REPORT 951*

SHARING BETWEEN THE INTER-SATELLITE SERVICE AND THE BROADCASTING-SATELLITE SERVICE IN THE VICINITY OF 23 GHz

(Question 1/10 and 11)

(1982)

1. Introduction

The WARC-79 has allocated the band 22.5 to 23 GHz in Regions 2 and 3 to the broadcasting-satellite service (BSS), part of which, namely the band 22.55 to 23 GHz, is shared with, among others, the inter-satellite service (ISS).

On the basis of studies carried out in the USA and Japan this Report examines parametrically the orbital spacing required between space stations employing inter-satellite links and broadcasting satellites with respect to interference into the ISS link [CCIR, 1978-82a and b] and interference into the BSS receiver [CCIR, 1978-82c].

These analyses use new system characteristics from an example in Report 215 for high-definition TV using an RF bandwidth of 125 MHz. However, an example for conventional TV is also given in Report 215. The analyses presented in this Report can also be applied to that case. Preliminary calculations done in the United States show that the high-definition case presented here would prove to be the more conservative.

The parameters for the ISS assumed in the two analyses are given in §§ 2.1 and 3.1. As the definition of the ISS is in an early stage, the parameters assumed in the two sections are different. Further study is required.

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* This Report should be brought to the attention of Study Group 4.

2. Interference to the inter-satellite service by emissions in the broadcasting-satellite service

2.1 *Characteristics of the inter-satellite service*

Inter-satellite links in the 23 GHz band are expected to be primarily over relatively short spans of orbital arc, for example 4°, based on the results of analysis presented in Report 451.

The inter-satellite link receiving system is assumed to consist of an antenna with a gain of 52 dB and a circular beam of 0.4° at the 3 dB beamwidth, and a receiver with an operating noise temperature of 1000 K. The off-axis antenna discrimination is assumed to conform to that given in Report 558. The receiver bandwidth is 850 MHz.

2.2 *Characteristics of the broadcasting-satellite service*

Table XIVa of Report 215 provides example system characteristics of a broadcasting-satellite system for community reception operating at 22.75 GHz. In this analysis, an RF bandwidth of 125 MHz for high-definition FM-TV transmissions and beam centre e.i.r.p. of about 78 dBW have been assumed. In addition, a satellite transmitting antenna beamwidth of 1° has also been assumed since it may result in practical worst-case interference to the ISS receiver. The gain of the antenna is 44 dB, and feed and filter losses are 1 dB, thereby requiring 2.5 kW (34 dBW) of radio-frequency power at the antenna feed.

2.3 *Interference analysis*

The interference geometry is shown in Fig. 1. ISS 2 is transmitting to ISS 1 which is located θ_2 degrees of longitude away. The BSS is located θ_1 degrees of longitude away from ISS 1; and is transmitting to a service area on the equator whose beam centre is γ_0 degrees from nadir.

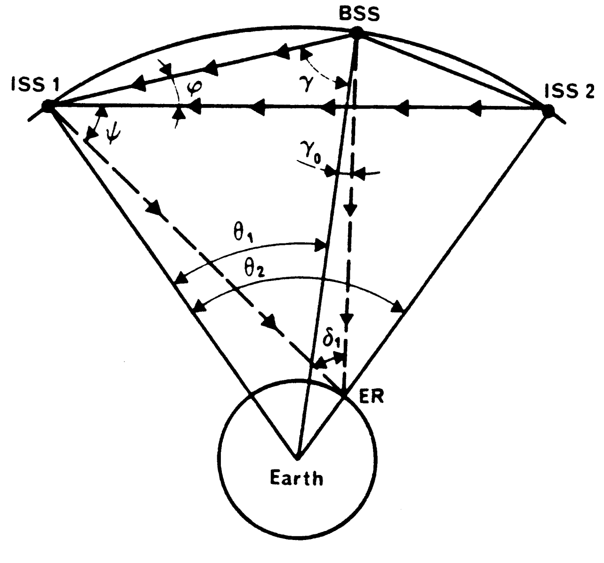


FIGURE 1 – *Interference geometry*

ER: earth station receiver

δ_1: angular separation between the satellites ISS 1 and BSS as seen at the earth station

ψ: angular separation between ISS 2 and the earth station as seen from ISS 1

The interference to the ISS 1 receiving antenna appears at an off-axis angle of φ degrees. Similarly, the e.i.r.p. toward ISS 1 from the BSS is at an off-axis angle of $\gamma + \gamma_0$.

