RECOMMENDATION ITU-R SF.1483

MAXIMUM ALLOWABLE VALUES OF pfd PRODUCED AT THE EARTH's SURFACE BY NON-GSO SATELLITES IN THE FSS OPERATING IN THE 17.7-19.3 GHz BAND

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

(2000)

The ITU Radiocommunication Assembly,

considering

a) that WRC-97 adopted provisional limits on the power flux-density (pfd) produced at the surface of the Earth by non-GSO satellites operating in the FSS (space-to-Earth) in the band 17.7-19.3 GHz in order to protect terrestrial services;

b) that Resolution 131 (WRC-97) invited ITU-R to study, as a matter of urgency, the appropriate pfd values to be applied to non-GSO satellite systems in the FSS to ensure the protection of the fixed service without unduly constraining the development of either service;

c) that Recommendation ITU-R F.1495 provides the aggregate FS protection criteria in the 17.7-19.3 GHz band;

d) that the GSO interference is well below that of the non-GSO FSS aggregate interference at the FS receivers;

e) that the number of non-GSO FSS satellite constellations able to operate co-frequency in this frequency band is likely to be small;

f) that the projected development of non-GSO FSS usage in these bands indicate that co-frequency systems will not be homogeneous,

recommends

1 that in the band 17.7-19.3 GHz, the maximum pfd at the surface of the Earth from any non-GSO satellite in the FSS should not exceed, in any 1 MHz band (see Notes 1 to 3):

$-115 - X$	dB(W/m^2)	for	$\theta \leq 5°$
$-115 - X + ((10 + X)/20)\,(\theta - 5)$	dB(W/m^2)	for	$5° < \theta \leq 25°$
-105	dB(W/m^2)	for	$25° < \theta \leq 90°$

where:

θ: angle of arrival above the horizontal plane

X: function of the number of satellites in the non-GSO FSS constellation, n, as follows:

– for $n \leq 50$ $X = 0$ dB

– for $50 < n \leq 288$ $X = \frac{5}{119}(n - 50)$ dB

– for $n > 288$ $X = \frac{1}{69}(n + 402)$ dB

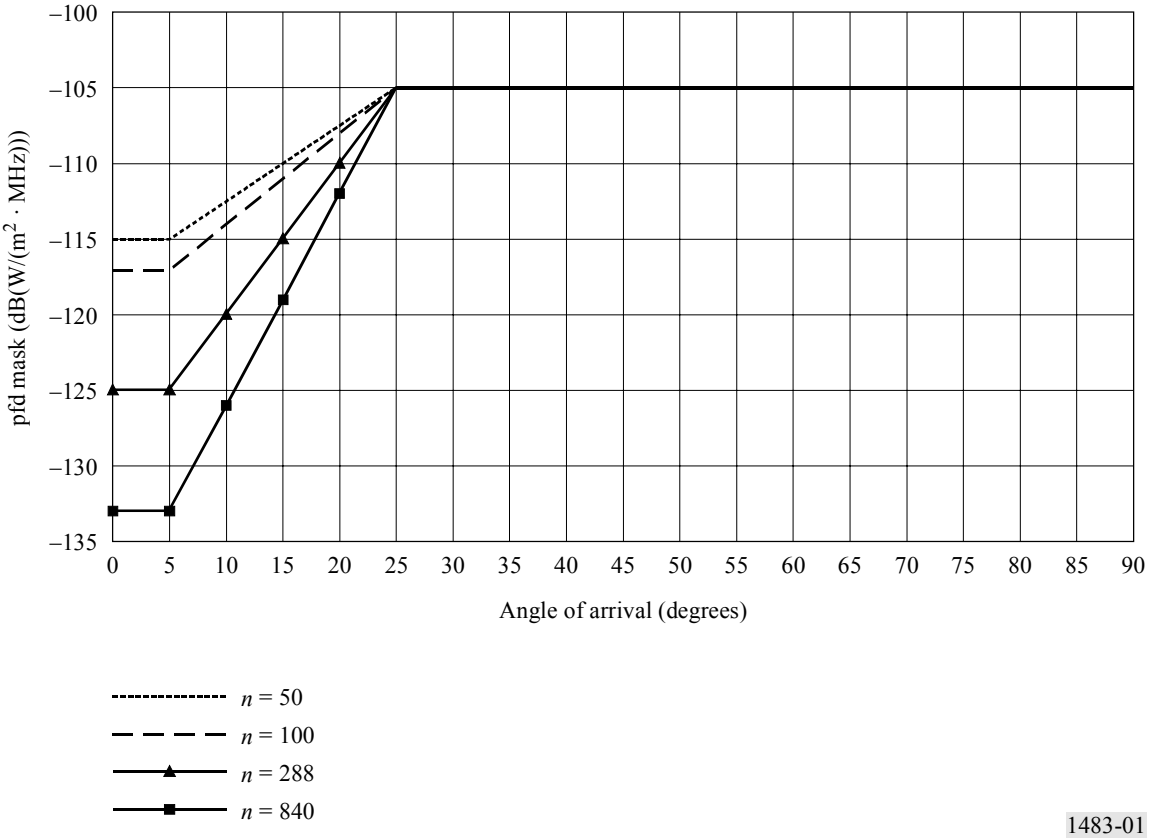
2 that these values relate to the pfd which would be obtained under assumed free-space propagation conditions;

3 that the information contained in Annex 1 was used in the derivation of these pfd limits and should be considered as guidance for their application.

NOTE 1 – The pfd limits specified in *recommends* 1 are illustrated in Fig. 1.

