RECOMMENDATION ITU-R S.1151*,**

Sharing between the inter-satellite service involving geostationary satellites in the fixed-satellite service and the radionavigation service at 33 GHz

(1995)

The ITU Radiocommunication Assembly,

considering

a) that the frequency band 32-33 GHz is allocated on an equal basis to the inter-satellite service (ISS) and to the radionavigation service;

b) that the band may be used for links between satellites of the fixed-satellite service (FSS);

c) such information as is available in existing ITU-R texts regarding the technical characteristics of the two services, supplemented by reasonable assumptions where information is lacking;

d) that inter-satellite links of various path lengths should be taken into account;

e) the content of Recommendation ITU-R M.496;

f) that the space research service (deep space) (space-to-Earth) shares the band 32-32.3 GHz on a primary basis and that protection and sharing criteria exist for this service (Recommendation ITU-R SA.578);

g) that analysis and conclusions concerning sharing in the band 32-32.3 GHz should take into account the allocation to the space research service;

h) the analysis contained in Annex 1,

recommends

1 that to avoid the requirement of power limitations to emissions of the ISS and the radionavigation service, the maximum geocentric separation angle of the two ends of the inter-satellite link should not exceed 90°;

2 that, whenever it is not practicable to observe the angular limitation in § 1, sharing between these two services should be accomplished by means of the following criteria:

2.1 for emissions of the ISS, the maximum power flux-density (pfd) at the Earth's surface from geostationary satellites should be limited to the values given by curve B of Fig. 2;

2.2 for continuous wave emissions of the radionavigation service, the e.i.r.p. density of individual transmitters should be limited to:

$$A - 43 - 10 \log D \quad \text{dB(W/MHz), for separation angles of} \leq 140°$$

where A is the aggregate e.i.r.p. spectral density given by Fig. 2 and D is the estimated geographical density of radionavigation transmitters per km^2 simultaneously active in any 1 MHz band, taking

* This Recommendation should be brought to the attention of Radiocommunication Study Group 8.

** Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

into account future needs and averaged over the territory of the administration concerned or over an area of 10^6 km^2, whichever is less (see Annex 1 to Recommendation ITU-R M.496).

NOTE 1 – *recommends* 2.2 is restricted to continuous wave emissions. Further study is required for pulsed radionavigation systems. Information on pulsed systems is given in Annex 2.

ANNEX 1

Sharing criteria between inter-satellite links connecting geostationary satellites in the fixed-satellite service and the radionavigation service at 33 GHz

1 Introduction

In the near term there may be a need for a limited form of inter-satellite link having a relatively short inter-satellite spacing and operating between about 15 and 33 GHz.

At the World Administrative Radio Conference (Geneva, 1979) (WARC-79) a band in this range was allocated to the ISS (32-33 GHz), shared with the radionavigation service.

The feasibility of sharing between inter-satellite links of geostationary satellites in the FSS and the radionavigation service is considered below.

2 Characteristics of inter-satellite links in the frequency range 32-33 GHz

It is assumed that the links would probably be few in number, would be used for relatively short inter-satellite distances to minimize transit-time delay, and, if required soon, would rely as much as possible on existing spacecraft technology. Parameters which might represent typical links are presented in Table 1. The links considered here are assumed to connect satellites at varying orbital separations, to employ tracking antennas of 2 m diameter and to operate at a carrier-to-noise ratio of 25 dB such that the inter-satellite link contributes a relatively small part of the allowable channel noise.

TABLE 1

Assumed characteristics of inter-satellite link (ISL) and radionavigation service (RN)

	ISL	RN
Receiver system noise temperature *T* (K) 10 log *T*	31	30
Receive, transmit antenna diameter (m)	2	–
Receive, transmit antenna gain (dBi)	54	50 35 (airborne)
Receive noise power per MHz (dB(W/MHz)) (referred to antenna port)	–138	–139
Carrier-to-noise ratio (dB)	25	–
Required carrier at receiver (dB(W/MHz))	–113	
Maximum permissible interference level, below noise (dB)	–10	–10
Maximum permissible unwanted signal level (dB(W/MHz))	–148	–149
Combined tracking loss (dB)	1	–
Path loss (Earth-to-space geostationary orbit) (dB)	215	–
Half power beamwidth (ISL) (degrees)	0.32	–

From the values derived, it is possible to assess the levels of interference caused to, and received from, the radionavigation services.