For orbital separations between the ISS and BSS less than 134°, the gain of the BSS satellite transmitting antenna in the direction of the ISS receiver will be isotropic regardless of the BSS antenna pointing direction (γ_0).

Analysis of the interference to noise ratio (I/N) at ISS 1 yields:

$$I/N = R_0 \frac{p_3}{T_1 B_1 f^2}$$

where

$$R_0 = \frac{c^2}{(4\pi)^2 k} \frac{G_1 D_1(\varphi)}{x^2}$$

and

p_3 : the BSS transmitted power delivered to antenna (W)

T_1 : the ISS receiver noise temperature (K)

B_1 : the ISS receiver noise bandwidth (Hz)

f: the frequency (Hz)

c : the velocity of light (m/s)

k : Boltzmann's constant (J/K)

G_1 : the ISS 1 antenna on-axis gain

$D_1(\varphi)$: the ISS 1 antenna discrimination toward BSS

x : the distance between BSS and ISS 1 satellites (m).

The parameter R_0 involves a number of constants, and three terms that depend on the ISS antenna half-power beamwidth and BSS-ISS 1 separation. For given values of these parameters, R_0 has been evaluated and is shown in Fig. 2.

For satisfactory operation, it is assumed that I/N must be less than or equal to a specific value, $(I/N)_0$. The requirement at the ISS receiver for frequency sharing with the BSS is then:

$$I/N = R_0 \frac{p_3}{T_1 B_1 f^2} \leqslant (I/N)_0$$

or

$$R_0 \leqslant (I/N)_0 \frac{T_1 B_1 f^2}{p_3}$$

In decibel notation,

$$10 \log R_0 \leqslant 10 \log (I/N)_0 + 10 \log T_1 + 10 \log B_1 + 20 \log f - 10 \log p_3$$

This equation, coupled with the curves in Fig. 2, and known characteristics of ISS and BSS systems, allows evaluation of the sharing possibilities.

2.4 *Results*

The BSS and ISS characteristics discussed earlier are summarized:

T_1 = 1000 K

B_1 = 125 MHz (see below)

f = 22.75 GHz

p_3 = 2500 W

It is assumed that the ISS bandwidth is greater than 125 MHz and has potential BSS interferers throughout. So the calculation is based upon one interferer per 125 MHz of bandwidth. $(I/N)_0$ is assumed to be one-tenth, for negligible interference.

Then:

$$R_0 \leqslant 274 \quad \text{dB}$$

This value is shown in Fig. 2.

Three cases are analyzed in Fig. 2. Spacings between satellites in the ISS have been assumed to be 4°, 10° and 20°.

