

RECOMMENDATION ITU-R S.1589

Continuous curves of $\text{epfd}_{\downarrow}$ versus geostationary fixed-satellite service earth station antenna diameter and $\text{epfd}_{\uparrow}$ versus geostationary fixed-satellite service space station antenna beamwidth to indicate the protection afforded by systems complying with the limits to antennas with diameters other than those in Article 22 of the Radio Regulations

(Question ITU-R 231/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that the frequency bands 11-14 GHz and 20-30 GHz are available to systems in the fixed-satellite service (FSS) employing satellites in both geostationary (GSO) and non-GSO orbits;
- b) that earth stations in the FSS employing satellites in GSO orbits need to be protected from unacceptable interference by satellites in non-GSO orbits transmitting in the shared frequency bands;
- c) that in order to provide the requisite protection from such interference, the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) adopted validation single-entry limits on the maximum permissible equivalent power flux-densities (epfd) which satellites in non-GSO orbits may radiate in some frequency bands, for certain specified earth station antenna diameters;
- d) that the Radiocommunication Bureau (BR) will certify compliance with the maximum permissible downlink epfd ($\text{epfd}_{\downarrow}$) validation limits only for those earth station antenna diameters specified in Article 22 of the Radio Regulations (RR);
- e) that as indicated in *resolves* 3 of Resolution 137 (WRC-2000) there is a need for GSO FSS network designers to be able to assess the level of interference generated by a non-GSO system meeting the $\text{epfd}_{\downarrow}$ limits for earth station antennas with diameters other than those specified in RR Article 22;
- f) that the BR will certify compliance with the maximum permissible uplink epfd ($\text{epfd}_{\uparrow}$) validation limits only for those reference radiation patterns specified in RR Article 22;
- g) that as indicated in *resolves* 3 of Resolution 137 (WRC-2000) there is a need for GSO FSS network designers to be able to assess the level of interference generated by a non-GSO system meeting the $\text{epfd}_{\uparrow}$ limits for space station antenna beamwidths other than those specified in RR Article 22,

recommends

1 that the methodologies in Annexes 1 and 2 be used within their specified contexts, for the guidance of designers of GSO FSS links on the maximum expected epfd levels for earth station antenna diameters other than those specified in RR Article 22 (see Notes 1 and 2);

2 that the methodology in Annex 3 be used, within its specified context, for the guidance of designers of GSO FSS links on the maximum expected epfd levels for space station antenna beamwidths other than those specified in RR Article 22.

NOTE 1 – The guidance to the GSO FSS designers is to be taken in this context: the continuous curves provide an approximation of how the regulatory limits of RR Article 22 could appear if they were defined for an arbitrary antenna diameter. In this respect these continuous curves are intended to provide guidelines on the upper bound of interference that GSO FSS earth stations might receive.

NOTE 2 – The epfd levels in this Recommendation are referenced to a bandwidth of 40 kHz. To convert to other bandwidths, a correction factor of $10 \log(B/40)$ may be added to the value of epfd, where B is the required bandwidth (kHz).

ANNEX 1

Methodology to derive continuous curves of epfd_↓ versus GSO FSS earth station antenna diameter in the frequency range 10.7-12.75 GHz

(Validation limits in RR Table 22-1A;
additional operational limits in RR Table 22-4A1)

1 Introduction

RR Article 22 contains limits to the epfd, which may be radiated by non-GSO FSS systems transmitting in the shared frequency bands, in order to protect FSS systems operating in the GSO from unacceptable interference. The epfd limits are defined for a small number of GSO FSS earth station antenna diameters, and it is recognized that designers of GSO FSS networks would need some guidance on the expected levels of interference into antennas with other diameters. This Annex provides such guidance, in the form of continuous curves of epfd, derived from the single-entry values for the validation limits and for the additional operational limits in RR Article 22 which apply in the 10.7-12.75 GHz frequency bands.

