station interference parameters and criteria | *p*0 (%) | | 0.03 | 0.005 |  | 0.005 | 0.03 | 0.005 | 0.002 | 0.001 | 0.083 | 0.011 | 0.001 | 0.1 | 0.03 | 0.003 | 0.03 | 0.003 | 0.003 |  | 0.003 |
| *n* | | 3 | 3 |  | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 |  | 2 |
| *p* (%) | | 0.01 | 0.0017 |  | 0.0017 | 0.01 | 0.0017 | 0.001 | 0.0005 | 0.0415 | 0.0055 | 0.001 | 0.05 | 0.015 | 0.0015 | 0.03 | 0.003 | 0.0015 |  | 0.0015 |
| *NL* (dB) | | 1 | 1 |  | 1 | 1 | 1 | – | – | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |  | 1 |
| *Ms* (dB) | | 7 | 2 |  | 2 | 7 | 2 | – | – | 2 | 4.7 | 0.5 | 1 | 7 | 4 | 7 | 4 | 4 |  | 6 |
| *W* (dB) | | 4 | 0 |  | 0 | 4 | 0 | – | – | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 0 | 0 |  | 0 |
| Terrestrial station parameters | *E* (dBW) in *B*2 | A | 923 | 923 |  | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 25 5 | 255 | 40 | 40 | 55 | 55 |  |  | 35 |
| N | 424 | 424 |  | 42 | 42 | 42 | 42 | 42 | 42 | 42 | −18 | −18 | 43 | 43 | 42 | 42 |  | 40 | 40 |
| *Pt* (dBW)  in *B* | A | 403 | 403 |  | 13 | 13 | 13 | 13 | 13 | 13 | 13 | −175 | −175 | −5 | −5 | 10 | 10 |  |  | −10 |
| N | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | −60 | −60 | −2 | −2 | −3 | −3 |  | −7 | −5 |
| *Gx* (dBi) | | 523, 4 | 523, 4 |  | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 45 | 45 | 45 | 45 |  | 47 | 45 |
| Reference band- width6 | *B* (Hz) | | 106 | 106 |  | 106 | 106 | 106 | 107 | 107 | 106 | 106 | 1 | 1 | 106 | 106 | 27 × 106 | 27 × 106 |  |  | 106 |
| Permissible interference power | *Pr*( *p*) (dBW) in *B* | |  |  |  | −151.2 |  |  | −125 | −125 | −15411 | −142 | −220 | −216 |  |  | −131 | −131 |  |  |  |

*Notes to Table 8c:*

1 A: analogue modulation; N: digital modulation.

2 *E* is defined as the equivalent isotropically radiated power of the interfering terrestrial station in the reference bandwidth.

3 In this band, the parameters for the terrestrial stations associated with transhorizon systems have been used. If an administration believes that transhorizon systems do not need to be considered, the line-of-sight radio-relay parameters associated with the frequency band 3.4-4.2 GHz may be used to determine the coordination area.

4 Digital systems assumed to be non-transhorizon. Therefore *Gx* = 42.0 dBi. For digital transhorizon systems, parameters for analogue transhorizon systems above have been used.

5 These values are estimated for 1 Hz bandwidth and are 30 dB below the total power assumed for emission.

6 In certain systems in the fixed-satellite service it may be desirable to choose a greater reference bandwidth *B*. However, a greater bandwidth will result in smaller coordination distances and a later decision to reduce the reference bandwidth may require recoordination of the earth station.

7 Geostationary-satellite systems.

8 Non-geostationary satellites in the meteorological-satellite service notified in accordance with No. **5.461A** may use the same coordination parameters.

9 Non-geostationary-satellite systems.

10 Space research earth stations in the band 8.4-8.5 GHz operate with non-geostationary satellites.

11 For large earth stations: *Pr*(*p*) = (*G* − 180) dBW

For small earth stations: *Pr*(20%) = 2 (*G* − 26) − 140 dBW for  26 < *G* ≤ 29 dBi

*Pr*(20%) = *G* − 163 dBW for        *G*  29 dBi

*Pr*(*p*)% = *G* − 163 dBW for        *G* ≤ 26 dBi

12 Applies to the broadcasting-satellite service in unplanned bands in Region 3.

TABLE 8d     (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a receiving earth station