It is recognized that the link considered in Table 1 is only one possible design of an inter-satellite link, and other designs involving techniques such as FM remodulation have also been postulated. However, such links would be characterized by a lower transmitter power density and probably a lower susceptibility to interference, so it is considered that the characteristics given represent a sufficiently conservative case.

3 Characteristics of the radionavigation service at 32-33 GHz

It is not possible to predict, with precision, the technical characteristics that will be adopted for systems in the radionavigation service. However, certain assumptions have had to be made and they are detailed in Table 1 for continuous wave systems. Two antenna gains have been postulated, one for ground and one for airborne installations. These characteristics are used in the following analyses to arrive at the *recommends* for continuous wave radionavigation systems.

4 Interference from inter-satellite links to the radionavigation service

The interference from an inter-satellite link is considered in terms of power flux-density at the Earth's surface.

There are two factors contributing to this pfd, firstly the power per MHz into the inter-satellite service link antenna (P_T) which is proportional to the inter-satellite link distance, and secondly the off boresight gain $G(\theta)$ (see Recommendation ITU-R S.672) towards the Earth of the transmitting antenna. Both of these are dependent upon the separation angle φ (see Fig. 1) and it can be shown that the pfd on the surface (pfd_{ISL}) is approximately equal to:

$$pfd_{ISL} \approx P_T(\varphi) + G(\theta) - 10 \log (4\pi\, d^2) \qquad \text{dB(W/(m}^2 \cdot \text{MHz))}$$

where:

$P_T(\varphi)$: power (dB(W/MHz)) delivered to the satellite

$G(\theta)$: gain (dB) relative to that of an isotropic radiator, of the ISL satellite antenna in an off-axis direction tangential to the Earth's surface

d: path distance from the satellite to the Earth's surface in the direction θ (m).

Since the required value of $P_T(\varphi)$ is determined by the power level needed at the input to the receiver at the other end of the inter-satellite link (typically –112 dB(W/MHz)), then:

$$P_T(\varphi) = -112 + 20 \log (\lambda / 4\pi\, L) + 2 \times G_0 \qquad \text{dB(W/(m}^2 \cdot \text{MHz))}$$

where:

λ: wavelength (m)

L: length of the ISL (m)

G_0: on-axis gain of each ISL satellite antenna (dBi).

Combining these factors, and expressing L and θ in terms of φ the power flux-density for the worst case (low angle of arrival) becomes:

$$pfd_{ISL} \approx -220 + 20 \log \left[\frac{8\pi \times 4.22 \times 10^7 \sin(\varphi/2)}{\lambda} \right] + 54 - 25 \log \left(\frac{163 - \varphi}{0.32} \right) - 164$$

and results in the expression:

$$pfd_{ISL} \approx 10 \log \left[\frac{8\pi \times 4.22 \times 10^7 \sin(\varphi/2)}{\lambda} \right]^2 - 25 \log \left(\frac{163 - \varphi}{0.32} \right) - 330 \qquad \text{dB(W/(m}^2 \cdot \text{MHz))}$$