This Annex covers a subset of the limits defined in RR Article 22. The frequency bands considered are:

- 10.7-11.7 GHz in all Regions;
- 11.7-12.2 GHz in Region 2;
- 12.2-12.5 GHz in Region 3;
- 12.5-12.75 GHz in Regions 1 and 3.

The values of $\text{epfd}_\downarrow$ derived are:

- referenced to a bandwidth of 40 kHz;
- applicable to GSO systems with inclination angles less than 2.5° ;
- applicable to latitudes below 60° ;
- where relevant, applicable after 31 December 2005;
- applicable to antenna diameters in the range 0.6-18 m for the validation limits;
- applicable to antenna diameters in the range 3-18 m for the additional operational limits.

The curves for $\text{epfd}_\downarrow$ are derived from curve-fitting to the values tabulated in RR Article 22, and are only intended as best approximations.

2 RR Article 22 validation limits

The validation limits for the frequency band 10.7-12.75 GHz are given in Table 1, based on RR Table 22-1A, in terms of the percentage of time during which the $\text{epfd}_\downarrow$ level may be exceeded.

TABLE 1

Limits to the $\text{epfd}_{\downarrow}$ radiated by non-GSO FSS systems in certain frequency bands

Frequency band (GHz)	$\text{epfd}_{\downarrow}$ (dB(W/m ²))	Percentage of time during which $\text{epfd}_{\downarrow}$ level may be exceeded	Reference bandwidth (kHz)	Reference antenna diameter and reference radiation pattern
10.7-11.7 in all Regions; 11.7-12.2 in Region 2; 12.2-12.5 in Region 3 and 12.5-12.75 in Regions 1 and 3	-175.4	100	40	60 cm Recommendation ITU-R S.1428
	-174	10		
	-170.8	1		
	-165.3	0.07		
	-160.4	0.009	40	1.2 m Recommendation ITU-R S.1428
	-160	0.003		
	-160	0		
	-181.9	100		
	-178.4	0.5		
	-173.4	0.26		
	-173	0.143		
	-164	0.046		
	-161.6	0.016		
	-161.4	0.009		
	-160.8	0.003		
	-160.5	0.003		
	-160	0.0007		
	-160	0		
	-190.45	100	40	3 m Recommendation ITU-R S.1428
	-189.45	10		
	-187.45	0.5		
	-182.4	0.3		
	-182	0.145		
	-168	0.029		
	-164	0.012		
	-162	0.005		
	-160	0.001		
	-160	0		
	-195.45	100	40	10 m Recommendation ITU-R S.1428
	-195.45	1		
	-190	0.35		
	-190	0.29		
	-172.5	0.01		
	-160	0.002		
	-160	0		

The validation limit reference curves are constructed by linear interpolation between values of $\text{epfd}_{\downarrow}$ (dB) and by logarithmic interpolation between values of percentage of time for which the $\text{epfd}_{\downarrow}$ may be exceeded.

The additional operational limits for the frequency band 10.7-12.75 GHz are given in Table 2, based on RR Table 22-4A1, in terms of the percentage of time during which the $epfd_{\downarrow}$ level may be exceeded.

TABLE 2

Additional operational limits on the $epfd_{\downarrow}$ radiated by non-GSO FSS systems into 3 m and 10 m GSO FSS earth station antennas

$epfd_{\downarrow}$ (dB(W/(m ² · 40 kHz)))	Percentage of time during which $epfd_{\downarrow}$ level may be exceeded	Receive GSO earth station antenna diameter (m)
-182 -179 -176 -171 -168 -165 -163 -161.25 -161.25	0.1 0.06 0.03 0.02 0.016 0.007 0.001 0.00025 0	3
-185 -183 -179 -175 -171 -168 -166 -166	0.03 0.02 0.01 0.004 0.002 0.001 0.0002 0	10

3 Continuous curves for validation limits (RR Table 22-1A)

3.1 Antenna diameters between 0.6 and 10 m

Two limits are defined for the values of $epfd_{\downarrow}$ (dB(W/(m² · 40 kHz))) which may be exceeded for 0% and 100% of time:

$$epfd_0 = -160.0 \text{ dB(W/(m}^2 \cdot 40 \text{ kHz))} \quad (1)$$

$$epfd_{100} = \begin{cases} -180.18 - 21.53 \log D & \text{for } D < 3 \\ -185.89 - 9.562 \log D & \text{for } D \geq 3 \end{cases} \quad (2)$$

where D is the antenna diameter (m).