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Receiving space radiocommunication service designation | | | Meteorological- satellite | Fixed-satellite | Fixed-satellite3 | Broadcasting-satellite | Earth exploration-satellite4 | Earth exploration-satellite5 | Space research (deep space) | Space research | | Fixed-satellite6 | Fixed- satellite5 | Mobile-satellite | Broadcasting-satellite, fixed‑satellite | Mobile-satellite | Radio-navigation-satellite | |
|  | | |  |  |  |  |  |  |  | Unmanned | Manned |  |  |  |  |  |  | |
| Frequency bands (GHz) | | | 18.0-18.4 | 18.8-19.3 | 19.3-19.7 | 21.4-22.0 | 25.5-27.0 | 25.5-27.0 | 31.8-32.3 | 37.0-38.0 | | 37.5-40.5 | 37.5-40.5 | 39.5-40.5 | 40.5-42.5 | 43.5-47.0 | 43.5-47.0 | |
| Transmitting terrestrial service designations | | | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed, mobile | Fixed,  radio- navigation | Fixed, mobile | | Fixed, mobile | Fixed, mobile | Fixed, mobile | Broadcasting, fixed | Mobile | Mobile | |
| Method to be used | | | § 2.1 | § 2.1, § 2.2 | § 2.2 | § 1.4.5 | § 2.2 | § 2.1 | § 2.1, § 2.2 | § 2.1, § 2.2 | | § 2.2 | § 2.1 | § 1.4.6 | § 1.4.5, § 2.1 | § 1.4.6 | – | |
| Modulation at earth station1 | | | N | N | N |  | N | N | N | N | | N | N | N | – | N |  | |
| Earth station interference parameters and criteria | *p*0 (%) |  | 0.05 | 0.003 | 0.01 |  | 0.25 | 0.25 | 0.001 | 0.1 | 0.001 | 0.02 | 0.003 |  |  |  |  | |
| *n* |  | 2 | 2 | 1 |  | 2 | 2 | 1 | 1 | 1 |  | 2 |  |  |  |  | |
| *p* (%) |  | 0.025 | 0.0015 | 0.01 |  | 0.125 | 0.125 | 0.001 | 0.1 | 0.001 |  | 0.0015 |  |  |  |  | |
| *NL* (dB) |  | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | | 1 | 1 |  |  |  |  | |
| *Ms* (dB) |  | 18.8 | 5 | 5 |  | 11.4 | 14 | 1 | 1 | | 6.8 | 6 |  |  |  |  | |
| *W* (dB) |  | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | | 0 | 0 |  |  |  |  | |
| Terrestrial station parameters | *E* (dBW) in *B* 2 | A |  | – | – |  | – | – | – | – | | – | – | – | – |  |  | |
| N | 40 | 40 | 40 | 40 | 42 | 42 | −28 | −28 | | 35 | 35 | 35 | 44 | 40 | 40 | |
| *Pt* (dBW) in *B* | A |  | – | – |  | – | – | – | – | | – | – | – | – |  |  | |
| N | −7 | −7 | −7 | −7 | −3 | −3 | −81 | −73 | | −10 | −10 | −10 | −1 | −7 | −7 | |
| *Gx* (dBi) |  | 47 | 47 | 47 | 47 | 45 | 45 | 53 | 45 | | 45 | 45 | 45 | 45 | 47 | 47 | |
| Reference bandwidth6 | *B* (Hz) |  | 107 | 106 | 106 |  | 107 | 107 | 1 | 1 | | 106 | 106 | 106 | 106 |  |  | |
| Permissible interference power | *Pr* ( *p*) (dBW) in *B* | | −115 | −140 | −137 |  | −120 | −116 | −216 | −217 | | −140 |  |  |  |  |  | |
| 1 A: analogue modulation; N: digital modulation.  2 *E* is defined as the equivalent isotropically radiated power of the interfering terrestrial station in the reference bandwidth.  3 Non-geostationary mobile-satellite service feeder links.  4 Non-geostationary-satellite systems.  5 Geostationary-satellite systems.  6 Non-geostationary fixed-satellite service systems. | | | | | | | | | | | | | | | | | |

TABLE 9a    (Rev.WRC‑12)

Parameters required for the determination of coordination distance for a transmitting earth station  
in bands shared bidirectionally with receiving earth stations

