

RECOMMENDATION ITU-R S.1588

Methodologies for calculating aggregate downlink equivalent power flux-density produced by multiple non-geostationary fixed-satellite service systems into a geostationary fixed-satellite service network*

(Question ITU-R 236/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) adopted the combination of single-entry validation, single-entry operational and, for certain antenna sizes, single-entry additional operational downlink equivalent power flux-density (epfd_↓) limits, contained in Article 22 of the Radio Regulations (RR), along with the aggregate limits in Resolution 76 (WRC-2000), which apply to non-geostationary (GSO) fixed-satellite service (FSS) systems, to protect GSO networks in parts of the frequency range 10.7-30 GHz;
- b) that WRC-2000 adopted Resolution 76 (WRC-2000) which resolved “that, in the event that the aggregate interference levels in Tables 1A to 1D are exceeded, administrations operating non-GSO FSS systems in these frequency bands shall take all necessary measures expeditiously to reduce the aggregate epfd levels to those given in Tables 1A to 1D, or to higher levels where those levels are acceptable to the affected GSO administration”;
- c) that the single entry epfd_↓ validation limits in RR Article 22 were derived from the aggregate epfd_↓ masks contained in Resolution 76 (WRC-2000) assuming a maximum effective number of non-GSO FSS systems of 3.5;
- d) that ITU-R, using software based on the specification in Recommendation ITU-R S.1503, will evaluate each non-GSO FSS system for compliance with the single entry validation epfd_↓ limits;
- e) that the software referred to in *considering* d) takes into account worst-case non-GSO FSS operating conditions;
- f) that, according to RR No. 22.5K, administrations operating or planning to operate non-GSO FSS systems in parts of the frequency range 10.7-30 GHz will ensure that the actual aggregate interference into GSO FSS and GSO broadcasting-satellite service (BSS) networks caused by such systems operating co-frequency in these frequency bands does not exceed the aggregate power levels in Resolution 76 (WRC-2000);

* This Recommendation should be brought to the attention of Radiocommunication Working Party 6S.

- g) that the actual aggregate non-GSO FSS $\text{epfd}_\downarrow$ interference statistics into GSO FSS and GSO BSS networks can only be assessed through calculation;
- h) that methodologies are needed by administrations in order to determine compliance with aggregate $\text{epfd}_\downarrow$ limits;
- j) that non-GSO FSS systems have a variety of orbital and operating characteristics and must coordinate under the provisions of RR No. 9.12 and are likely to implement interference mitigation techniques in order to operate co-frequency with each other;
- k) that some of the technical characteristics of the non-GSO FSS constellations are available in RR Appendix 4, ITU-R Recommendations and other published information on the non-GSO FSS system;
- l) that the detailed mitigation techniques used by each non-GSO FSS system as mentioned in *considering j)*, as well as other proprietary information such as the beam switching strategy, and traffic loading on each beam of the non-GSO FSS system may not be publicly available;
- m) that it is likely that the maximum $\text{epfd}_\downarrow$ interference from different non-GSO FSS systems will occur at different locations on the Earth, and since they will have different $\text{epfd}_\downarrow$ characteristics it is likely that more than 3.5 actual non-GSO systems could operate and still be below the aggregate $\text{epfd}_\downarrow$ limits in Resolution 76 (WRC-2000);
- n) that one of the uses of the methodologies given in this Recommendation could be to compare the aggregate $\text{epfd}_\downarrow$ levels produced by multiple non-GSO systems when evaluating the joint compliance of four or more operating or planned non-GSO systems with the aggregate $\text{epfd}_\downarrow$ limits;
- o) that Resolution 76 (WRC-2000) invited ITU-R to develop, as a matter of urgency, a suitable methodology for calculating the aggregate $\text{epfd}_\downarrow$ produced by all non-GSO FSS systems operating or planning to operate co-frequency in parts of the frequency range 10.7-30 GHz into GSO FSS and GSO BSS networks, and a recommendation on the accurate modelling of interference from non-GSO FSS systems,

recommends

- 1 that the methodology(ies) described in Annex 1 (see Note 1) be used for calculating the aggregate $\text{epfd}_\downarrow$ produced by multiple non-GSO FSS systems operating or planning to operate co-frequency in the frequency bands given in Resolution 76 (WRC-2000) into earth station of GSO FSS networks, and be used to determine whether the systems are in compliance with the aggregate $\text{epfd}_\downarrow$ levels given in Resolution 76 (WRC-2000);
- 2 that Methods 1A or 1B may be used to perform an initial evaluation to determine if the aggregate $\text{epfd}_\downarrow$ levels in Resolution 76 (WRC-2000) are exceeded using the satellite pfd approach of Recommendation ITU-R S.1503, when different earth station test points are available for each non-GSO FSS system;