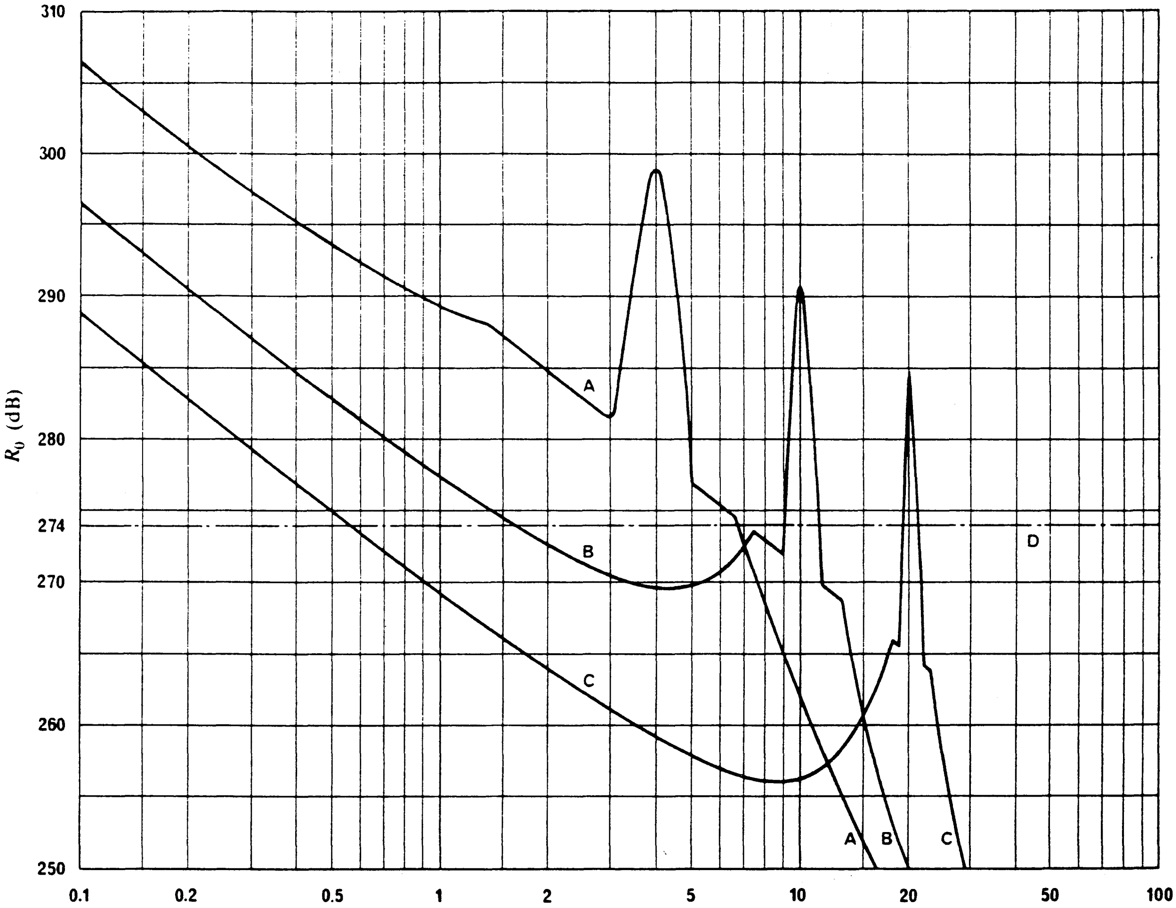


FIGURE 2 – *Parameter R_0 as a function of BSS-ISS satellite spacing for ISS satellite antenna gain = 52 dB*

Curves A: ISS satellite spacing = 4°
B: ISS satellite spacing = 10°
C: ISS satellite spacing = 20°

D: region of negligible interference (below the line marked D)
R_0 is defined by an equation in § 2.3

For a 4° geocentric separation between ISS 1 and ISS 2, it is not feasible to place a BSS satellite closer than about 7° to realize a reasonable I/N of less than −10 dB.

Increasing the geocentric separation between ISS 1 and ISS 2 to 10° permits placing a single BSS satellite between them and still realize an I/N of less than −10 dB. A separation between 1.6° and 9° is required.

Increasing the geocentric separation between ISS 1 and ISS 2 to 20° permits placing a number of BSS satellites in the range between 0.6° and about 19° and still realize a single entry I/N of at least −10 dB.

Figure 3 is used to illustrate what may be called the "displacement effect" in the evolution of the deployment of ISS links. Assume that the orbital separation θ_1 between ISS 1 and ISS 2 is 4°, that ISS 2 is transmitting to ISS 1, and that according to curve A of Fig. 2, the orbital separation between BSS and ISS 1 is 7° so that the I/N at the input to the ISS 1 receiver is at most −10 dB. At some later time, a second ISS link is added such that ISS 2 transmits also to ISS 3 as shown in figure 3. At an orbital separation of 4° between ISS 2 and ISS 3, the I/N at the ISS 3 receiver will be about 6 dB, a 16 dB change in R_0 as shown by curve A of Fig. 2.