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Space service designation in which the transmitting  earth station operates | | Land mobile-satellite | Mobile-satellite | Land mobile-satellite | Earth  exploration-satellite, meteorological-satellite | Mobile-satellite | | Fixed-satellite, mobile-satellite | Aeronautical mobile-satellite (R) service | | Fixed- satellite3 | | Fixed-satellite | Fixed-satellite, meteorological-satellite | Fixed-satellite |
| Frequency bands (GHz) | | 0.1499-0.15005 | 0.272-0.273 | 0.3999-0.40005 | 0.401-0.402 | 1.670‑1.675 | | 2.655-2.690 | 5.030-5.091 | | 5.150-5.216 | | 6.700-7.075 | 8.025-8.400 | 8.025-8.400 |
| Space service designation in which the *receiving* earth station operates | | Radio-navigation-satellite | Space operation | Radio-navigation-satellite | Space operation | Meteorological-satellite | | Fixed-satellite, broadcasting-satellite | Aeronautical mobile-satellite (R) service | | Fixed-satellite | Radiodetermination-satellite | Fixed-satellite | Earth  exploration- satellite | Earth exploration- satellite |
| Orbit6 | |  | Non-GSO |  | Non-GSO | Non-GSO | GSO |  | Non-GSO | GSO | Non-GSO |  | Non-GSO | Non-GSO | GSO |
| Modulation at *receiving* earth station1 | |  | N |  | N | N | N |  |  |  |  |  | N | N | N |
| Receiving earth station interference parameters and criteria | *p*0 (%) |  | 1.0 |  | 0.1 | 0.006 | 0.011 |  |  |  |  |  | 0.005 | 0.011 | 0.083 |
| *n* |  | 1 |  | 2 | 3 | 2 |  |  |  |  |  | 3 | 2 | 2 |
| *p* (%) |  | 1.0 |  | 0.05 | 0.002 | 0.0055 |  |  |  |  |  | 0.0017 | 0.0055 | 0.0415 |
| *NL* (dB) | 0 | 0 | 0 | 0 | 0 | 0 |  |  |  |  |  | 1 | 0 | 1 |
| *Ms* (dB) | 2 | 1 | 2 | 1 | 2.8 | 0.9 | 2 |  |  | 2 | 2 | 2 | 4.7 | 2 |
| *W* (dB) | 0 | 0 | 0 | 0 | 0 | 0 |  |  |  |  |  | 0 | 0 | 0 |
| Receiving earth station parameters | *Gm* (dBi)2 | 0 | 20 | 0 | 20 | 30 | 45 |  | 45 | 45 | 48.5 |  | 50.7 |  |  |
| *Gr* (dBi)4 | 0 | 19 | 0 | 19 | 19 9 | 8 |  | 8 | 8 | 10 |  | 10 | 10 | 8 |
| ε*min* 5 | 3° | 10° | 3° | 10° | 5° | 3° | 3° | 10° | 10° | 3° | 3° | 3° | 5° | 3° |
| *Te* (K)7 | 200 | 500 | 200 | 500 | 370 | 118 | 75 | 340 | 340 | 75 | 75 | 75 |  |  |
| Reference bandwidth | *B* (Hz) | 4 × 103 | 103 | 4 × 103 | 1 | 106 | 4 × 103 |  | 37.5 × 103 | 37.5 × 103 |  |  | 106 | 106 | 106 |
| Permissible interference power | *Pr*( *p*) (dBW) in *B* | −172 | −177 | −172 | −208 | −145 | −178 |  | −163.5 | −163.5 |  |  | −151 | −142 | −154 |

*Notes to Table 9a:*

1 A: analogue modulation; N: digital modulation.

2 On-axis gain of the receive earth station antenna.

3 Feeder links of non-geostationary-satellite systems in the mobile‑satellite service.

4 Horizon antenna gain for the receive earth station (refer to § 3 of the main body of this Appendix).

5 Minimum elevation angle of operation in degrees (non-geostationary or geostationary).

6 Orbit of the space service in which the receiving earth station operates (non-geostationary or geostationary).

7 The thermal noise temperature of the receiving system at the terminal of the receiving antenna (under clear-sky conditions). Refer to § 2.1 of this Annex for missing values.

8 Horizon antenna gain is calculated using the procedure of Annex 5. Where no value of *Gm* is specified, a value of 42 dBi is to be used.

9 Non-geostationary horizon antenna gain, *Ge* = *Gmin* + 20 dB (see § 2.2), with *Gmin* = 10 – 10 log (*D*/), *D*/ = 13 (refer to Annex 3 for definition of symbols).

10 Unmanned space research is not a separate radiocommunication service and the system parameters are only to be used for the generation of supplementary contours.

