

SECTION 4B: SYSTEMS ASPECTS – PERFORMANCE AND AVAILABILITY

4B1: Systems aspects

RECOMMENDATION ITU-R S.728-1

**MAXIMUM PERMISSIBLE LEVEL OF OFF-AXIS e.i.r.p. DENSITY
FROM VERY SMALL APERTURE TERMINALS (VSATs)**

(Question ITU-R 23/4)

(1992-1995)

The ITU Radiocommunication Assembly,

considering

- a) that geostationary-satellite networks in the fixed-satellite service (FSS) operate in the same frequency bands;
- b) that interference between networks in the FSS contributes to noise in the network;
- c) that it is necessary to protect a geostationary-satellite network in the FSS from interference by other such networks;
- d) that it is necessary to specify the maximum permissible levels of off-axis e.i.r.p. density from VSAT earth stations, to promote harmonization between geostationary-satellite networks;
- e) that networks in the FSS may receive interference into the space station receiver;
- f) that the use of antennas with good off-axis performance will lead to the most efficient use of radio-frequency spectrum and the geostationary-satellite orbit (GSO);
- g) that progress in the development of VSAT antennas indicates that improved side-lobe performance antennas are widely available;
- h) that off-axis e.i.r.p. density levels can be limited through the choice of antenna and/or transmission parameter, e.g. using high gain forward error correction scheme for demodulation or using the spread-spectrum technique;
- j) that in some VSAT systems the code division multiple access (CDMA) scheme is used so that multiple VSATs may transmit simultaneously in the same frequency channel,

recommends

1 that VSAT earth stations operating with geostationary satellites in the 14 GHz frequency band used by the FSS be designed in such a manner that at any angle φ specified below, off the main-lobe axis of an earth-station antenna, the maximum e.i.r.p. in any direction within 3° of the GSO should not exceed the following values:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. in any 40 kHz band</i>
$2^\circ \leq \varphi \leq 7^\circ$	$33 - 25 \log \varphi$ dBW
$7^\circ < \varphi \leq 9.2^\circ$	12 dBW
$9.2^\circ < \varphi \leq 48^\circ$	$36 - 25 \log \varphi$ dBW
$\varphi > 48^\circ$	-6 dBW

In addition, the cross-polarized component in any direction ϕ degrees from the antenna main-lobe axis should not exceed the following limits:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. in any 40 kHz band</i>
$2^\circ \leq \phi \leq 7^\circ$	$23 - 25 \log \phi$ dBW
$7^\circ < \phi \leq 9.2^\circ$	2 dBW

2 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – Maximum e.i.r.p. density values in § 1 above may need to be decreased up to 8 dB in the systems where the satellite spacing is near 2° .

NOTE 2 – For the systems in which the earth stations are expected to transmit simultaneously in the same 40 kHz band, e.g. for the systems employing CDMA, the maximum e.i.r.p. values in § 1 above should be decreased by $10 \log N$ (dB), where N is the number of earth stations which are expected to transmit simultaneously on the same frequency.

NOTE 3 – Recommendations for VSATs operating in the 6 GHz and other frequency bands are under study. Provisionally Recommendation ITU-R S.524 should be applied for these bands.

NOTE 4 – The values given in § 1 may be exceeded over the range of angles for which the particular feed system may give rise to relatively high levels of spill-over.

NOTE 5 – The limits given in § 1 could be increased up to the limits of Recommendation ITU-R S.524 in case of very large service areas.

NOTE 6 – Annex 1 describes the calculation of permissible off-axis e.i.r.p. density for VSATs.

NOTE 7 – Earth station antennas with D/λ ratios less than 50 are likely to have main beams which extend beyond an off-axis angle of 2° to 3° . Annex 2 shows examples of the main beamwidths of some of these antennas. The off-axis e.i.r.p. limitations at the lower off-axis angles in § 1 can be met by constraining the transmit power spectral flux-density of these antennas.