Two intermediate functions, Φ_1 and Φ_2 are first defined, which are combined by taking their mean value to yield the final curve.

The function Φ_1 , derived from curve-fitting to the validation limits, is defined as:

$$\Phi_1(p, D) = -179.77 + \frac{15.114 + 4.794 D}{1 + \exp \left(\frac{0.7042 + 0.159 D + \log p}{1.948 - \frac{1}{0.5976 + (\log D - 0.263)^2}} \right)} - 19.16 \log D \quad (3)$$

where:

p : percentage of time that the level of epfd may be exceeded

D : antenna diameter (m).

The value of Φ_1 is subject to the following three boundary conditions:

$$\Phi_1(p, D) = \begin{cases} \text{epfd}_0 & \text{if } p \leq 0.001 \\ \text{epfd}_0 & \text{if } \Phi_1 > \text{epfd}_0 \\ \text{epfd}_{100} & \text{if } \Phi_1 < \text{epfd}_{100} \end{cases} \quad (4)$$

The function Φ_2 , derived from an interpolation between the reference curves, is given by:

$$\Phi_2(p, D) = \begin{cases} \text{epfd}_{v0.6}(p) + 3.3219 [\text{epfd}_{v1.2}(p) - \text{epfd}_{v0.6}(p)] \log \left(\frac{D}{0.6} \right) & \text{for } 0.6 \leq D \leq 1.2 \\ \text{epfd}_{v1.2}(p) + 2.5130 [\text{epfd}_{v3}(p) - \text{epfd}_{v1.2}(p)] \log \left(\frac{D}{1.2} \right) & \text{for } 1.2 < D \leq 3 \\ \text{epfd}_{v3}(p) + 1.9125 [\text{epfd}_{v10}(p) - \text{epfd}_{v3}(p)] \log \left(\frac{D}{3} \right) & \text{for } 3 < D \leq 10 \end{cases} \quad (5)$$

where $\text{epfd}_{v0.6}(p)$, $\text{epfd}_{v1.2}(p)$, $\text{epfd}_{v3}(p)$ and $\text{epfd}_{v10}(p)$ are the validation limits in RR Table 22-1A for the respective antenna diameters, interpolated to the appropriate percentage of time.

The resulting value of $\text{epfd}_\downarrow$ (dB(W/(m² · 40 kHz))) for antenna diameters between 0.6 m and 10 m is given by:

$$\text{epfd}_{22-1A}(p, D) = -\sqrt{\Phi_1(p, D) \cdot \Phi_2(p, D)} \quad \text{for } 0.6 \leq D \leq 10 \quad (6)$$

3.2 Antenna diameters between 10 m and 18 m

The curves are extrapolated up to an antenna diameter of 18 m by treating the short-term and long-term components separately. The short-term part of the curve is derived through time-shifting by scaling p by $(D_{ref}/D)^2$, while the long-term part is derived through power-addition of the epfd by adding $20 \log(D_{ref}/D)$. Two intermediate functions, Φ_3 and Φ_4 , are defined, corresponding to the long-term and short-term parts, respectively:

$$\Phi_3(p, D) = \text{epfd}_{v10}(p) + 20 \log \left(\frac{10}{D} \right) \quad (7)$$

$$\Phi_4(p, D) = \text{epfd}_{v10} \left(p \cdot \frac{D^2}{100} \right) \quad (8)$$

