

RECOMMENDATION ITU-R S.524-9

Maximum permissible levels of off-axis e.i.r.p. density from earth stations in geostationary-satellite orbit networks operating in the fixed-satellite service transmitting in the 6 GHz, 13 GHz, 14 GHz and 30 GHz frequency bands

(Questions ITU-R 70/4 and ITU-R 259/4)

(1978-1982-1986-1990-1992-1994-2000-2001-2003-2006)

Scope

This Recommendation provides maximum off-axis e.i.r.p. levels not to be exceeded by earth stations associated with geostationary-satellite networks operating in the fixed-satellite service and transmitting in the 6 GHz, the 13 GHz, the 14 GHz and the 30 GHz frequency bands. A number of notes provides additional guidelines on the application of the off-axis e.i.r.p. levels.

The ITU Radiocommunication Assembly,

considering

- a) that geostationary satellite networks in the fixed-satellite service (FSS) operate in the same frequency bands;
- b) that some non-geostationary satellite networks in the FSS may operate in the same frequency bands as some geostationary satellite networks in accordance with the Radio Regulations (RR);
- c) that interference between networks in the FSS contributes to noise in the network;
- d) that it is necessary to protect a network in the FSS from interference by other such networks;
- e) that it is necessary to specify the maximum permissible levels of off-axis e.i.r.p. density from earth stations, to promote harmonization between geostationary satellite networks, and also where applicable to limit interference power from GSO FSS earth stations to uplinks of non-GSO systems;
- f) that the contribution of interference from an earth station of an adjacent satellite network into a space station receiver is a function of the earth station off-axis e.i.r.p. density;
- g) that the use of antennas with the best off-axis performance will lead to the most efficient use of radio-frequency spectrum and the GSO;
- h) that off-axis e.i.r.p. density levels are determined by the side-lobe gain, the transmitter output power level and spectral distribution of that power,

noting

- a) that Annex 1 and Annex 2 describe the basis on which certain of the levels in this Recommendation were derived,

recommends

1 that earth stations operating in GSO networks in the FSS transmitting in the 5 725-7 075 MHz frequency band should be designed in such a manner that at any angle, ϕ , which is 2.5° or more off the main lobe axis of the earth station antenna, the e.i.r.p. density in any direction within 3° of the GSO does not exceed the following values:

1.1 for emissions in systems other than those considered in § 1.2 and 1.3 below:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 4 kHz</i>
$2.5^\circ \leq \phi < 48^\circ$	$(35 - 25 \log \phi) \text{ dB(W/4 kHz)}$
$48^\circ \leq \phi \leq 180^\circ$	-7 dB(W/4 kHz) ;

1.2 for emissions in voice-activated telephony SCPC/FM systems:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 40 kHz</i>
$2.5^\circ \leq \phi < 48^\circ$	$(42 - 25 \log \phi) \text{ dB(W/40 kHz)}$
$48^\circ \leq \phi \leq 180^\circ$	0 dB(W/40 kHz) ;

1.3 for emissions in voice-activated telephony SCPC/PSK systems:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 40 kHz</i>
$2.5^\circ \leq \phi < 48^\circ$	$(45 - 25 \log \phi) \text{ dB(W/40 kHz)}$
$48^\circ \leq \phi \leq 180^\circ$	3 dB(W/40 kHz) ;

2 for new antennas of an earth station transmitting in the 5 725-7 075 MHz frequency band and installed after 1988, using emissions other than those considered in *recommends* 1.2 and 1.3, the e.i.r.p. density should not exceed the following values:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 4 kHz</i>
$2.5^\circ \leq \phi \leq 7^\circ$	$(32 - 25 \log \phi) \text{ dB(W/4 kHz)}$
$7^\circ < \phi \leq 9.2^\circ$	11 dB(W/4 kHz)
$9.2^\circ < \phi \leq 48^\circ$	$(35 - 25 \log \phi) \text{ dB(W/4 kHz)}$
$48^\circ < \phi \leq 180^\circ$	-7 dB(W/4 kHz) ;

3 that earth stations operating in GSO networks in the FSS transmitting in the 12.75-13.25 GHz and 13.75-14.5 GHz frequency bands should be designed in such a manner that at any angle, ϕ , which is 2.5° or more off the main lobe axis of the earth station antenna, the e.i.r.p. density in any direction within 3° of the GSO does not exceed the following values:

3.1 for emissions in systems other than those considered in *recommends* 3.2:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 40 kHz</i>
$2.5^\circ \leq \phi \leq 7^\circ$	$(39 - 25 \log \phi) \text{ dB(W/40 kHz)}$
$7^\circ < \phi \leq 9.2^\circ$	18 dB(W/40 kHz)
$9.2^\circ < \phi \leq 48^\circ$	$(42 - 25 \log \phi) \text{ dB(W/40 kHz)}$
$48^\circ < \phi \leq 180^\circ$	0 dB(W/40 kHz) .