TABLE 9b

Parameters required for the determination of coordination distance for a transmitting earth station  
in bands shared bidirectionally with receiving earth stations

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Space service designation in which the transmitting earth station operates | | | Fixed-satellite | | | Fixed-satellite | | | Fixed- satellite 3 | Fixed-satellite | Fixed-satellite | Fixed- satellite3 | Fixed- satellite3 | Earth exploration- satellite, space research | |
| Frequency bands (GHz) | | | 10.7-11.7 | | | 12.5-12.75 | | | 15.43-15.65 | 17.3-17.8 | 17.7-18.4 | 19.3-19.6 | 19.3-19.6 | 40.0-40.5 | |
| Space service designation in which the *receiving* earth station operates | | | Fixed-satellite | | | Fixed-satellite | | | Fixed-satellite3 | Broadcasting-satellite | Fixed-satellite, meteorological- satellite | Fixed-satellite3 | Fixed-satellite4 | Fixed-satellite, mobile‑satellite | |
| Orbit7 | | | GSO | | Non-GSO | GSO | | Non-GSO | Non-GSO |  | GSO | Non-GSO | GSO | GSO | Non-GSO |
| Modulation at *receiving* earth station1 | | | A | N | N | A | N |  |  |  | N | N |  |  |  |
| Receiving earth station interference parameters and criteria | | *p*0 (%) | 0.03 | 0.003 | | 0.03 | 0.003 | | 0.003 |  | 0.003 | 0.01 | 0.003 | 0.003 | |
| *n* | 2 | 2 | | 2 | 2 | | 2 |  | 2 | 1 | 2 | 2 | |
| *p* (%) | 0.015 | 0.0015 | | 0.015 | 0.0015 | | 0.0015 |  | 0.0015 | 0.01 | 0.0015 | 0.0015 | |
| *NL* (dB) | 1 | 1 | | 1 | 1 | | 1 |  | 1 | 0 | 1 | 1 | |
| *Ms* (dB) | 7 | 4 | | 7 | 4 | | 4 |  | 6 | 5 | 6 | 6 | |
| *W* (dB) | 4 | 0 | | 4 | 0 | | 0 |  | 0 | 0 | 0 | 0 | |
| Receiving earth station parameters | | *Gm* (dBi) 2 |  |  | 51.9 |  |  | 31.2 | 48.4 |  | 58.6 | 53.2 | 49.5 | 50.8 | 54.4 |
| *Gr* 5 | 9 | 9 | 10 | 9 | 9 | 1111 | 10 |  | 9 | 10 | 10 | 9 | 7 12 |
| *min* 6 | 5° | 5° | 6° | 5° | 5° | 10° | 5° |  | 5° | 5° | 10° | 10° | 10° |
| *Te* (K)8 | 150 | 150 | | 150 | 150 | | 150 |  | 300 | 300 | 300 | 300 | |
| Reference bandwidth | | *B* (Hz) | 106 | 106 | | 106 | 106 | | 2 × 106 |  | 106 | 106 |  |  | |
| Permissible interference power | | *Pr*( *p*) (dBW) in *B* | −144 | −144 | −144 | −144 | −144 | −144 | −141 |  | −138 | −141 |  |  | |
| *Notes to Table 9b:*  1 A: analogue modulation; N: digital modulation.  2 On-axis gain of the receive earth station antenna.  3 Feeder links of non-geostationary-satellite systems in the mobile‑satellite service.  4 Geostationary‑satellite systems.  5 Horizon antenna gain for the receive earth station (refer to § 3 of the main body of the Appendix).  6 Minimum elevation angle of operation in degrees (non-GSO or GSO).  7 Orbit of the space service in which the receiving earth station operates (GSO or non-GSO).  8 The thermal noise temperature of the receiving system at the terminal of the receiving antenna (under clear-sky conditions). Refer to § 2.1 of this Annex for missing values.  9 Horizon antenna gain is calculated using the procedure of Annex 5. Where no value of *Gm* is specified, a value of 42 dBi is to be used.  10 Horizon antenna gain is calculated using the procedure of Annex 5, except that the following antenna pattern may be used in place of that given in § 3 of Annex 3:  *G* = 32 − 25 log φ for 1° ≤ φ < 48°; and *G* = −10 for 48° ≤ φ < 180° (refer to Annex 3 for definition of symbols).  11 Non-geostationary horizon antenna gain. *Ge* = *Gmax* (see § 2.2 of the main body of this Appendix) for *G* = 36 − 25 log (φ) > −6 (refer to Annex 3 for definition of symbols).  12 Non-geostationary horizon antenna gain. *Ge* = *Gmax* (see § 2.2 of the main body of this Appendix) for *G* = 32 − 25 log (φ) > −10 (refer to Annex 3 for definition of symbols). | | | | | | | | | | | | | | | |

