

RECOMMENDATION ITU-R SF.1602

Methodology for determining power flux-density statistics for use in sharing studies between fixed wireless systems and multiple fixed-satellite service satellites

(Questions ITU-R 217/9-250/4 and ITU-R 206/9-237/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that it is necessary to ensure that emissions from satellites do not exceed permissible interference to fixed wireless systems (FWS) in the bands shared between FS and FSS;
- b) that FWS can be adequately protected from the aggregate emissions from multiple satellites (non-GSO constellations or fully populated GSO arc) by placing suitable limits on the power flux-density (pfd) in a reference bandwidth produced by individual satellites at the surface of the Earth;
- c) that any limitations of the pfd produced at the surface of the Earth should not place undue restrictions on the design of GSO and non-GSO FSS;
- d) that Recommendations ITU-R SF.1482 and ITU-R SF.1483 provide maximum allowable values of pfd at the surface of the Earth produced by non-GSO satellites in the FSS to protect the FS in, respectively, the 10.7-12.75 GHz and the 17.7-19.3 GHz bands;
- e) that the pfd levels specified in the Recommendations mentioned in *considering* d) were developed from a pfd mask analysis used to calculate the statistics of aggregate power levels received at an FS station by applying pfd levels under consideration to each visible satellite of the non-GSO FSS constellation;
- f) that, when considering a multi-satellite environment, such as non-GSO constellation or fully populated GSO arc, all the visible satellites may not simultaneously radiate the maximum pfd limit in the direction of the FS system under consideration,

recommends

- 1 that the methodology described in Annex 1 may be used for determining pfd statistics for use in sharing studies between FWS and multiple FSS satellites, taking into account satellite systems characteristics.

Annex 1

1 Introduction

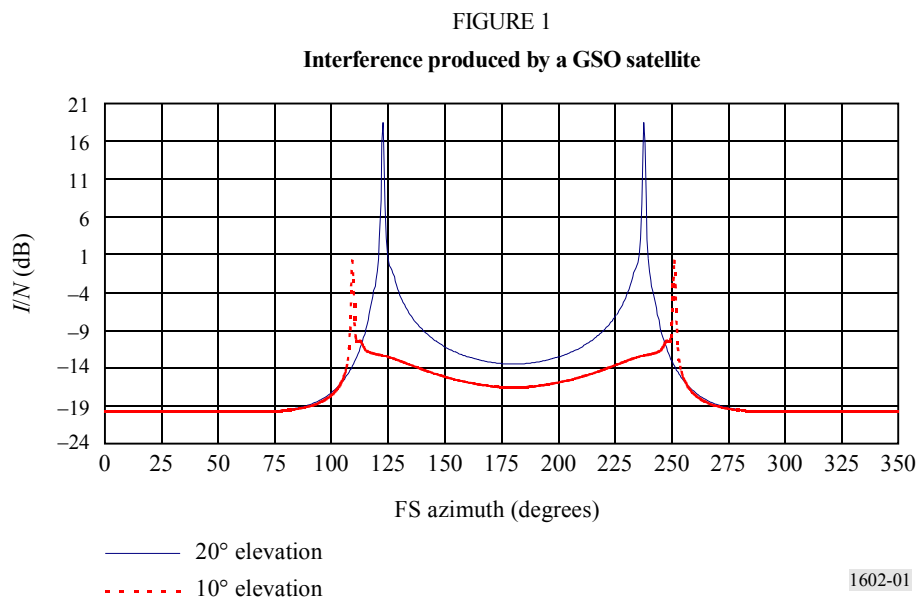
This Annex presents statistical methodology concerning the impact of non-GSO and GSO satellites on FWS. It takes into account realistic satellite characteristics and is intended for use as guidance in sharing analysis between FS and satellite services.

It should also be noted that Recommendations ITU-R SF.1482 and ITU-R SF.1483 dealing with maximum allowable values of pfd at the surface of the Earth produced by non-GSO satellites in the FSS to protect the FS provides general background to this methodology.

2 Description of the pfd mask analysis

The existing methodology for evaluating the pfd mask used either for GSO or non-GSO satellite systems, such as in the above-mentioned Recommendations ITU-R SF.1482 and ITU-R SF.1483, aggregates the interference from all visible satellites to the FS using a regulatory pfd mask such as defined in Article 21 of the Radio Regulations.