FIGURE 1

Inter-satellite link

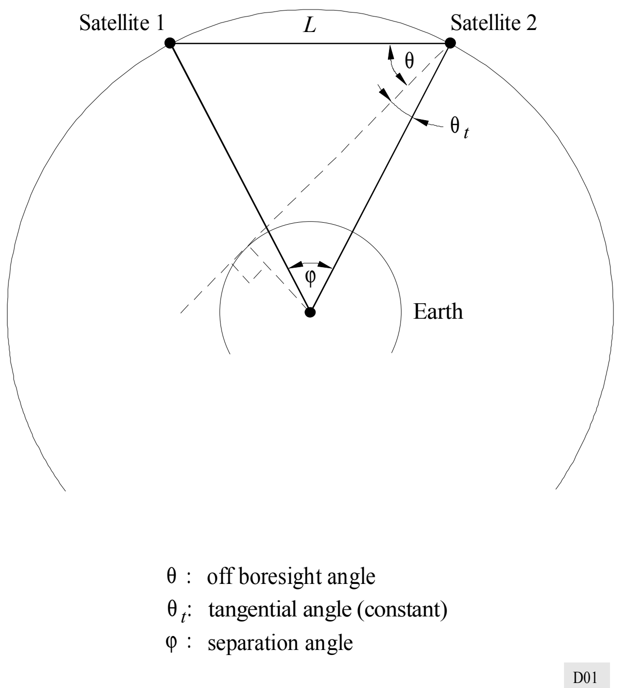
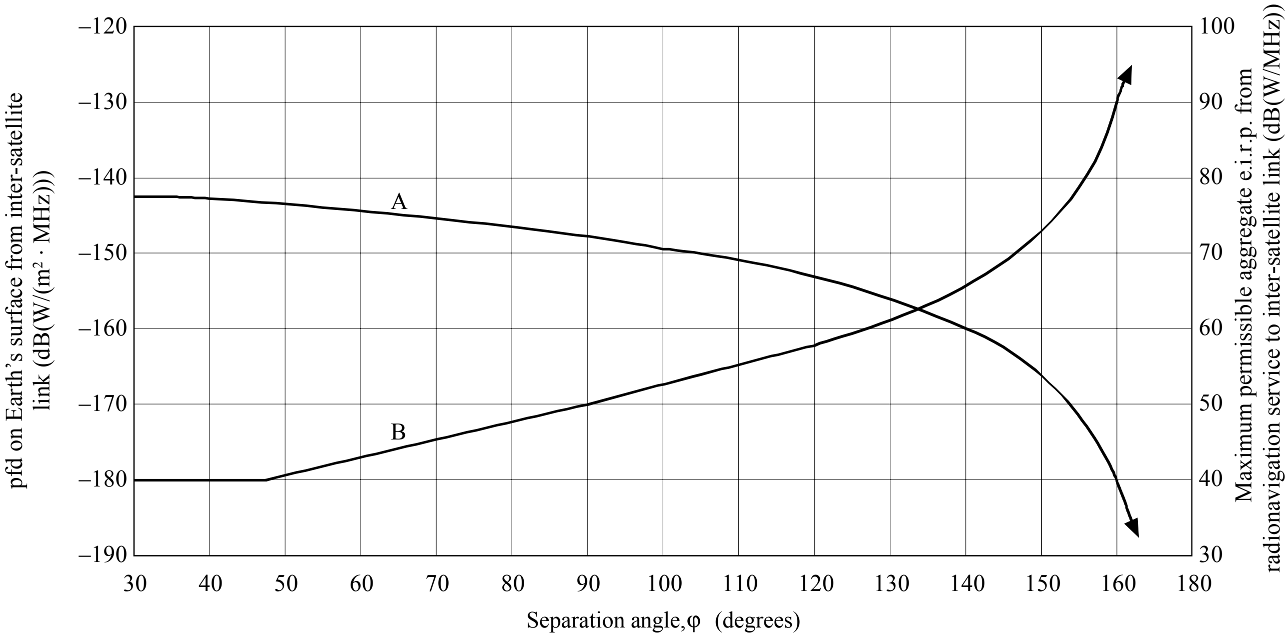


Figure 2 shows the pfd estimate from the characteristics assumed and over separation angles from 40° to 160°. Note that the term used above for off-beam antenna gain reduces to –10 dB for a satellite separation angle φ of 46.6°. This results in the flattening and discontinuity shown in Fig. 2.

