



Recommendation ITU-R S.1714-1
(01/2022)

**Static methodology for calculating $epfd_{\downarrow}$
to facilitate coordination of very
large antennas under Nos. 9.7A and 9.7B
of the Radio Regulations**

S Series
Fixed-satellite service



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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R S.1714-1

Static methodology for calculating $\text{epfd}_{\downarrow}$ to facilitate coordination of very large antennas under Nos. 9.7A and 9.7B of the Radio Regulations

(2005-2022)

Scope

This Recommendation provides a methodology for calculating the worst-case static $\text{epfd}_{\downarrow}$ value from a non-GSO (non-geostationary-satellite orbit) system at any GSO earth station the geographic coordinates of which are known (specific GSO earth station) and the antenna of which is pointed towards the wanted GSO space station..

Keywords

epfd , non-GSO, methodology, **9.7A**, **9.7B**, static

Abbreviations/Glossary

Alpha angle (Alpha): the minimum angle at the GSO earth station between the line to the non-GSO satellite and the lines to the GSO arc.

$\text{epfd}_{\downarrow}$: equivalent power flux-density, as defined in RR No. **22.5C.1**, emissions from the non-GSO satellite system into a GSO satellite earth station.

pfd mask: power flux-density mask used to define the emissions of the non-GSO satellite in the $\text{epfd}_{\downarrow}$ calculation.

X angle (X): the minimum angle at the non-GSO satellite between the line from the GSO earth station and the lines to the GSO arc.

Related ITU Recommendations, Reports

Recommendation ITU-R S.1503-3	Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite service systems or networks with limits contained in Article 22 of the Radio Regulations
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The ITU Radiocommunication Assembly,

considering

- a) that WRC-2000 adopted, in Article **22** of the Radio Regulations (RR), equivalent power flux-density (epfd) limits to be met by non-GSO FSS (fixed-satellite service) systems in order to protect GSO FSS and GSO broadcasting-satellite service networks in parts of the frequency range 10.7-30 GHz;
- b) that WRC-2000 agreed that additional protection above that provided by the epfd limits in *considering a)* is required for certain GSO FSS networks with specific receive earth stations having all of the following characteristics:
 - i) earth station antenna maximum isotropic gain greater than or equal to 64 dBi for the frequency band 10.7-12.75 GHz or 68 dBi for the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz;
 - ii) G/T of 44 dB/K or higher;
 - iii) emission bandwidth of 250 MHz or more for the frequency bands below 12.75 GHz or 800 MHz or more for the frequency bands above 17.8 GHz;