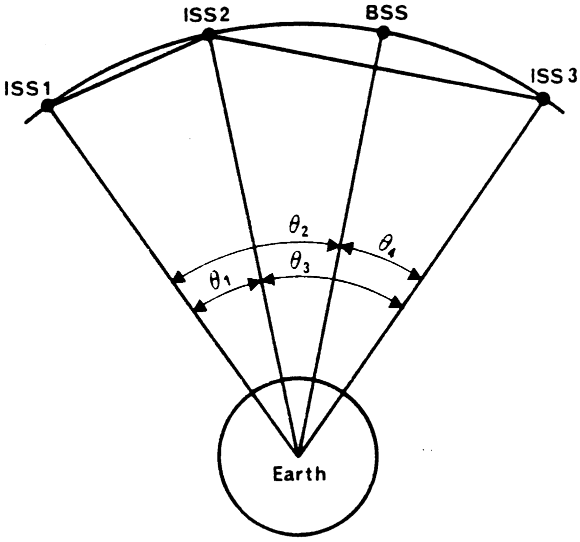


FIGURE 3 – *Displacement effect*

One method to reduce the I/N at the input to the ISS 3 receiver to at most -10 dB is to increase the orbital separation between ISS 2 and ISS 3 to 10°. At this separation, the I/N will be about -12 dB at the input to the ISS 3 receiver. For this method, the net effect of adding the second ISS link is to displace ISS 3 from its preferred 4° spacing to 10° spacing.

3. Interference to the broacasting-satellite service by emissions in the inter-satellite service

3.1 *Characteristics of the inter-satellite service*

Two types of inter-satellite links, i.e., short and long ISS links, are assumed, as described in Report 451. For short ISS links two types of satellite-borne antennas, tracking and non-tracking, are considered. For long ISS links the system parameters are assumed to be based on the examples of the short ISS links.

In the analysis it is assumed that the maximum e.i.r.p. from ISS stations is about 55 to 75 dBW for short ISS links with tracking antennas, 78 to 80 dBW with non-tracking antennas and 78 to 90 dBW for long ISS links, with an antenna diameter of 1 m, and a radio-frequency bandwidth of 100 MHz. Table I indicates the required satellite antenna beamwidth for short link ISS with non-tracking satellite antennas, and Table II shows the required antenna beamwidth in relation to pointing error versus satellite spacing (Table III, Annex I to Report 451).

TABLE I – *Required satellite antenna beamwidth for short link ISS with non-tracking satellite antennas*

Orbital separation between the two satellites (degrees)	2	3	4	6	10	15	20
Required antenna beamwidth (degrees)	12.98	8.47	6.33	4.25	2.64	1.85	1.46

TABLE II – *Required antenna beamwidth in relation to pointing error versus satellite spacing*

Spacing*	Effective pointing error*	Required antenna beamwidth
2°	1.01°	2.02°
3°	0.833°	1.67°
4°	0.739°	1.48°
5°	0.693°	1.39°

* (Table III, Annex I to Report 451)

3.2 *Characteristics of the broadcasting-satellite service*

As an example the system characteristics of a broadcasting-satellite system are assumed, with wide-band analogue modulation suitable for use for, among other things, high definition television in the future, as given in Report 215, Table XIVa. The BSS receiving system is assumed to consist of an antenna of 0.8 m diameter (beamwidth of 1.2°) and an operating noise temperature of 1100 K. The off-axis antenna discrimination is assumed to conform to that given in Report 558. In the absence of other data the carrier-to-interference ratio required for protecting the BSS is assumed to be 40 dB.

3.3 *Interference analysis and results*

The interference geometry is shown in Fig. 1. Three cases have been analyzed with the results shown in Fig. 4 for worst case interference to the BSS receiver (ER). Short ISS links with tracking antennas (Curve A with $\theta_2 < 20°$) and non-tracking antennas (Curve B) and long ISS links (Curve A with $\theta_2 > 60°$) are assumed.

