

RECOMMENDATION ITU-R SF.1004*

**MAXIMUM EQUIVALENT ISOTROPICALLY RADIATED POWER TRANSMITTED
TOWARDS THE HORIZON BY EARTH STATIONS OF THE FIXED-SATELLITE
SERVICE SHARING FREQUENCY BANDS WITH THE FIXED SERVICE**

(1993)

The ITU Radiocommunication Assembly,

considering

- a) that systems in the fixed-satellite service (FSS) and the fixed service share certain frequency bands;
- b) that, to avoid significant interference to systems in the fixed service, it is necessary to define maximum allowable values for the equivalent isotropically radiated power (e.i.r.p.) of earth stations in the FSS towards the horizon;
- c) that the maximum allowable values of radiated power should be such as not to place undue restriction on the design of earth stations of the FSS,

recommends

1. that in those frequency bands** between 1 and 15 GHz, shared between the FSS (Earth-to-space) and the fixed service, the equivalent isotropically radiated power (e.i.r.p.) transmitted in any direction towards the horizon by an earth station of the FSS shall not exceed the following limits except as provided in § 4:

+40 dBW in any 4 kHz band for $\theta \leq 0^\circ$

+40 +3 θ dBW in any 4 kHz band for $0^\circ < \theta \leq 5^\circ$

where θ is the angle of elevation of the horizon viewed from the centre of radiation of the antenna of the earth station and measured in degrees as positive above the horizontal plane and negative below it;

2. that, in those frequency bands** above 15 GHz, shared between the FSS (Earth-to-space) and the fixed service, the e.i.r.p. transmitted in any direction towards the horizon by an earth station of the FSS shall not exceed the following limits except as provided in § 4:

+64 dBW in any 1 MHz band for $\theta \leq 0^\circ$

+64 +3 θ dBW in any 1 MHz band for $0^\circ < \theta \leq 5^\circ$

where θ is as defined in § 1;

3. that for angles of elevation of the horizon greater than 5° there shall be no restriction as to the e.i.r.p. transmitted by an earth station towards the horizon;
4. that the limits given in § 1 and 2 may be exceeded by not more than 10 dB; however, when the resulting coordination area extends into the territory of another country, such increase shall be subject to agreement by the administration of that country;
5. that Annex 1 should be referred to for the background information for determining the maximum allowable values of radiated power (see Note 2).

Note 1 – Definitive limits applicable in shared frequency bands are laid down in Article S21 of the Radio Regulations (RR) (Nos. S21.8 to S21.12). This issue continues to be studied, and may lead in the future to a Recommendation that the limits should be revised. At the present time, no changes are proposed to the limits as laid down in the RR.

* Radiocommunication Study Groups 4 and 9 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

** The frequency bands concerned are given in the Radio Regulations.

Note 2 – Annex 1 mainly discusses the case of analogue systems operating in frequency bands between 1 and 15 GHz. Further study is required for analysis of the cases of digital systems operating in frequency bands below 15 GHz and analogue and digital systems above 15 GHz.

ANNEX 1

Determination of the power in any 4 kHz band radiated towards the horizon by earth stations of the fixed-satellite service sharing frequency bands below 15 GHz with the fixed service

1. Requirements of systems in the fixed-satellite service (FSS)

In considering a limit on the permissible horizontally radiated power of earth stations, it is important to bear in mind the needs of systems in the FSS that can reasonably be foreseen. This must include systems for multi-channel telephony, television and sound. The use of telephony channels to convey signals such as voice-frequency telegraphy, data and tones for test and signalling purposes must be taken into account, where this affects the maximum power to be transmitted in any 4 kHz band. This bandwidth is appropriate for the protection of analogue angle-modulated radio-relay systems against interfering signals. Any limit of power so established must be suitable for the various methods of modulation, numbers of telephone channels and earth-station antenna sizes that might be used. It is also necessary to consider the characteristics of the satellites which may be used, including the apportionment of noise and the satellite antenna gain. Operational requirements for margin and carrier energy dispersal also bear significantly on the final result.

2. Equivalent isotropically radiated power (e.i.r.p.) of earth-station main beam

Consideration is given to the power requirements for two types of multi-channel telephony systems which are illustrative of those likely to require the highest value of transmitted power in any 4 kHz band. The requirements for frequency-modulated television transmission are not thought likely to exceed the values for equal-baseband telephony transmissions, assuming that suitable energy dispersal techniques are being employed.

General equations are presented for the determination of acceptable levels of radiated powers of earth stations. The actual powers may be calculated by substituting the values appropriate to the satellite system under consideration.