NOTE 8 – This Recommendation applies to protection between geostationary-satellite networks in the FSS. Potential interference between geostationary-satellite systems and non-geostationary-satellite systems is to be addressed by other Recommendations.

NOTE 9 – The revision in § 1 above to reduce the minimum off-axis angle from 2.5° to 2° applies to earth stations brought into service after the end of 1995 for all geostationary-satellite networks.

ANNEX 1

Calculation of permissible off-axis e.i.r.p. density for VSATs

1 System noise budget

According to Recommendation ITU-R S.523 which deals with permissible interference level in digital satellite transmission, 20% of the total noise power at the demodulator input is allocated to the interference caused by other networks in frequency bands in which the networks practice frequency re-use. Also, 6% of the total noise power is allocated for the single entry interference.

While the off-axis emissions from earth stations cause up-link interference to the adjacent satellites, the emissions from the adjacent satellites cause down-link interference to the receiving earth stations. Therefore, the single entry allocation of 6% should be further divided into up-link and down-link interference. The antenna diameter of the receiving earth station affects the division. If it is larger, the down-link interference becomes less because of its better off-axis isolation, while the up-link interference becomes severer because the total system thermal noise decreases due to increased earth-station G/T .

In considering the off-axis e.i.r.p. limit of VSATs, it may be appropriate to assume that the antenna diameter of the receiving earth station of the interfered network is around 5 m. In this case the budget for the single entry down-link interference can be assumed as less than 1% considering the off-axis gain performance of the antenna. Then the budget for the single entry up-link interference can be assumed as 5%.

Further, the total system noise budget can be assumed as follows:

Thermal noise (up link + down link)	50%
Interference from other satellite networks	20% (Recommendation ITU-R S.523)
Interference due to cross-polarization	5%
Intermodulation noise due to transponder	25%

Therefore, the ratio of 5%/50% can be used in comparing the up-link single entry interference power density with the thermal noise density.

2 Derivation of system total thermal noise

In calculating the system total thermal noise, both the up-link and the down-link thermal noise should be considered. The up-link carrier-to-noise density ratio $(C/N_0)_U$, the down-link carrier-to-noise density ratio $(C/N_0)_D$ and the total carrier-to-noise density ratio $(C/N_0)_T$ can be calculated as follows:

$$(C/N_0)_U = e.i.r.p.E - L_U - L_{UA} - L_{UR} + (G/T)_S + 228.6 \quad (1)$$

$$\begin{aligned} (C/N_0)_D &= e.i.r.p.S - OBO - L_D - L_{DA} - L_{DR} + (G/T)_E + 228.6 \\ &= e.i.r.p.E - L_U - L_{UA} - L_{UR} + G_S - L_D - L_{DA} + L_{DR} + (G/T)_E + 228.6 \end{aligned} \quad (2)$$

$$(C/N_0)_T = -10 \log (10^{-(C/N_0)_U/10} + 10^{-(C/N_0)_D/10}) \quad (3)$$

where:

$e.i.r.p.E$:	e.i.r.p. of the transmit earth station of wanted signal
$e.i.r.p.S$:	saturation e.i.r.p. of the satellite
L_U :	up-link free-space loss
L_D :	down-link free-space loss
L_{UA} :	up-link clear-air attenuation
L_{DA} :	down-link clear-air attenuation
L_{UR} :	up-link rain fade
L_{DR} :	down-link rain fade
$(G/T)_S$:	G/T of the satellite
$(G/T)_E$:	G/T of the receiving earth station of wanted signal
OBO :	output back-off of the satellite
G_S :	small signal gain of the transponder

$$G_S = G_1 + (e.i.r.p.S - SFD) + (IBO - OBO) \quad (4)$$

where:

SFD :	saturation flux-density of the satellite
IBO :	input back-off of the satellite
G_1 :	gain of an ideal antenna area of 1 m ²
	$G_1 = 44.4$ dB at 14 GHz