3 that if the evaluation in *recommends* 2 indicates that the aggregate $\text{epfd}_{\downarrow}$ levels given in Resolution 76 (WRC-2000) are exceeded then an evaluation using Methods 2A or 2B should be performed at the same set of earth station test points;

4 that, when the evaluation referred to in *recommends* 3 indicates that the aggregate $\text{epfd}_{\downarrow}$ levels would be exceeded, a more accurate evaluation using Methods 3A or 3B should be performed using coordination, operating and mitigation strategies employed between non-GSO systems and identifying the maximum pfd levels that could be produced on the Earth.

NOTE 1 – The methods in Annex 1 may be used individually or in the sequence as suggested in *recommends* 2, 3 and 4. For the determination of the exceedance of the $\text{epfd}_{\downarrow}$ levels the most accurate methodology in *recommends* 2 to 4 should be used taking into account the availability of detailed information on the non-GSO systems.

ANNEX 1

Methodologies for calculating aggregate $\text{epfd}_{\downarrow}$

1 Introduction

Three methods for calculating aggregate $\text{epfd}_{\downarrow}$ by simulation alone or simulation and convolution are described in this Annex: Methods 1 and 2 rely on the use of Recommendation ITU-R S.1503 for checking the compliance of a non-GSO system with the validation limits in RR Article 22 (Tables 22-1A, 22-1B and 22-1C), and differ in the choice of the set of test points. Method 3 proposes more detailed modelling along the lines of Recommendation ITU-R S.1325 and allows for simultaneous simulations of all the non-GSO systems.

In each method, one or more options being proposed is based on convolution. The convolution options assume a means of generating single entry $\text{epfd}_{\downarrow}$ curves for specified locations on the Earth. The additional software to do the convolution merely performs a mathematical function and therefore does not require an additional software recommendation.

However, the convolution options are potentially less accurate than the straightforward simultaneous simulation of non-GSO systems. The convolution options will lead to extremely low probabilities for the highest power $\text{epfd}_{\downarrow}$ levels. Therefore, it is proposed to truncate the calculated aggregate curve at $\text{epfd}_{\downarrow}$ levels exceeded for the shortest percentage of the time somewhere before the 0% point in the aggregate $\text{epfd}_{\downarrow}$ curve.

The convolution options assume that the interference from multiple non-GSO systems is uncorrelated. This may not be a good assumption since all non-GSO systems are required to use mitigation techniques to avoid interfering with GSO systems and other non-GSO systems. The use of simultaneous simulations are to be used to cover this case.

The three methods that are described in this Annex are increasingly accurate and as a consequence increasingly complex to run. The choice of the method to be used is likely to depend on the information available to the party that carries out the calculations. In the case of Methods 1 and 2

the calculation relies on the information provided to the Radiocommunication Bureau (BR). Method 3 goes into more detail of the non-GSO system and departs from the satellite pfd mask approach of Recommendation ITU-R S.1503 to permit simulations that take into account the coordination, operating and mitigation strategies agreed between non-GSO system operators.

2 Method 1: Convolution of the envelope of single entry $\text{epfd}_{\downarrow}$ curves at several test points

This method uses single entry $\text{epfd}_{\downarrow}$ curves generated using Recommendation ITU-R S.1503. These curves will be readily available from the BR validation assessment required of each non-GSO system. The BR will check the compliance of a non-GSO system at a single test point as defined in Recommendation ITU-R S.1503. This method, however, also covers the case where several points would be tested for a given non-GSO system, in which case the corresponding single entry $\text{epfd}_{\downarrow}$ curves would need to be produced. Since this option does not use common test locations for all non-GSO systems it can only be used to provide a preliminary check of the aggregate limits.

There are two ways that this method can be implemented. The first option is to convolve with each other one single entry $\text{epfd}_{\downarrow}$ curve from each non-GSO system to generate an aggregate mask. Therefore, if there are N non-GSO systems under test then each aggregate $\text{epfd}_{\downarrow}$ curve is the convolution of N single-entry $\text{epfd}_{\downarrow}$ curves. The result of this convolution is compared to the aggregate limit to determine if there is an exceedance. This method would require the single entry $\text{epfd}_{\downarrow}$ curve from each test location of each non-GSO system to be convolved with the single entry $\text{epfd}_{\downarrow}$ curve from each test location of all other non-GSO systems. Thus if there are M test locations for each of the N non-GSO systems then M^N convolutions are required. In this instance M refers to the test locations examined by BR.