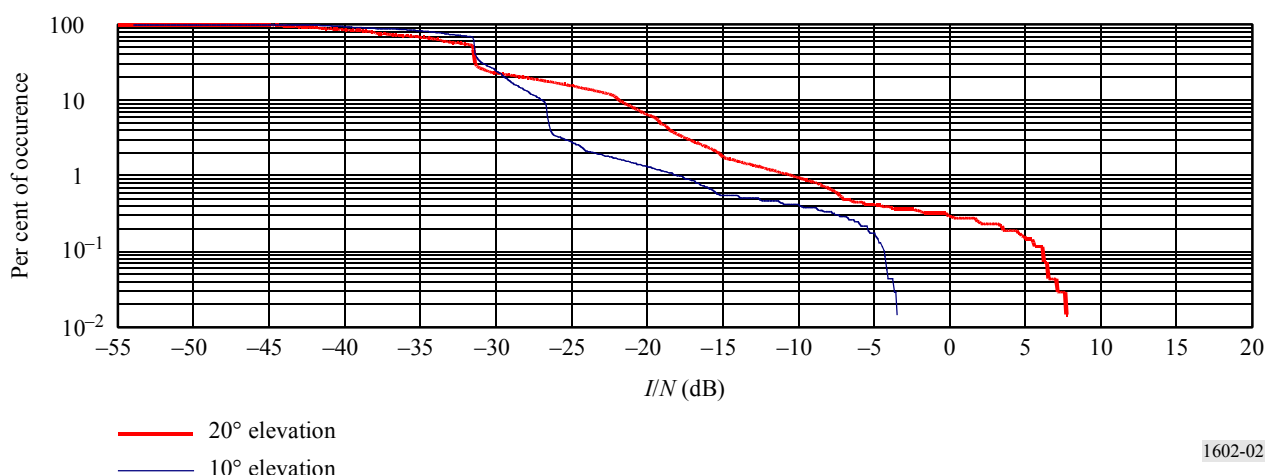
In a typical application of this methodology for the case of GSO satellites, the geostationary arc is filled with a given number of satellites (e.g. 1 every 4°) which produces permanent interference. Representative results produced by the application of this methodology are shown on Fig. 1 for all the FS azimuths.



1602-01

For the case of non-GSO systems, and on the basis of the characteristics of each single constellation (number of satellites, number of planes, inclination(s), altitude, ...), the statistics of the theoretical aggregate power levels received at an FS station are calculated by applying pfd limits under consideration to each visible satellite of the non-GSO FSS constellation (see Recommendation ITU-R F.1108). In a typical application of this methodology, the interference distribution is calculated for the FS azimuth (and for a single elevation angle) that represents the constellation worst-case, which results in distribution of interference level versus percentage of time such as given in Fig. 2.

FIGURE 2
Interference distribution produced by a non-GSO system



This methodology has typically been used as a basis in inter-service sharing studies. This has the advantage of being a simple calculation but also represents an overestimation of the real interference that could be suffered by FS stations.

With regard to the FSS characteristics, the analysis assumes that all the visible satellites radiate simultaneously at the maximum pfd limits, in the direction of the FS system under consideration. Such an assumption does not take into account the patterns of the real satellite antenna, the power limitations of each satellite or the restrictions that self-interference (as a result of frequency reuse) would impose on an FSS system as well as the fundamental operational constraints of FSS systems.

The methodology described in § 3 provides a statistical approach toward accommodating the FSS operational characteristics.

3 pfd analysis and satellite models

This methodology takes into account realistic satellite antenna patterns, the power limitations of each satellite and the restrictions that self-interference would impose on a non-GSO FSS system, as well as the fundamental operational constraints of non-GSO FSS systems.

This methodology assumes that, in a multi-satellite environment, all the satellites visible from a given point on the Earth do not simultaneously produce the maximum pfd allowed by a mask.

The parameters necessary to accurately model the pfd produced by a given satellite (maximum power, number of beams, antenna gain and antenna pattern) can generally be found in ITU-R documentation. The following is an analytical model of some of the possible parameters of a GSO FSS and a non-GSO FSS system.

The values of such parameters depend on the considered frequency band and the type of satellite (GSO or non-GSO). It is possible to derive a general equation linking them together.

In the main beam, for single beam coverage satellites, which could be implemented in certain frequency bands, the radiated power of the satellite necessary to produce the maximum pfd in the main beam is:

$$P_s = pfd_m - G_s + 10 \log(4\pi d^2) \quad (1)$$

where:

- P_s : power density of the satellite (dB(W/MHz))
- pfd_m : the maximum value of the pfd mask
- G_s : antenna gain of the satellite (dBi)
- d : range from the satellite to its sub-satellite point (m).

However, in high frequency bands such as the 20/30 GHz or 40/50 GHz bands, most satellites will more likely deploy multiple beams with higher antenna gain, transmitting on several channels. In this case, the power density of each individual beam can be calculated as:

$$P_{ds} = 10 \log \left(\frac{P_f}{BW_f} \right) = 10 \log \left(\frac{\frac{P_{tot}}{N' \times N}}{\frac{BW_{tot}}{N'}} \right) = 10 \log \left(\frac{P_{tot}}{N \times BW_{tot}} \right) \quad (2)$$

where:

- P_{ds} : satellite power density per beam (dB(W/MHz))
- P_f : power per beam (W)
- BW_f : beam bandwidth (MHz)
- P_{tot} : total radiated power available on the satellite (W)
- BW_{tot} : total bandwidth of the satellite (MHz)
- N' : number of frequency channels in BW_{tot}
- N : number of co-frequency beams.