- c) that, in order to provide this additional protection, WRC-2000 adopted RR Nos. **9.7A** and **9.7B**, establishing a procedure for effecting coordination between specific earth stations in a geostationary network in the FSS and systems in the FSS using satellites in non-GSO in certain frequency bands;
- d) that the technical conditions for triggering coordination under RR Nos. **9.7A** and **9.7B** are defined in RR Appendix 5 and include the thresholds in *considering b)* and the following $\text{epfd}_{\downarrow}$ radiated by the non-GSO FSS satellite system into the earth station employing the very large antenna when this antenna is pointed towards the wanted GSO satellite:
- i) in the frequency band 10.7-12.75 GHz:
 - a) $-174.5 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$ for any percentage of time for non-GSO satellite systems with all satellites only operating at or below 2 500 km altitude; or
 - b) $-202 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))}$ for any percentage of the time for non-GSO satellite systems with any satellites operating above 2 500 km altitude;
 - ii) in the frequency bands 17.8-18.6 GHz or 19.7-20.2 GHz:
 - a) $-157 \text{ dB(W/(m}^2 \cdot \text{MHz))}$ for any percentage of time for non-GSO satellite systems with all satellites only operating at or below 2 500 km altitude; or
 - b) $-185 \text{ dB(W/(m}^2 \cdot \text{MHz))}$ for any percentage of the time for non-GSO satellite systems with any satellites operating above 2 500 km altitude;
- e) that the calculation of $\text{epfd}_{\downarrow}$ produced by a non-GSO satellite system as a function of time requires the use of a suitable simulation software tool;
- f) that Recommendation ITU-R S.1503 provides a specification for a software simulation tool for calculating $\text{epfd}_{\downarrow}$ as a function of time, however it does not take into account the inclination of a GSO satellite;
- g) that as a consequence of the high gain of the very large GSO earth station antennas and the nature of the $\text{epfd}_{\downarrow}$ equation, non-GSO satellites in the side lobes of the very large GSO earth station antennas do not significantly contribute to the $\text{epfd}_{\downarrow}$ value;
- h) that WRC-03 adopted Resolution **85 (WRC-03)** which allows, on a provisional basis until appropriate software is available, for coordination under RR Nos. **9.7A** and **9.7B** to be effected using only the characteristics of the GSO FSS network;
- i) that there is limited guidance for conducting coordination under RR Nos. **9.7A** and **9.7B**,
- recommends*
- 1 that the methodology in Annex 1 to this Recommendation could be used by administrations effecting coordination under RR Nos. **9.7A** and **9.7B** to calculate the worst-case static $\text{epfd}_{\downarrow}$ value from a non-GSO system at a specific GSO earth station antenna when this antenna is pointed towards the wanted GSO satellite;
 - 2 that the results from *recommends 1* should be compared to the $\text{epfd}_{\downarrow}$ protection criterion of the GSO network and the criterion referred to in *considering d)* to determine if there is potential for the non-GSO system to not meet this protection criterion;
 - 3 that if the non-GSO system meets the GSO $\text{epfd}_{\downarrow}$ protection criterion and the criterion referred to in *considering d)* then the relevant provisions of the Radio Regulations could be considered as complied with;
 - 4 that if the non-GSO system does not meet the GSO $\text{epfd}_{\downarrow}$ protection criterion or the criterion referred to in *considering d)* then a more detailed analysis should be conducted.

Annex 1

1 Description of the methodology

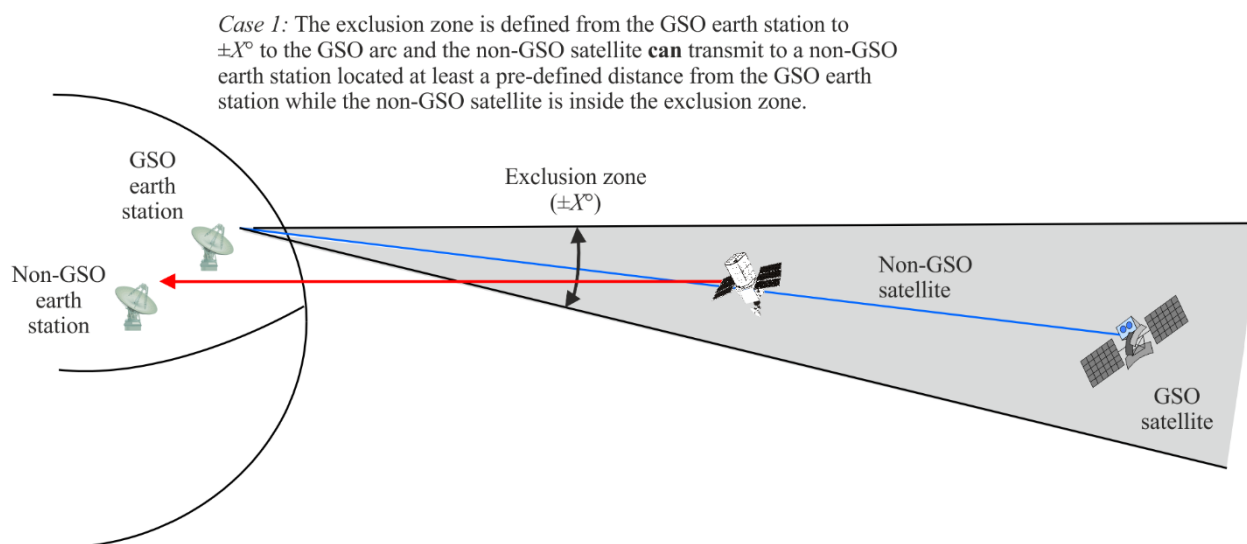
In Circular Letter CR/176, the Radiocommunication Bureau requested that administrations responsible for non-GSO satellite systems in certain frequency bands subject to epfd limits submit supplementary information to the ITU within six months of 26 March 2002 pursuant to *resolves* 2 of Resolution **59 (WRC-2000)**. This supplementary information contains the details about the satellite network operations and the pfd masks that are required to calculate the epfd levels produced by the non-GSO systems. The methodology proposed in this Recommendation makes use of this supplementary information and does not require any other additional information regarding the non-GSO satellite systems.