2.1 Frequency-modulation systems

The required total signal power, P_r , at the input to a satellite receiver is given by:

$$P_r = S/N + 10 \log (k T b) - P - 20 \log (f_r / f_m) \quad \text{dBW} \quad (1)$$

where:

- S/N : signal-to-noise power ratio corresponding to an assumed up-path noise contribution in a band of width b (usually a telephone channel) (dB)
- k : Boltzmann's constant: 1.38×10^{-23} J/K
- T : noise temperature of satellite receiving system (K)
- b : bandwidth of a channel considered (Hz). For a telephone channel $b = 3\,100$ Hz
- P : pre-emphasis improvement (dB)
- f_r : r.m.s. channel test tone (0 dBm0) deviation (MHz)
- f_m : top baseband frequency (MHz).

To realize the required carrier power at the satellite input an earth station may have to radiate an e.i.r.p., D_s , in a 4 kHz band of up to:

$$D_s = P_r - (28 + 10 \log dF) + M_u - 20 \log (\lambda / 4 \pi R) - G_r + 3 \quad \text{dBW} \quad (2)$$

where:

the 3 dB accounts for light loading conditions when spectrum dispersal techniques are applied according to Recommendation ITU-R S.446

M_u : up-path transmission margin (dB)

λ : wavelength of carrier frequency (m)

R : range to satellite (m)

G_r : receive gain of satellite antenna (dB).

The second term in the expression for D_s establishes the highest occurring ratio between the power in a 4 kHz band and the total carrier power (see Recommendation ITU-R S.446), under the assumption that the spectral distribution of the radio-frequency signal is Gaussian with a multi-channel r.m.s. deviation of:

$$dF = f_r L \quad \text{MHz} \quad (3)$$

where:

$$L = 0.178 \sqrt{n}$$

n : number of telephone channels considered.

Dispersal techniques are specified in Recommendation ITU-R S.446 which are intended to limit spectral densities from reaching significantly higher values under light loading conditions.

2.2 Single-sideband, amplitude-modulation systems (SSB/AM)

For an SSB/AM system, the power per channel to be received at the satellite input is given by:

$$P_r = S/N + 10 \log (k T b) \quad \text{dBW} \quad (4)$$

which, with the usual channel spacing of 4 kHz, yields the required earth station e.i.r.p. in a 4 kHz band from:

$$D_s = P_r - 20 \log (\lambda / 4 \pi R) - G_r + M_u \quad \text{dBW} \quad (5)$$

for a 0 dBm0 exciting signal. It should be noted that there is considerable variation of speech signal power among the telephone circuits, but it is considered appropriate to take a value of 0 dBm0 as the maximum power in a telephone channel, averaged over an integrating time of a few seconds.

3. Power radiated towards the horizon, in any 4 kHz band

Since earth stations will usually take advantage of site shielding, knowledge of radiated power in the horizontal plane, as previously defined, is of limited practical interest. Instead, to describe more clearly the radiation characteristics of an earth station, the effective radiated power toward the physical horizon, in any 4 kHz band, should be determined and stated.

It is necessary to determine the smallest occurring angle ϕ between the main beam of an antenna and the physical horizon, since a decrease of this angle is accompanied by a prohibitive increase in the noise temperature of the receiving system and, at many locations, in depth of fade, a minimum value of $\phi = 1^\circ$ is stipulated.

Given the minimum angle of elevation, ϵ , of the main beam of the earth station, then ϕ is to be computed from $\phi = \epsilon - \theta_E$ where θ_E is the angle of elevation of the horizon at the same azimuth for which ϵ occurs. All angles are in degrees.

With ϕ given, the e.i.r.p. towards the horizon, in any 4 kHz band, may be computed:

$$\begin{aligned} E_H &= D_s - G_s + 32 - 25 \log \phi & \text{dBW} & \quad \text{for } 1^\circ \leq \phi \leq 48^\circ \\ &= D_s - G_s - 10 & \text{dBW} & \quad \text{for } 48^\circ < \phi \leq 180^\circ \end{aligned} \quad (6)$$