3.2 for FM-TV emissions with or without energy dispersal, the off-axis total e.i.r.p. of the transmitted FM-TV carrier should not exceed the following values:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p.</i>
$2.5^\circ \leq \phi \leq 7^\circ$	$(53 - 25 \log \phi)$ dBW
$7^\circ < \phi \leq 9.2^\circ$	32 dBW
$9.2^\circ < \phi \leq 48^\circ$	$(56 - 25 \log \phi)$ dBW
$48^\circ < \phi \leq 180^\circ$	14 dBW

FM-TV emissions with or without energy dispersal should be modulated at all times with programme material or appropriate test patterns to reduce interference to other networks. Figure 1 of Annex 1 provides an example of typical spectral distribution of an FM-TV carrier modulated by programme material, together with energy dispersal. In the event that the FM-TV emission is not being modulated, energy dispersal should be used such that the levels in *recommends* 3.1 are exceeded by no more than 3 dB;

3.3 for any direction in the region outside 3° of the GSO, the levels given in *recommends* 3.1 and 3.2 may be exceeded by no more than 3 dB;

4 that earth stations operating in GSO networks in the FSS transmitting in the 27.5-30 GHz frequency band be designed in such a manner that at any angle, ϕ , which is 2° or more off the main lobe axis of the earth station antenna, the e.i.r.p. density 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. per 40 kHz</i>
$2^\circ \leq \phi \leq 7^\circ$	$(19 - 25 \log \phi)$ dB(W/40 kHz)
$7^\circ < \phi \leq 9.2^\circ$	-2 dB(W/40 kHz)
$9.2^\circ < \phi \leq 48^\circ$	$(22 - 25 \log \phi)$ dB(W/40 kHz)
$48^\circ < \phi \leq 180^\circ$	-10 dB(W/40 kHz).

For any direction in the region outside 3° of the GSO, the above levels may be exceeded by no more than 3 dB.

Studies are being conducted which may lead to revision of this value;

5 that the following Notes should be regarded as part of this Recommendation:

NOTE 1 – Values in *recommends* 1.2 above apply to normal operation of voice telephony in a 4 kHz baseband and are based on a mean power noise analysis.

NOTE 2 – Enhanced orbit utilization and easier coordination would be attained with lower side-lobe e.i.r.p. density values, and therefore, administrations are encouraged to achieve lower values where practicable (e.g. by using antenna having an improved pattern performance in the GSO plane).

NOTE 3 – The values in *recommends* 1 to 4 are maximal values under clear-sky conditions. In case of systems employing uplink power control, these levels include any additional margins above the minimum clear-sky level necessary for the implementation of uplink power control. When uplink power control is used and rain fades make it necessary, the levels stated in *recommends* 3 and 4 may be exceeded for the duration of that period. When uplink power control is not used and the e.i.r.p. density levels given in the above *recommends* 3 and 4 are not met, different values can be agreed upon through bilateral coordination taking into account the specific requirements (e.g. rain fade effects) and parameters of the satellite networks involved.

NOTE 4 – The e.i.r.p. density levels for off-axis angles less than 2.5° (for the 6 GHz, 13 GHz and 14 GHz ranges) and less than 2° (for the 30 GHz range) may be determined through coordination agreements taking into account the specific parameters of the two satellite networks involved.

NOTE 5– The off-axis e.i.r.p. density levels outside 3° of the GSO do not apply to earth station antennas ready to be in service¹ prior to 2 June 2000 nor to earth stations associated with a satellite network in the FSS for which complete coordination or notification information has been received before 2 June 2000.

The uplinks to non-GSO FSS systems using the bands 12.75-13.25 GHz and 13.75-14.5 GHz should be designed allowing for interference from the earth stations of GSO FSS networks exceeding the off-axis e.i.r.p. density levels in *recommends* 3 within 3° of the GSO by up to 3 dB.

NOTE 6 – For GSO systems in which the earth stations are expected to transmit continuously and simultaneously in the same 40 kHz band, e.g. for the GSO systems employing code division multiple access (CDMA), the maximum off-axis e.i.r.p. density values should be decreased by 10 $\log(N)$ dB, where N is the number of earth stations which are in the receive satellite beam of the satellite to which these earth stations are communicating and which are expected to transmit simultaneously on the same frequency.

NOTE 7 – Earth stations operating in the 27.5-30 GHz frequency band should be designed in such a manner that 90% of their peak off-axis e.i.r.p. density levels do not exceed the levels given in *recommends* 4. Further study is needed to determine the off-axis angular range over which these exceedances would be permitted, taking into account the interference level into adjacent satellites. The statistical processing of the off-axis e.i.r.p. density peaks should be dealt with using the method given in Recommendation ITU-R S.732.