In order to meet the epfd_↓ limits, non-GSO satellite systems will need to employ some sort of mitigation technique. One of the most common techniques is GSO arc avoidance. GSO arc avoidance can be employed by means of establishing an exclusion zone in three different ways:

- the exclusion zone is defined from the GSO earth station to $\pm X^\circ$ to the GSO arc and the non-GSO satellite can transmit to a non-GSO earth station located at least a predefined distance from the GSO earth station while inside the exclusion zone;
- the exclusion zone is as defined in Fig. 1 however, the non-GSO satellite cannot transmit while inside the exclusion zone;
- the exclusion zone is defined by latitude, and the non-GSO satellite cannot transmit when its sub-satellite latitude is between a certain $\pm X$ latitude range.

A diagram of each of these three types of GSO arc avoidance techniques is provided in Figures 1 through 3.

FIGURE 1
Case 1 – Exclusion zone

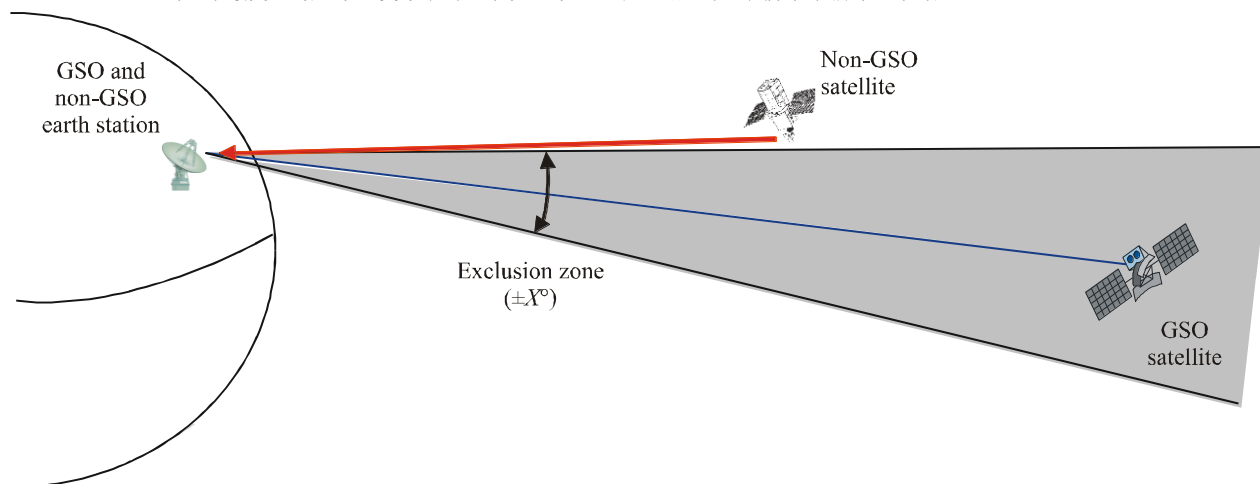


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FIGURE 2

Case 2 – Exclusion zone

Case 2: The exclusion zone defined from the GSO earth station to $\pm X^\circ$ to the GSO arc. Non-GSO satellite **cannot** transmit while inside exclusion zone.

