

RECOMMENDATION ITU-R S.1559

Methodology for computing the geographical distribution of maximum downlink equivalent power flux-density levels generated by non-geostationary fixed-satellite service systems using circular orbits

(Question ITU-R 236/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that interference from non-geostationary (GSO) systems into GSO networks will likely have significant variations both geographically and temporally;
- b) that geographic distributions of interference levels caused by non-GSO systems vary with traffic loading, cell layouts, and constellation configurations;
- c) that interference from non-GSO systems into GSO networks can vary with beam scheduling algorithms of the non-GSO system;
- d) that non-GSO beam scheduling algorithms may likely be adjusted to meet traffic loading variations and other factors;
- e) that non-GSO interference levels are dependent on the geographic location of the GSO ground station and GSO satellite location;
- f) that information on the geographical distribution of maximum downlink equivalent power flux-density ($\text{epfd}_{\downarrow}$) levels generated by non-GSO systems may be useful to GSO systems designers in order to determine the expected level of non-GSO interference,

recommends

- 1 that the method described in Annex 1 could be used to construct geographic distributions of maximum $\text{epfd}_{\downarrow}$ levels generated within a GSO satellite coverage area by a non-GSO system that uses circular orbits;
- 2 that Annex 1 could be used by administrations, including GSO/fixed-satellite service (FSS) network operators, to provide them with guidance for designing links for a specific geographical location given the following Notes:

NOTE 1 – Validation software has been specified to check compliance of a non-GSO system with $\text{epfd}_{\downarrow}$ limits in Article 22 of the Radio Regulations (see Recommendation ITU-R S.1503). This software generates $\text{epfd}_{\downarrow}$ levels which are meant to be an absolute envelope and are not representative of what would be generated over time by the non-GSO FSS system in operation.

NOTE 2 – If the methodology in Annex 1 is applied using the assumptions and satellite pfd mask approach as defined in the Recommendation ITU-R S.1503 validation approach, geographical distribution will be obtained of the absolute maximum $\text{epfd}_{\downarrow}$ envelope. In the case where the method in Annex 1 is applied to simulation models more representative of the non-GSO operation, the maps generated are likely to vary during the lifetime of the non-GSO system as operating parameters will change.

ANNEX 1

Algorithm for calculating geographic distribution of maximum $\text{epfd}_{\downarrow}$ interference levels caused by non-GSO systems**1 Introduction**

Since non-GSO interference will vary geographically it could be useful for administrations to be able to quantify this interference using software that can estimate the geographic and temporal distribution of non-GSO FSS interference.

The analysis will represent the maximum interference expected over the life of the non-GSO system. Analyses of typical scenarios provide little value since the interference levels can have extremely large variations.

The methodology presented in this Annex could be used to generate maps showing representative maximum non-GSO interference power levels that could be received on any land area. The maps will provide guidance for GSO operators for designing links. These maps would provide GSO operators with additional knowledge of maximum $\text{epfd}_{\downarrow}$ locations.

This Annex gives a method for calculating the geographic distribution of maximum epfd levels for non-GSO systems with circular orbits that use an exclusion angle for GSO interference mitigation. For these non-GSO systems the maximum $\text{epfd}_{\downarrow}$ interference levels (for GSO ground stations with 3 m or greater antennas) occur on or near where the non-GSO spacecraft is inline between the GSO ground station and the GSO spacecraft. For non-GSO systems where this is not the case this approach does not apply.

The maximum $\text{epfd}_{\downarrow}$ is found from a computer simulation of the non-GSO system. However, since the value is near an inline situation, only a small number of time points need to be simulated to determine the maximum $\text{epfd}_{\downarrow}$. Only points that are within the 10 dB beamwidth of the GSO ground station need to be considered since in these types of non-GSO systems locations outside of the 10 dB beamwidth will almost certainly be at least 10 dB below the maximum $\text{epfd}_{\downarrow}$ value found on the Earth's surface.

Since most non-GSO systems have unique characteristics, the proposed method does not describe how to simulate the specific non-GSO system. Instead it computes the time periods needed to be simulated.

A resolution of 1° longitude by 1° latitude is sufficient resolution to show the general variations in interference levels, however finer resolution may be necessary for more detailed studies, especially in the case of larger antennas. It is noted that non-GSO systems with continuously repeating ground tracks will have maximum $\text{epfd}_{\downarrow}$ variations over a much smaller area.

2 Outline of algorithm

The method given can be used to calculate time periods during a non-GSO simulation when a spacecraft passes through a given beamwidth of a GSO ground antenna. First a piece-wise linear approximation to the intersection of the GSO ground antenna beam with the non-GSO sphere is

computed. For each point on the intersection, exact orbital parameters of a non-GSO spacecraft are computed such that the spacecraft will intersect the point on the next orbit. By comparing a given spacecraft's orbital parameters with the orbital parameters at each point, the exact times when the satellite passes through the antenna beam can be determined.

3 Symbols used

ER:	Earth rotational coordinates. An orthogonal three-dimensional coordinate system centred on Earth's centre. ER's z-axis passes through the North Pole and the x-axis passes through the longitude 0 latitude 0 point
GT :	three dimensional location of GSO ground station in ER coordinates
G :	three dimensional location of GSO satellite in ER coordinates
G_x :	x component of vector G
G_y :	y component of vector G
G_z :	z component of vector G
$\sim$:	normalizes a vector (i.e. $\sim V$ is equivalent to $V / V $)
$\cdot$:	dot product operator
$\times$:	cross product operator
$\text{Min}(Q_i)$	determines the minimum of Q_i for all i
$\text{Max}(Q_i)$	Determines the maximum of Q_i for all i
A_x :	x axis of coordinate system pointing from GSO ground station to the GSO
A_y :	y axis of coordinate system pointing from GSO ground station to the GSO
A_z :	z axis of coordinate system pointing from GSO ground station to the GSO
α :	half of the -3 dB beamwidth of GSO ground station antenna
V_i :	vectors forming a cone with half angle α and centre pointing in z direction
W_i :	vectors forming a cone with half angle α and centre pointing in GSO direction
Q_i :	locations on the non-GSO sphere that intersect vectors W_i
v_0 :	mean anomaly = 0
ω_0 :	perigee argument at an initial moment
ω_r :	perigee argument precession rate
Ψ :	initial longitude
Φ_r :	ascending node longitude precession rate
Φ_e :	Earth's rotation rate