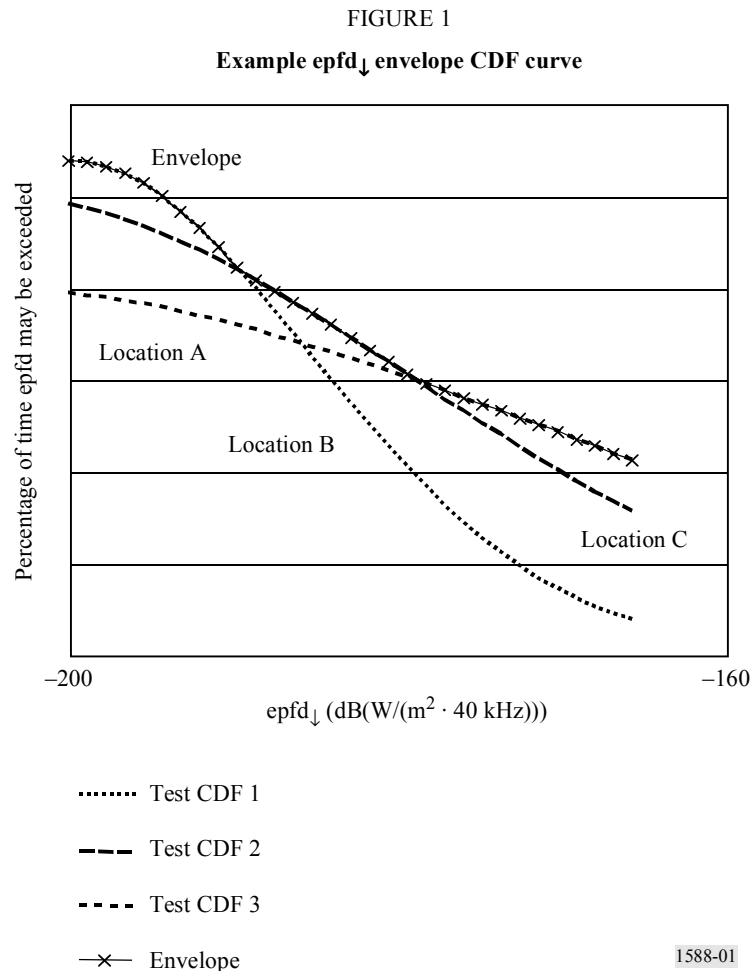
As an example consider two non-GSO systems each with three single entry $\text{epfd}_{\downarrow}$ curves generated using the satellite pfd mask approach in Recommendation ITU-R S.1503 at three different test locations. The first non-GSO system is evaluated at test locations A, B and C while the second system is evaluated at test locations D, E and F. In this case nine convolutions are required (see Table 1). Before convolving $\text{epfd}_{\downarrow}$ curves, the power values in dBW must be changed to numeric values. If no exceedance is detected for any of the resulting convolutions, then the non-GSO systems under test meet the aggregate limit requirement. However, if there is a determination that the limits have been exceeded then further investigation using Methods 2 or 3 will be required.

TABLE 1

Example of a M^N ($M = 3$, $N = 2$) convolution matrix

	A	B	C
D	A*D	B*D	C*D
E	A*E	B*E	C*E
F	A*F	B*F	C*F

A second implementation of this method is to produce for each non-GSO system a cumulative density function (CDF) envelope curve that bounds all the single entry $\text{epfd}_{\downarrow}$ curves (i.e. curves representing all the test locations) for each non-GSO system. This is illustrated in Fig. 1 for a non-GSO system with three test locations.



In this second implementation option, an aggregate test mask is calculated based on the convolution of the envelope of all the $\text{epfd}_{\downarrow}$ CDF curves of the non-GSO systems under consideration. The convolution of the $\text{epfd}_{\downarrow}$ envelope CDF curves is compared to the aggregate limits to determine if there is an exceedance.

