REPORT 809-3*

INTER-REGIONAL SHARING OF THE 11.7 TO 12.75 GHz FREQUENCY BAND BETWEEN THE BROADCASTING-SATELLITE SERVICE AND THE FIXED-SATELLITE SERVICE

(Question 1/10 and 11, Study Programme 1A/10 and 11)

(1978-1982-1986-1990)

1. Introduction

As a result of different regional allocations to the fixed-satellite service and the broadcasting-satellite service in the 12 GHz band, several inter-regional sharing situations arise between these space services.

The World Administrative Radio Conference for planning the broadcasting-satellite service in the 12 GHz frequency band, Geneva, 1977 took the following action:

- it adopted a detailed orbital position and frequency assignment Plan for the broadcasting-satellite service in Region 1 (11.7 to 12.5 GHz) and Region 3 (11.7 to 12.2 GHz);
- it adopted a set of provisions governing the broadcasting-satellite service in Region 2 pending the establishment of a detailed plan. These provisions included division of the available orbital arc into separate segments for the broadcasting-satellite service and the fixed-satellite service, and a Regional Administrative Conference to be held not later than 1982 for the purpose of carrying out detailed planning for the broadcasting-satellite and fixed-satellite services in Region 2 (see Recommendation No. Sat-8 of the WARC-BS-77 (see also Resolution No. 701 of the WARC-79).

Subsequently, the WARC-79 allocated separate frequency bands for the two space services in Region 2, thus obviating the need for orbital arc segmentation (see Resolution No. 504 of the WARC-79). The band allocated to the broadcasting-satellite service has a lower limit of 12.2 GHz as determined at the Regional Administrative Radio Conference, RARC SAT-83 – and an upper limit of 12.7 GHz. The various space service sharing situations are summarized in Table I which makes reference to the applicable footnotes in the Radio Regulations. Table I does not include the terrestrial services allocated in the band 11.7 to 12.75 GHz.

Characteristics of typical fixed-satellite systems are contained in Report 207. However, in Region 1, the band 12.5 to 12.75 GHz (see note) is allocated exclusively to the fixed-satellite service which may make its parameters different from fixed-satellite systems in which sharing is required.

Note. – Radio Regulation footnotes 848, 849 and 850 allocate this band on a shared basis to other services in some countries of Region 1.

2. Sharing between the broadcasting-satellite and fixed-satellite services

The problem of sharing between the broadcasting-satellite service and the fixed-satellite service, particularly on the space-to-Earth paths, is a problem of sharing between dissimilar (inhomogeneous) networks. The factors that tend to enhance orbit-spectrum utilization are reasonably well understood. The extent to which these factors can actually be exploited depends on many operational, economic and design constraints.

Sharing between the broadcasting-satellite service serving Regions 1 and 3 and the fixed-satellite service serving Region 2 and *vice versa* is a case of sharing between dissimilar networks with special features:

- the areas served by the two services are separated generally by large bodies of water with the boundaries running north-south, which facilitates sharing as the side-lobe discrimination of the space station antenna will tend to reduce the interference.

All Regions have established detailed Plans (Regions 1 and 3 in 1977, and Region 2 in 1983) for the broadcasting-satellite service.

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

TABLE I – *FSS and BSS sharing situations in the 12 GHz band*

Frequency band (GHz)	Region 1	Region 2	Region 3
11.7 to 12.1	BSS (S-E)	FSS (S-E) BSS (FN 836) (S-E)	BSS (S-E)
12.1 to 12.2	BSS (S-E)	FSS *or* BSS (S-E) (FN 841)	BSS (S-E)
12.2 to 12.3	BSS (S-E)	FSS *or* BSS (S-E) (FN 841)	FSS (FN 845) (S-E)
12.3 to 12.5	BSS (S-E)	BSS (S-E) FSS (FN 846) (S-E)	FSS (FN 845) (S-E)
12.5 to 12.7	FSS (S-E) (E-S)	BSS (S-E) FSS (FN 846) (S-E)	FSS (S-E) BSS (FN 847) (S-E)
12.7 to 12.75	FSS (S-E) (E-S)	FSS (E-S)	FSS (S-E) BSS (FN 847) (S-E)

(S-E): space-to-Earth
(E-S): Earth-to-space

FSS: fixed-satellite service
BSS: broadcasting-satellite service
FN: footnote

Sharing criteria between these services can be established, in principle, in terms of a power flux-density limit over the area to be protected, or in terms of a minimum orbital separation of space stations in the two services, or in terms of a combination of both. Appendix 30 to the Radio Regulations deals with the problem according to the last of these choices.

Considering, in addition, that the nominal spacing between space stations in the western portion of the arc serving Region 1 is 6° according to the Plan, this means that a space station in the fixed-satellite service with characteristics specified in the Radio Regulations (on-axis gain of the earth-station receiving antenna of 53 dB and side-lobe gain following the law:

$$\text{Gain (dBi)} = 32 - 25 \log \varphi \qquad (1)$$

where φ is the off-axis angle in degrees) could be placed midway between two broadcasting satellites serving Region 1 providing its characteristics are such that it can tolerate an interfering flux-density of about -161 dB(W/m^2) at the specified test point. This imposes restrictions on the kind of service that can be provided by the fixed-satellite system, and may prevent certain sensitive systems, such as single-channel-per-carrier (SCPC) or 24-channels-per-carrier systems from using these orbital positions at certain frequencies. However, not all orbital locations in the Plan use all possible frequencies, and it may be possible to accommodate such carriers at these frequencies.