NOTE 8 – In the frequency band 29.5-30 GHz, the off-axis e.i.r.p. density levels given in *recommends* 4 do not apply to earth stations associated with GSO networks brought into use before 2 June 2000.

NOTE 9 – The application of *recommends* 4 for earth stations operating with GSO networks in the 27.5-29.5 GHz frequency band requires taking into account existing GSO networks as of 1 July 2003.

NOTE 10 – FSS earth stations operating in the 27.5-30 GHz band, which have lower elevation angles to the GSO will require higher e.i.r.p. levels relative to the same terminals at higher elevation angles to achieve the same power flux-densities (pfd) at the GSO due to the combined effect of increased distance and atmospheric absorption. Earth stations with low elevation angles may exceed the levels of *recommends* 4 by the following amount (see Annex 2):

Elevation angle to GSO (ϵ)	Increase in e.i.r.p. density (dB)
$\epsilon \leq 5^\circ$	2.5
$5^\circ < \epsilon \leq 30^\circ$	$3 - 0.1 \epsilon$

NOTE 11 – The levels given in *recommends* 3 may be exceeded by telecommand and ranging carriers transmitted to GSO FSS satellites in both normal and emergency modes of telecommand operation. The amount by which these levels may be exceeded when operating in normal mode is 16 dB. For earth stations operating telecommand and ranging carriers in the 27.5-30 GHz band further study is required.

¹ “Ready to be in service” relates to the case where antennas have been installed but the start of service has been delayed due to *force majeure*.

NOTE 12 – In the frequency range 27.5-29.0 GHz for earth stations whose antenna diameter is less than 65 cm, the off-axis e.i.r.p. density levels given in *recommends* 4 may be exceeded by up to 3 dB provided that the maximum off-axis e.i.r.p. density does not exceed the following values:

<i>Angle off-axis</i>	<i>Maximum e.i.r.p. per 2 MHz</i>
$2^{\circ} \leq \varphi \leq 7^{\circ}$	$(37 - 25 \log \varphi - 10 \log M) \text{ dB(W/2 MHz)}$
$7^{\circ} < \varphi \leq 9.2^{\circ}$	$(16 - 10 \log M) \text{ dB(W/2 MHz)}$
$9.2^{\circ} < \varphi \leq 48^{\circ}$	$(40 - 25 \log \varphi - 10 \log M) \text{ dB(W/2 MHz)}$
$48^{\circ} < \varphi \leq 180^{\circ}$	$(7 - 10 \log M) \text{ dB(W/2 MHz)}$

where M is the number of earth stations which are in the receive beam of the satellite to which these earth stations are communicating and which are expected to transmit simultaneously in the same 2 MHz band and in the same polarization. It should be noted that for these cases a reduction in e.i.r.p. density, or additional orbital separation, would be required in order to arrive at the same adjacent satellite interference in the Earth-to-space direction as would result from the off-axis e.i.r.p., values as specified in *recommends* 4.

NOTE 13 – The levels in *recommends* 4 applicable to the off-axis angle range from 48° to 180° are intended to account for spillover effects.

Annex 1

1 Introduction

Interference from an earth station transmitter into the satellite receivers of other networks can be related directly to the off-axis spectral e.i.r.p. density of the interfering earth station antenna. This is a function not only of the earth station antenna side-lobe performance but also depends on the transmitter power level and its spectral density which, in turn, will be influenced by the overall satellite system design.

The establishment of a recommended limit for off-axis spectral e.i.r.p. density can be approached from two viewpoints:

- limitation of the interference level entering another satellite taking particular account of interference to networks employing large earth station antennas;
- determination of the on-axis e.i.r.p. requirements for earth stations, particularly those employing relatively small antennas and consideration of the on-axis and off-axis gain that such antennas could be expected to provide.

2 Consideration of an off-axis e.i.r.p. density limit for the 6 GHz band

An examination from both of the viewpoints mentioned above has led to the conclusion that the recommended limit should take the following form for uplink emission at about 6 GHz.

At any angle, ϕ , 2.5° or more off the main lobe axis of an earth station antenna, the e.i.r.p. per 4 kHz 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. per 4 kHz</i>
$2.5^\circ \leq \phi \leq 25^\circ$	$(E - 25 \log \phi) \text{ dB(W/4 kHz)}$
$25^\circ < \phi \leq 180^\circ$	$(E - 35) \text{ dB(W/4 kHz)}$

where the value of E should be within the range 32.0 to 38.5. The value of E should be as small as practicable, and will vary from one frequency band to another. For some satellite system applications, it may be desirable to develop an off-axis e.i.r.p. density limit by using a more stringent value of E (e.g. 32) in the near-in angular region (e.g. $\phi \leq 7^\circ$) and then to relax the value of E at larger off-axis angles. This type of stepped limit would constrain the off-axis radiation in those angular regions where the value would be more effective in limiting interference to adjacent satellites.