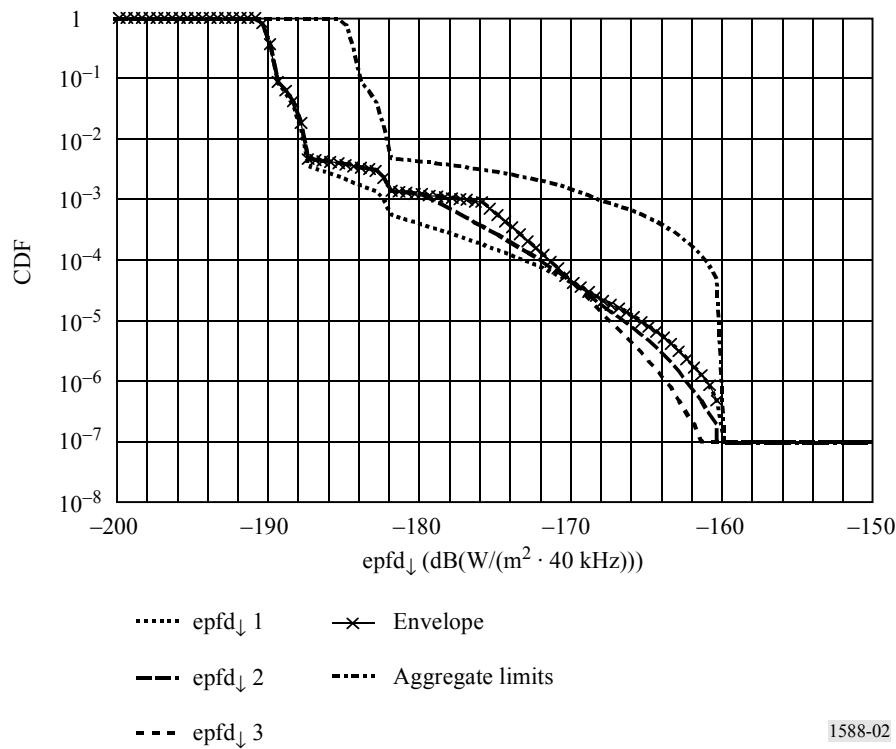
The example below demonstrates that this second implementation is equivalent to the first and has the advantage that only one convolution is required between the two non-GSO systems. In the case of n non-GSO systems there would be $n - 1$ convolutions.

2.1 Example of method

As an example, $\text{epfd}_{\downarrow}$ curves for two non-GSO satellite systems are shown in Figs. 2 and 3. Each Figure shows curves taken at three separate points, as well as the envelope of the three. For reference, the aggregate limits are also shown.

FIGURE 2

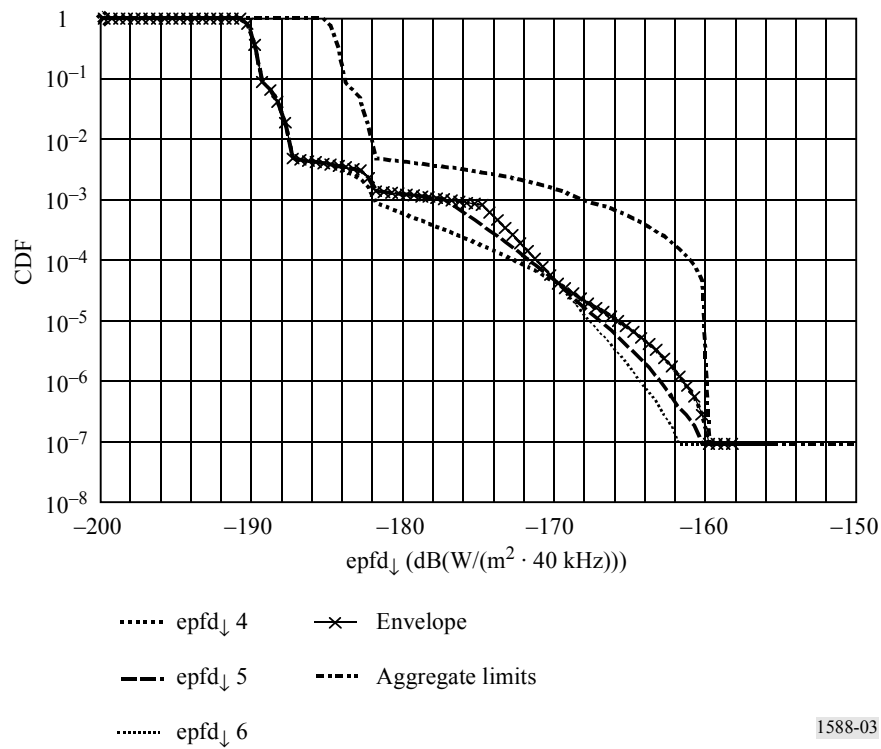
epfd_↓ curve from non-GSO system 1



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FIGURE 3

epfd_↓ curve from non-GSO system 2



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