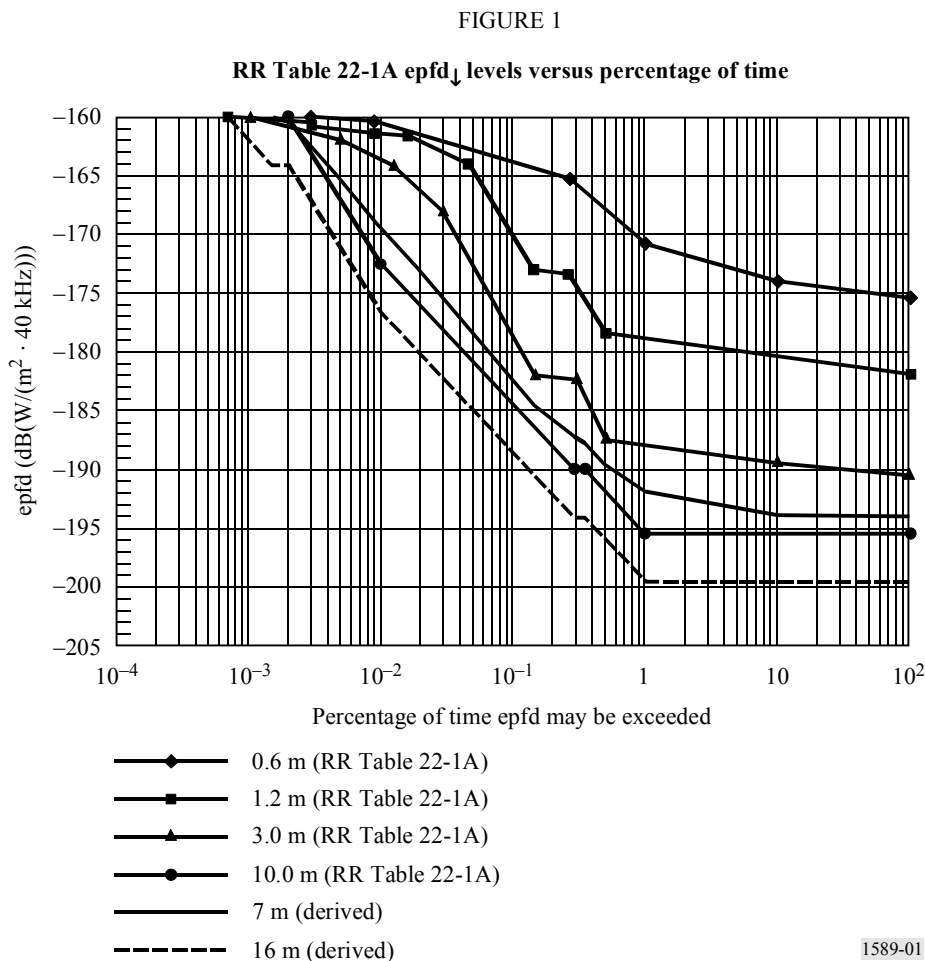
The resulting value for $epfd$ is derived from the short-term curve for increasing time percentages up to the first point at which the curves intersect, and from the long-term curve for higher time percentages. This intersection point is defined in terms of the antenna diameter by:

$$p_{c1} = 0.000179 + \frac{0.0182}{D} \quad (9)$$

The value of $epfd_{\downarrow}$ (dB(W/(m² · 40 kHz))) for antenna diameters between 10 m and 18 m is then given by:

$$epfd_{22-1A}(p, D) = \begin{cases} \Phi_3(p, D) & \text{for } 0 \leq p \leq p_{c1} \quad \text{and } 10 < D \leq 18 \\ \Phi_4(p, D) & \text{for } p_{c1} < p \leq 100 \quad \text{and } 10 < D \leq 18 \end{cases} \quad (10)$$

Figure 1 shows the RR Table 22-1A limits together with derived values for antenna diameters of 7 m and 16 m, while Fig. 2 illustrates the variation with antenna diameter for the levels of $epfd_{\downarrow}$ which may be exceeded for some example percentages of time.



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