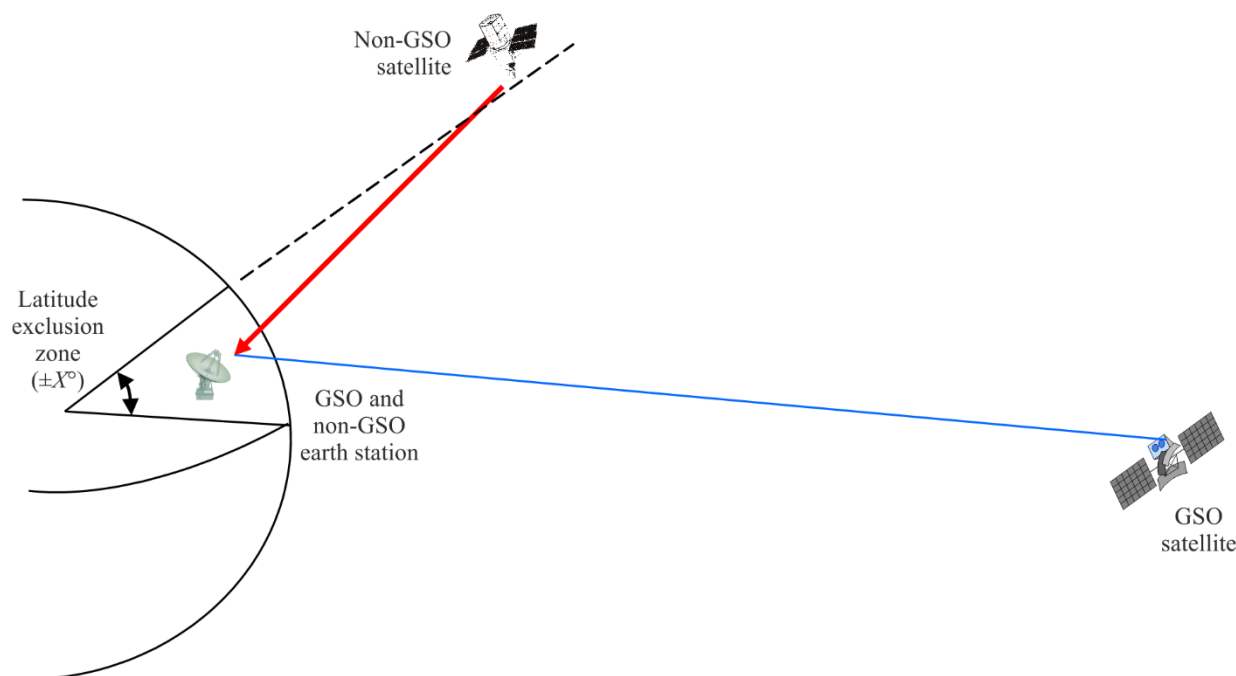


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FIGURE 3

Case 3 – Exclusion zone

Case 3: The non-GSO satellite cannot transmit when the sub-satellite latitudes is between a certain latitude range. For example, a medium earth orbit (MEO) would not transmit between + and $-X^\circ$ latitude. A high earth orbit (HEO) would not transmit below $+X^\circ$ latitude or above $-X^\circ$ latitude depending on the hemisphere of the apogee.



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Cases 1 and 2 describe the forms of GSO arc avoidance that would most likely be used by a low earth orbit (LEO) constellation; whereas Case 3 would most likely be used with a HEO type constellation, while all three types of arc avoidance could be used with a MEO constellation. Because it is unlikely for a HEO to use the arc avoidance described in Cases 1 and 2, the calculations in these methodologies are limited to circular orbits. The methodology for Case 3 can be utilized for a HEO constellation as

long as the radius to the HEO satellite when it crosses the cut on/off latitude is known. The $\text{epfd}_{\downarrow}$ thresholds in RR Appendix 5 used to determine the technical conditions for triggering coordination between non-GSO FSS systems and specific earth stations in a GSO FSS network are defined on the basis of altitude, with one trigger for non-GSO systems with all satellites operating at or below 2 500 km altitude and another trigger value for non-GSO FSS systems with any satellites operating above 2 500 km altitude. Table 1 shows the relationship between non-GSO orbit type, RR Appendix 5 coordination trigger, and the cases considered for mitigation techniques.