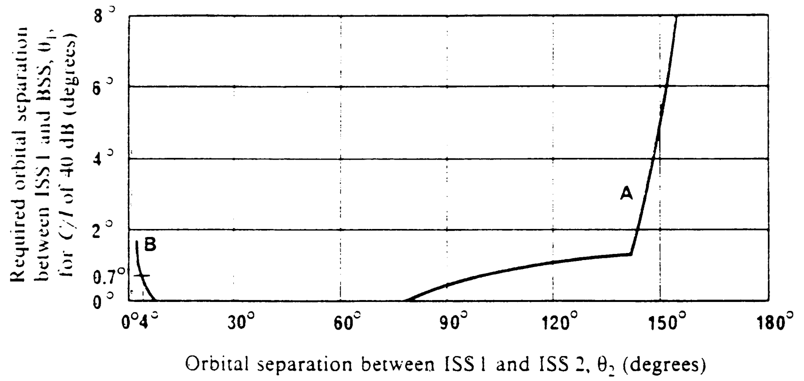
It is seen from the figures that for the short link ISS with tracking satellite antennas there should be no interference at the BSS receiver. However, for short link ISS with non-tracking satellite antennas some interference may arise at the BSS receiver, when θ_2 is less than about 6° and θ_1 is 0°, or when θ_2 is about 4° and θ_1 is less than 1° (as an example), when the ISS antenna beamwidth has to cover excursions of the two satellites with station-keeping accuracy of ± 0.1° for north-south and east-west directions and satellite attitude errors of ± 0.15°. If the ISS satellites with non-tracking antennas have pointing errors as indicated in Table II, there should be no interference at the BSS receiver. For long ISS links the worst interference ratios may become less than 40 dB, for θ_2 greater than 80° and $\theta_1 \approx 0°$.

4. Conclusions

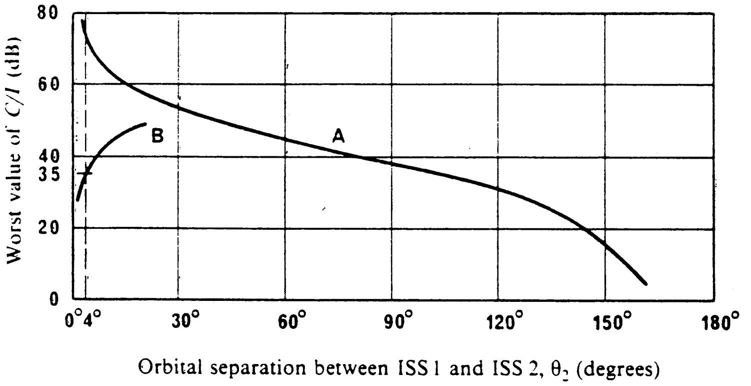
For the technical parameters assumed in this study, which may change in the future, it is concluded that:

- for short ISS links, where the orbital separation is on the order of 4°, it may not be desirable to place a BSS in between; it may be more desirable to place the broadcasting satellite outside the orbital arc occupied by the ISS satellites.
- for ISS orbital separations of 10° and greater, it is possible to place the broadcasting satellite in between. As the ISS orbital separation increases, the range over which broadcasting satellites may be accommodated within the orbital arc between the ISS satellites, and therefore their number, increases.
- as for interference to the BSS receiver by emissions in the ISS, there may be no interference by short ISS links with tracking antennas; however, the worst case of interference may arise from short ISS links with non-tracking antennas for an orbital separation between two ISS satellites less than 6° and between two satellites in the BSS and ISS nearly equal to 0°. If the ISS satellites with pointing errors are as indicated in Table II, there may be no interference.

Additional study is required to determine the amount of interference for broadcasting satellites and ISS satellites of different characteristics.



a) θ_2 as a function of orbital separation, θ_1, between ISS 1 and BSS, for a value of *C/I* of 40 dB



b) θ_2 as a function of *C/I* for $\theta_1 = 0°$

FIGURE 4 – *Orbital separation between two ISS satellites,* θ_2, *and the worst value of interference ratio, C/I at the BSS receiver*

Curves A: ISS with tracking satellite antennas

B: ISS with non-tracking satellite antennas

REFERENCES

CCIR Documents

[1978-82]: **a.** 10-11S/26 (USA); **b.** 10-11S/136 + Add. 1 (USA); **c.** 10-11S/115 (Japan).