FIGURE 2

Criteria for the case of interference between an inter-satellite link and the radionavigation service



Curves A: radionavigation service to inter-satellite link ($e.i.r.p._{RNmax}$)
B: inter-satellite link to radionavigation service (pfd_{ISL})

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5 Interference from the radionavigation service to inter-satellite links

Interference from the radionavigation service will depend mainly on the receiving antenna gain of the inter-satellite link in the direction of the Earth $G(\theta)$, and the e.i.r.p. from the radionavigation service.

Assuming that the total interference power must be limited to one tenth of the receiver system noise, then a carrier to overall interference ratio of 35 dB would be appropriate (compared with 25 dB carrier-to-noise ratio).

Thus for these conditions the maximum e.i.r.p., $e.i.r.p._{RNmax}$ from the radionavigation service can be estimated for different separation angles, thus:

$$e.i.r.p._{\,RNmax} \approx \text{path loss} - \text{maximum permitted interference} - G(\theta)$$

$$\approx 215 \; - \; 148 \; - \; G(\theta)$$

$$\approx 13 \; + \; 25 \log \left(\frac{163 - \varphi}{0.32} \right) \qquad \text{dB(W/MHz)}$$

Figure 2 shows the maximum e.i.r.p. for separation angles from 40° to 160°.

6 Results

From the curves in Fig. 2 it can be seen that a given pfd limitation to protect the radionavigation service places a maximum value on the permissible separation angle of the inter-satellite link. Conversely the maximum link separation angle to which the inter-satellite links may be limited determine the maximum permissible e.i.r.p. limitation on the radionavigation service.

6.1 Inter-satellite link to the radionavigation service

Taking an antenna gain value of 50 dB and a noise power figure of –139 dB(W/MHz) for the radionavigation service, this would give a limit of –155 dB(W/($m^2 \cdot$ MHz)) on the inter-satellite link, leading to an angular separation limit of 140°.

6.2 Radionavigation service to inter-satellite link

From § 6.1 a maximum separation angle of 140° would give an aggregate e.i.r.p. limitation of about 60 dBW.

7 Conclusion for continuous wave systems in the radiolocation service

It is concluded that there will be no interference problems for either service for short links (separation angle up to 90°). For long links, the satellite link is more capable of causing or receiving interference, and based on the assumed characteristics of Table 1 it appears that it may be necessary to limit separation angles to about 140°.

ANNEX 2

Pulsed radionavigation system characteristics

The characteristics of an airborne pulsed radionavigation system have been identified and the characteristics are given in Table 2. The peak pulse power of these systems exceeds the e.i.r.p. limits in *recommends* 2, but the average e.i.r.p. is much lower than these limits; i.e. a low duty cycle. Analyses need to be made in order to assess the interference to ISL links.

TABLE 2

Characteristics of an airborne pulsed radionavigation system

Emission 17M4PON (fixed mode) 117MPON (agile mode)	**Tuning** Fixed – 9 channels spaced at 100 MHz; agile (spread spectrum) over 100 MHz
Power output 38.6 kW (peak pulse power)	**Pulse characteristics** Rate: 1 600 p.p.s. Width: 0.2 µs (Unmodulated pulses)
Output device Inverted co-axial magnetron Servo controlled	
Transmitting and receiving antenna	
Antenna type: Simple beam (Antenna 1)	Antenna pattern type: $cosec^2 \cdot cosine$[1] (Antenna 2)
Scan: Vertical –29° to +10°, mechanical Horizontal ± 135 at 7, 13 or 21 r.p.m.	Scan: Vertical –29° to +10°, mechanical Horizontal ± 135 at 7, 13 or 21 r.p.m.
Gain: 41.1 dBi 23.1 dBi at 1.1° off-axis in azimuth 17.2 dBi at 1.4° off-axis in elevation	Gain: 35.2 dBi 30.1 dBi at –31° elevation 23.1 dBi at –3° elevation
Polarity: Horizontal or LHC	Polarity: Horizontal or LHC
Beamwidth (degrees): 0.8 H, 1.0 V	Beamwidth (degrees): 0.8 H proportional to $cosec^2 \cdot cosine$[1] from –3 to –31 V

[1] Note that $cosec^2 \cdot cosine$ is a generic pattern description used for many radars.