From the viewpoint of tolerable interference into a satellite network with large station antennas, it may be noted that a value of 38.5 for E would permit a maximum e.i.r.p. density of 21.0 dB(W/4 kHz) to be radiated from an earth station at 5° off-axis.

From the viewpoint of the reasonable requirements of earth stations with small antennas, four cases that might be considered are:

Case 1: high density FM carrier – large station;

Case 2: FM-TV – small station (global satellite antenna);

Case 3: FM-TV – broadcast satellite uplink;

Case 4: SCPC – narrow-band.

Assuming the following:

- the satellite noise temperature $\leq 3\,000$ K;
- the satellite antenna gain ≥ 16 dB;
- the earth-station antenna conforms to Recommendation ITU-R S.465 for off-axis angles less than 25° , but the side-lobe envelope has a constant level of -3 dBi beyond 25° ;
- $10 \log$ (earth station noise temperature) ≥ 19 .

(Values for the minimum power density at an off-axis angle of 5° are shown in Table 1.)

TABLE 1
Minimum off-axis e.i.r.p. density for typical carriers

	FDM-FM 1 332 channels 36 MHz RF bandwidth	FM-TV	FM-TV broadcasting satellite uplink	SCPC global
Satellite G/T (dB(K ⁻¹))	-7	-17	0	-17
Uplink C/T (dB(W/K))	-125	-137	-134	-154
e.i.r.p. (dBW)	82	80	66	63
Earth station antenna transmit gain (dB)	60	53	46	53
RF power input to earth station antenna (dBW)	22	27	20	10

TABLE 1 (*end*)

	FDM-FM 1332 channels 36 MHz RF bandwidth	FM-TV	FM-TV broadcasting satellite uplink	SCPC global
RF spectral power density input to earth station antenna (dB(W/4 kHz))	−8	0	−4	0
E_{5° (dB(W/4 kHz)) ⁽¹⁾	6.5	14.5	10.5	14.5

⁽¹⁾ Radiation at 5° assuming 32 – 25 log ϕ relationship.

The worst interference would be from Case 2 where a 53 dB gain corresponds to a 10 m diameter antenna. The required transmitter power would be about 500 W. With 27 dB (2 MHz) of spreading advantage, the nominal transmit power density would be 0 dB(W/4 kHz) resulting in an off-axis radiation of 14.5 dB(W/4 kHz) at 5°.

While Case 4 indicates a similar value for off-axis e.i.r.p. density radiations, other factors must be considered. SCPC are low level carriers with a nominal earth station transmit level of 63.5 dB(W/channel). Since TV normally only has spreading at a slow rate (25 or 30 Hz), it is considered that the total carrier power must be considered as pulsed interference. In this case, at 5° the C/I would be 22 dB on the uplink and 13 dB on the downlink. While criteria for interference in these cases do not exist, an overall C/I of 20 dB has been adopted in some analyses for such pulsed interference. Recognizing the severe incompatibility of this situation, the conclusion is reached that adequate protection is not reasonably attainable by satellite separation nor by more severe e.i.r.p. restrictions since the downlink is dominant. One solution is to restrict the uses of the two types of signals such that they would also be separated in frequency where the FSS is involved on both uplinks and downlinks. A second solution which might considerably relieve the problem noted above is a different method of carrier energy dispersal for television by transformation of the video signal.

Two examples from the Canadian TELESAT system show that at 6 GHz and an off-beam angle of 5°, a level of unwanted e.i.r.p. density in the approximate range 17-18 dB(W/4 kHz) is associated with SCPC transmissions from a 4 to 5 m diameter antenna and with TV transmissions from a 10 m diameter antenna.

As to Case 4, a study was made in Japan on the off-axis e.i.r.p. density per 4 kHz bandwidth for the SCPC-PSK carrier of the INTELSAT system and SCPC-FM and SCPC-PSK carriers of the MARISAT system. Based on the results of the above studies, it may be concluded that in the case of a transmission between Standard-B earth stations in the INTELSAT system, the worst value of off-axis e.i.r.p. density from the transmitting earth station is 6 dB higher than 35 – 25 log ϕ (dB(W/4 kHz)).

It should be noted that these figures are only an illustrative example of existing systems. In any event a Recommendation should not be tailored to a specific existing system but on the contrary future systems should be designed to meet the Recommendation in its final form.

Based on the foregoing, it is concluded that the utilization of the GSO at about 6 GHz could be protected, while permitting earth stations with antennas as small as 4 or 5 m in diameter to be used, by applying the following guidelines:

- care should be exercised in frequency planning to ensure that television transmissions in one network do not use the same frequencies as SCPC telephony transmissions in a network using a nearby satellite;