On this basis, equations (1) and (2) allow to derive the following general equation:

$$G_b = pfd_m - 10 \log \left(\frac{P_{tot}}{N \times BW_{tot}} \right) + 10 \log(4\pi d^2)$$

which gives:

$$G_b = pfd_m - 10 \log(P_{tot}) + 10 \log(N) + 10 \log(BW_{tot}) + 10 \log(4\pi d^2) \quad (3)$$

where:

- G_b : beam antenna gain (dBi)
- pfd_m : the maximum value of the pfd mask (dB(W/(m² · MHz)))
- P_{tot} : total radiated power available on the satellite (W)
- N : number of co-frequency beams
- BW_{tot} : total bandwidth of the satellite (MHz)
- d : distance from the satellite to the centre of its pointing zone (m).

Therefore, based on this equation (3) and using existing typical values that can generally be found in ITU-R texts, it is possible to define simple satellite models which could be used in sharing studies between FSS and terrestrial services.

As an example, and in order to facilitate the understanding of and support the statistical methodology presented in this Annex, example satellite models below, assumed to be consistent with equation (3) (with a -105 dB(W/(m² · MHz)) high elevation angle pfd level), have been considered:

GSO satellites:

Model GEO1:

- beam antenna gain: 60 dBi
- number of co-frequency beams: 6
- total transmit power (for all beams): 3.5 kW
- total bandwidth: about 1 000 MHz

Model GEO2:

- beam antenna gain: 55 dBi
- number of co-frequency beams: 4
- total transmit power (for all beams): 3.5 kW
- total bandwidth: about 500 MHz

Non-GSO satellites (10 000 km altitude assumed):

Model MEO1:

- beam antenna gain: 50 dBi
- number of co-frequency beams: 4
- total transmit power (for all beams): 1.1 kW
- total bandwidth: about 700 MHz

Model MEO2:

- beam antenna gain: 45 dBi
- number of co-frequency beams: 3
- total transmit power (for all beams): 1.1 kW
- total bandwidth: about 300 MHz

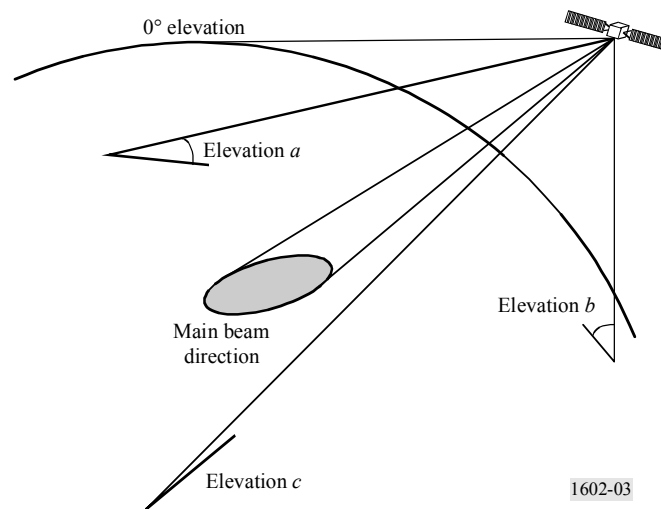
4 pfd distribution

4.1 Principles

As already stated above, the pfd produced by a given satellite, at any point on the surface of the Earth, depends on its transmitted power, antenna gain and antenna pattern.

Furthermore, as shown in Fig. 3, the maximum pfd available in the main beam is mainly controlled by the regulatory pfd limit and the antenna pattern. In many cases, depending on the pointing elevation of the satellite, the pfd in the main beam is lower than the one given by the pfd mask in order to stay within the mask for lower elevation (such as for Elevations a and c in Fig. 3).

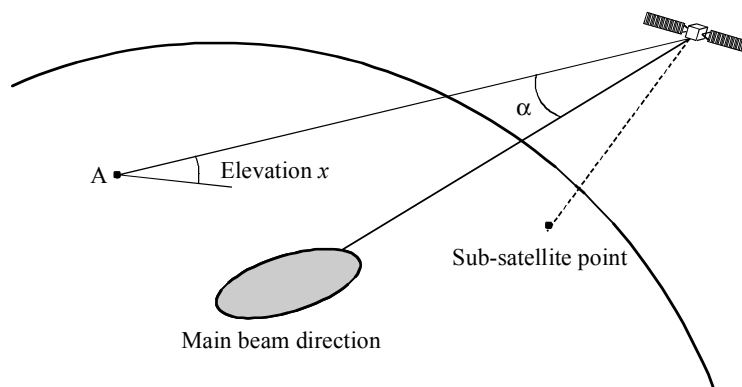
FIGURE 3



1602-03

Furthermore, as described in Figs. 4 and 5, a satellite seen from a given point A on the Earth with an Elevation x , does not generally produce a constant pfd at A. The received pfd level at A varies based on the satellite downlink beam pointing direction and may also vary based upon traffic load. However, this latter characteristic is not taken into account in this methodology.

FIGURE 4



1602-04