TABLE 1

Relationship between orbit type, RR Appendix 5 trigger, and mitigation technique

Orbit type	Appendix 5 coordination trigger (km)	Mitigation techniques
LEO	$\leq 2\,500$	Cases 1 and 2
MEO	$> 2\,500$	Cases 1, 2 and 3
HEO	$> 2\,500$	Case 3

2 Case 1

Case 1 depicts the scenario when an exclusion zone is defined from the GSO earth station to $\pm X^\circ$ to the GSO arc. When the non-GSO is within this exclusion zone it can transmit but not in the direction of the GSO earth station. The distance away from the GSO earth station that the non-GSO can transmit to is determined by the non-GSO operations. The worst-case geometry for this case is depicted in Fig. 1 where the non-GSO is directly in line between the GSO satellite and the GSO earth station, but the non-GSO is transmitting to an earth station away from the GSO earth station. This geometry produces a non-GSO side lobe into GSO main beam interference scenario. This mitigation technique would typically be used with a LEO constellation but would also work with a MEO constellation. The algorithm to calculate the $\text{epfd}_{\downarrow}$ value requires the following Steps:

Step 1: Inputs: Radius of the Earth, non-GSO orbit radius, non-GSO inclination, GSO orbit radius, GSO satellite longitude, GSO satellite inclination, GSO earth station latitude, GSO earth station longitude.

Step 2: Calculate the azimuth and elevation angles from the GSO earth station to the GSO satellite.

Step 3: Calculate the sub-satellite latitude and longitude of the non-GSO for the same azimuth and elevation as the GSO satellite.

Step 4: If the non-GSO pfd masks are presented in Alpha vs Delta longitude form (see Recommendation ITU-R S.1503 for Alpha and Delta longitude definitions).

- Calculate Alpha as the angle at the GSO earth station between the line to the non-GSO satellite and the line to the GSO arc.
- From the pfd masks choose the pfd for the latitude nearest the sub-satellite latitude of the non-GSO, Alpha, and the longitude difference between the GSO and the non-GSO satellites.
- Since this is an in-line event the $G(\theta)/G_{\max}$ portion of the epfd calculation is equal to 1 or 0 dB.
- Because the GSO satellite has a very large bandwidth, there may be several sets of pfd masks with overlapping frequencies; all of these should be included.
- Calculate the epfd as defined in RR No. 22.5C.

Step 5: If the non-GSO pfd masks are presented in azimuth vs. elevation form (see Recommendation ITU-R S.1503 for azimuth and elevation definitions).

- a) Calculate the Earth centred fixed (ECF) coordinates of the GSO satellite, earth station and non-GSO satellite.
- b) Translate and rotate vector between non-GSO satellite and GSO earth station from ECF coordinates to satellite centred coordinates.
- c) Calculate azimuth and elevation from the non-GSO satellite to the GSO earth station.
- d) From the pfd masks choose the pfd for the latitude nearest the sub-satellite latitude of the non-GSO satellite for the azimuth and elevation from the non-GSO satellite to the GSO earth station.
- e) Since this is an in-line event the $G(\theta)/G_{max}$ portion of the epfd calculation is equal to 1 (numerical) or 0 dB.
- f) Because the GSO has a very large bandwidth, there may be several sets of pfd masks with overlapping frequencies; all of these should be included.
- g) Calculate the epfd as defined in RR No. **22.5C**.

An Excel worksheet with the appropriate equations and calculations pre-programmed has been developed. A picture of the Case 1 calculation page is shown in Table 2. The input values for the non-GSO satellite system are fictional and do not represent any particular system.