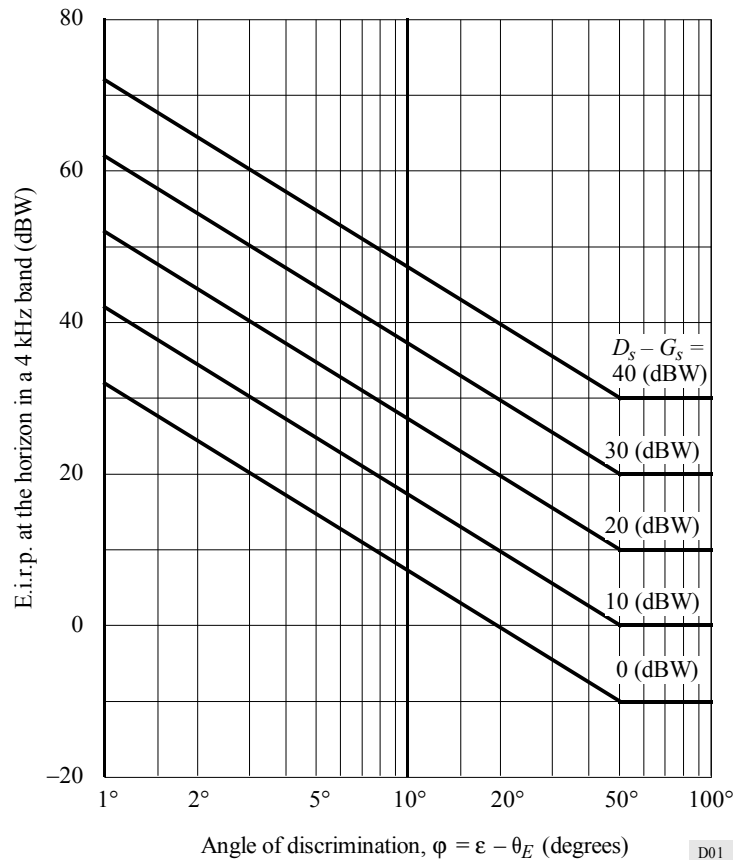
where G_s is the maximum antenna gain of the earth station.

The expression of E_H is derived from an equation describing large-aperture earth-station antenna patterns given in Recommendation ITU-R S.465, and the same reservations as to the validity of the equation apply as stated in the Recommendation. In particular, for some values of ϕ the real antenna gain component may exceed the corresponding value of the equation by several decibels.

The angle of elevation of the horizon, θ_E , should be determined from at least the centre altitude of the antenna.

Figure 1 shows the e.i.r.p. towards the horizon as a function of the angle of discrimination with the input power-density to the antenna in any 4 kHz band, $D_s - G_s$, as a parameter.

FIGURE 1
E.i.r.p. towards the horizon as a function of the angle of discrimination, ϕ
 $D_s - G_s$ (dBW) parameter



Values of $D_s - G_s$ not coinciding with any of the curves shown may be interpolated linearly in the decibel domain. Appendix 1 provides two representative examples for the derivation of values of $D_s - G_s$.

In the horizontal plane a value of e.i.r.p. of about 35 dBW in any 4 kHz band for an antenna operating at a main beam elevation angle of 3° is generally sufficient for the operation of current systems in the FSS. Some margin is required, however, to allow for future systems such as those using smaller diameter antennas, higher channel capacities and different methods of modulation. The limits which were established at the World Administrative Radio Conference (Geneva, 1979) (CAMR-79) appear to meet these requirements.

Specific limits for the e.i.r.p. of earth stations are laid down in the main text of this Recommendation.

4. Consideration of modulating signals other than telephone channels, or of types of modulation other than frequency modulation or single sideband

Where an earth station is being built to be used exclusively with systems in the FSS using modulating signals other than telephone channels, in particular television, or using methods of modulation other than frequency-modulation or single-sideband, calculation of values for D_s may be restricted to such modulating signals or methods of modulation.

APPENDIX 1

TO ANNEX 1

The following examples serve to illustrate the use of the equations. Representative parameter values for a 1 200 channel system in the FSS have been assumed.

Parameter	FDM/FM	SSB/AM
S/N up (dB) ⁽¹⁾	56 ⁽¹⁾	56 ⁽¹⁾
T (K)	1 500	1 500
P (dB)	2.5	
f_r (MHz)	1.1	
f_m (MHz)	5.0	
P_r (dBW)	−95	−106
dF (MHz)	6.8	
M_u (dB)	3.0	3.0
λ (m)	5×10^{-2}	5×10^{-2}
R (m)	4.16×10^7	4.16×10^7
G_r (dB)	13.0	13.0
D_s (dB(W/4 kHz))	62.1	84.4
G_s (dB)	64.0	64.0
$D_s - G_s$ (dB(W/4 kHz))	−2	20

⁽¹⁾ Corresponding to an up-path noise contribution of 1 400 pW.