FIGURE 1

Non-GSO FSS pfd mask for various values of *n*



NOTE 2 – The limits specified in this Recommendation are based on analyses of candidate pfd limits that would result in interference below permissible levels and enable satisfactory operation of satellite systems.

NOTE 3 – The specified pfd limits are based on analyses that assumed every satellite in the constellation produced emissions at the maximum levels allowed by the pfd limits for all angles of arrival. Analyses taking into account the actual operational characteristics of the non-GSO network have shown that substantially lower aggregate power flux-density (apfd) levels will be produced.

ANNEX 1

Derivation of pfd limits applicable to non-GSO FSS space stations in the band 17.7-19.3 GHz

1 Characteristics of the FS

The FS characteristics used for the evaluation of pfd limits for non-GSO FSS satellites in the 17.7-19.3 GHz band are given in Table 1.

TABLE 1

Elevation angles (degrees)	0 and 2.2
Antenna height (m)	0
Antenna gain (dBi)	32, 38 and 48
Antenna pattern	Recommendation ITU-R F.1245
Latitudes (degrees)	25, 45 and 60
Gaseous attenuation	Recommendation ITU-R SF.1395
Feeder loss (dB)	3
Polarization loss	Recommendation ITU-R F.1245 (Note 7)
Receiver thermal noise (dB(W/MHz))	–139

These characteristics are representative of a majority of links in that frequency range.

2 FS protection criteria

The aggregate FS protection criteria in the 17.7-19.3 GHz band are given as follows in Recommendation ITU-R F.1495:

Long-term: I/N should not exceed –10 dB for more than 20% of the time

Short-term: I/N should not exceed +14 dB for more than 0.01% of the time

I/N should not exceed +18 dB for more than 0.0003% of the time.

Note that the short-term criteria were established to protect sensitive FS links.

3 Methodologies used to assess the adequacy of the limits to protect the FS

Pfd mask analysis has been used for assessing the adequacy of the pfd limits for the protection of the FS; the statistics of the theoretical aggregate power levels received at a FS station are calculated by applying pfd limits under consideration to each visible satellite of the non-GSO FSS constellation (see Note 1).

In the derivation of the pfd limits defined in *recommends* 1, it was determined that if the calculated I/N results exceed the criteria of § 2 by no more than a few dB for worst-case geometries, this does not mean that the FS links would actually be impaired. It must be noted that the pfd mask analysis is overly conservative in that it computes interference (both long-term and short-term) that exceeds what would be produced by an operating non-GSO FSS system. This is because the analysis assumes that all the visible satellites of the non-GSO FSS satellite constellation radiate simultaneously the maximum pfd limit, in the direction of the FS system under consideration, which is unrealistic. In addition, 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 would impose on a non-GSO satellite system.

Calculations are made assuming that the FS receiver antenna is pointing in the direction of the worst-case azimuth for the non-GSO satellite constellation under consideration, since in that pointing direction, the long-term and short-term power levels generated by the non-GSO satellite constellation into the FS receivers are maximum.

Studies that have considered a more realistic modelling of the problem have produced results providing further evidence supporting that the pfd limits in *recommends* 1 are adequate. The method used takes into account some fundamental operational constraints of non-GSO FSS systems by using more realistic downlink models developed to generate pfd distribution profiles for a range of arrival angles which are used in place of the maximum-allowed pfd mask.

NOTE 1 – Annex 1 of Recommendation ITU-R F.1108 provides guidance on the calculation of visibility statistics of space stations operating in circular non-GSO orbits as seen by a terrestrial station.

4 Aggregation of multiple non-GSO satellite constellations in the FSS

Based on studies presented, the conclusion is that the aggregate interference criteria described in § 2 can be applied to each single FSS satellite constellation. These conclusions are based on simulations performed for three assumed non-homogeneous non-GSO satellite systems in the 18 GHz band, and are justified by the following considerations:

– the projected development of non-GSO FSS usage in these bands indicates that co-frequency systems will not be homogeneous, and therefore the worst-case azimuths will be different for each of the non-GSO FSS systems;

– the simulations for each given constellation are run in its worst-case azimuth which is different for each constellation since they are non-homogeneous;

– the expected number of co-frequency non-GSO FSS systems is expected to be small. The number of co-frequency non-homogeneous non-GSO FSS systems is expected to be less than the number of co-frequency homogeneous non-GSO FSS systems;

– it was agreed that these results would remain valid if the number of non-homogeneous non-GSO FSS systems were in the range 3 to 5;

– the methodology used for the simulations applied the full pfd mask for each satellite in view. This assumption is overly conservative (see § 3) in that all the satellites from the co-frequency constellations cannot be expected to transmit simultaneously the full power limits of the pfd mask in all directions.

5 Scaling function in pfd mask definition

The scaling function, X, contained in *recommends* 1 was developed on the basis of non-GSO FSS satellite constellations with 96, 288 and 840 satellites. Further simulations with different non-GSO FSS satellite constellations comprising a wide range in the number of satellites (63, 126, 189, 252 and 504 satellites) and using the conservative pfd mask simulation method have confirmed the adequacy of this scaling function.

6 Conclusion

Extensive studies have provided ample technical justification that the pfd limits of *recommends* 1 are certainly adequate to protect the FS systems from aggregate interference from the satellites of multiple, co-frequency non-GSO FSS systems operating in the 17.7-19.3 GHz band. Therefore the pfd limits of *recommends* 1 are acceptable in that they protect the FS systems without unduly constraining the development of non-GSO FSS networks.