TABLE 10     (WRC‑07)

Predetermined coordination distances

|  |  |  |
| --- | --- | --- |
| Frequency sharing situation | | Coordination distance (in sharing situations involving services allocated with equal rights) (km) |
| Type of earth station | Type of terrestrial station |
| Ground-based in the bands below 1 GHz to which No. **9.11A** applies. Ground-based mobile in the bands within the range 1‑3 GHz to which No. **9.11A** applies | Mobile (aircraft) | 500 |
| Aircraft (mobile) (all bands) | Ground-based | 500 |
| Aircraft (mobile) (all bands) | Mobile (aircraft) | 1 000 |
| Ground-based in the bands:  400.15-401 MHz 1 668.4-1 675 MHz | Station in the meteorological aids service (radiosonde) | 580 |
| Aircraft (mobile) in the bands:  400.15-401 MHz 1 668.4-1 675 MHz | Station in the meteorological aids service (radiosonde) | 1 080 |
| Ground-based in the radiodetermination-satellite service (RDSS) in the bands:  1 610-1 626.5 MHz 2 483.5-2 500 MHz  2 500-2 516.5 MHz | Ground-based | 100 |
| Airborne earth station in the radiodetermination-satellite service (RDSS) in the bands:  1 610-1 626.5 MHz 2 483.5-2 500 MHz 2 500-2 516.5 MHz | Ground-based | 400 |
| Receiving earth stations in the meteorological-satellite service | Station in the meteorological aids service | The coordination distance is considered to be the visibility distance as a function of the earth station horizon elevation angle for a radiosonde at an altitude of 20 km above mean sea level, assuming 4/3 Earth radius (see Note 1) |
| Non-GSO MSS feeder‑link earth stations (all bands) | Mobile (aircraft) | 500 |
| Ground-based in the bands in which the frequency sharing situation is not covered in the rows above | Mobile (aircraft) | 500 |
| NOTE 1 – The coordination distance, *d* (km), for fixed earth stations in the meteorological-satellite service vis-à-vis stations in the meteorological aids service assumes a radiosonde altitude of 20 km and is determined as a function of the physical horizon elevation angle ε*h* (degrees) for each azimuth, as follows:  for          ε*h*  ≥  11°  for 0° < ε*h*  <  11°  for          ε*h*  ≤  0°  The minimum and maximum coordination distances are 100 km and 582 km, and correspond to physical horizon angles greater than 11° and less than 0°. (WRC‑2000) | | |

1. 1 When *p* is a small percentage of the time, in the range 0.001% to 1.0%, the interference is referred to as “short‑term”; if *p* ≥ 20%, it is referred to as “long-term” (see § 1.5.3). [↑](#footnote-ref-1)
2. 2 If the earth station antenna has a wide beamwidth, the method can still be used to determine the propagation mode (2) contour. However, the fact that the antenna beam may be wider than the rain cell and hence not actually fully filled with hydrometeors will mean that the interference potential may be slightly overestimated. [↑](#footnote-ref-2)
3. 3 See equation (82). [↑](#footnote-ref-3)
4. 4 While some fixed satellite systems transmit to fixed earth stations operating at unspecified locations within a service area defined by an administration, methods for determining the coordination areas are specified only for individual sites. To minimize the number of individual earth stations requiring detailed coordination in these cases, administrations may wish to develop bilateral agreements based on distances, calculated in accordance with Recommendation ITU‑R SM.1448, extended from the periphery of a service area. [↑](#footnote-ref-4)
5. 5 These additional areas may be declared as coastal Zone A1 areas by administrations for inclusion in the ITU Digital World Map (IDWM). [↑](#footnote-ref-5)
6. 6 The same procedures are also used to develop supplementary and auxiliary contours (see Annex 6). [↑](#footnote-ref-6)
7. 7 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 by taking into account the horizon elevation angle in accordance with § 1 of Annex 1. [↑](#footnote-ref-7)
8. 8 This procedure does not apply for the case of an earth station sharing a frequency band with other earth stations operating in the opposite direction of transmission, as for that specific case the propagation mode (2) contour is based on a geometric construction. [↑](#footnote-ref-8)
9. 9 The method requires the antenna pattern to be monotonic in terms of the reduction in gain either side of the main beam axis. [↑](#footnote-ref-9)