Similar considerations apply to the fixed-satellite service in Regions 1 and 3 sharing with the Region 2 broadcasting-satellite service.

Under Resolution No. 503 of the WARC-79, the Region 2 broadcasting-satellite Plan adopted in 1983 had to take into account the planned Region 1 and 3 broadcasting-satellite services in the overlapping frequency band.

3. Required orbital separation between fixed satellites of one Region and broadcasting satellites of another Region [CCIR, 1978-82a and b]

In the band 12.5-12.7 GHz, it is possible that broadcasting satellites in Region 2 could cause interference to fixed-satellite service earth stations in Regions 1 and 3 and similarly in the band 11.7-12.2 GHz the Region 1 and 3 broadcasting satellites could cause interference to Region 2 fixed satellites. However, the possibility of this interference is greatly reduced in most cases due to the separation between coverage areas and between satellites.

The discrimination of the transmitting antenna pattern used to develop the BSS Plan for Regions 1 and 3 (Curve A of Fig. 1 in Report 810) is ≥ 30 dB for $\varphi/\varphi_0 \geq 1.6$, that is, a separation between the coverage areas greater than 1.6 beamwidths as seen from the satellite. Whilst no such plateau exists in the envelope for the Region 2 transmitting antenna, by careful design of this antenna using shaped beam techniques and possibly including controlled nulls, the actual discrimination can meet or exceed this criterion in particular directions close to the main beam area [CCIR, 1982-86a].

A further reduction of interference potential derives from the discrimination of the receiving antenna at the FSS earth station, and thus from the angular separation of fixed satellites in Regions 1 and 3 from broadcasting satellites in Region 2 and *vice versa.*

For example, consider a situation of a small FSS earth station with an antenna resembling a community reception BSS antenna for which we could use the antenna pattern as given in curve A' of Fig. 7, Annex 5, Appendix 30 (ORB-85) to the Radio Regulations. A discrimination of 35 dB is achieved at a value of φ/φ_0 just less than 10. Thus assuming a 1° beamwidth antenna (minimum community broadcasting size per Annex 5), an approximately 10° separation of satellite position would achieve a discrimination of 35 dB in the *same* service area.

Taking into account discrimination due to *both* coverage area and satellite separations, and assuming a coverage area separation of 1.6 beamwidths (as above) for a 30 dB discrimination, we note that an additional 10 dB discrimination (for total of 40 dB) will be achieved (using Fig. 7, Annex 5, Appendix 30 (ORB-85) to the Radio Regulations) at φ/φ_0 of 1, which is 1° satellite separation for the receiving antenna assumed.

While these examples illustrate the principle of using both coverage area separation and satellite angular separation to determine the need for coordination between the BSS in one region and the FSS in another region, the actual need for coordination depends on the particular systems being implemented, but can be quickly determined by the simple calculation shown below:

Coordination is not required when:

$$D_{B\,SAT} + D_{F\,Rx} > e.i.r.p._{B\,SAT} - e.i.r.p._{F\,SAT} + PR \qquad (2)$$

where

$D_{B\,SAT}$: Discrimination of BSS satellite transmit antenna.

$D_{F\,Rx}$: Discrimination of FSS earth station receive antenna.

$e.i.r.p._{B\,SAT}$: e.i.r.p. of BSS satellite.

$e.i.r.p._{F\,SAT}$: e.i.r.p. of FSS satellite.

PR: Protection ratio required by the FSS down link.

As one example, assume an $e.i.r.p._{B\,SAT}$ of 60 dBW and an $e.i.r.p._{F\,SAT}$ of 40 dBW and an FSS earth station antenna of 3.6 m diameter ($\varphi_0 = 0.5°$). If the respective coverage areas are separated by at least 1.6 beamwidth, a $D_{B\,SAT} \geq 30$ dB will be provided. For a protection ratio of 35 dB, the required $D_{F\,Rx}$ of 25 dB will be achieved at a φ/φ_0 of approximately 4 (from Curve A' of Fig. 7 mentioned above) which corresponds to an angular separation between the FSS satellite and the BSS satellite of 2°.

Further study of specific interference situations is required.

It should be noted that as the diameter of the FSS antenna is decreased, $D_{F\,Rx}$ decreases linearly thus worsening the sharing situation. However the gain of the FSS antenna decreases by the square. Thus, in the case where the remainder of the link budget parameters were designed for the smaller FSS antenna, $e.i.r.p._{F\,SAT}$ must increase by the square as well – which tends to improve the sharing situation. This is the equivalent of saying that the use of small FSS receiving antennas (and thus higher e.i.r.p. of FSS satellites) reduces the inhomegeneity between such systems and BSS systems.

Report 873 treats the general inter-regional sharing situation by way of several examples of FSS systems. Concern is expressed that sharing may produce difficulties for certain orbital separations between broadcasting satellites and fixed satellites for the particular criteria and parameters which were assumed for the FSS systems in Report 873.

In particular Report 873 deals with interference between the FSS and assignments in the BSS plans for all three ITU regions. In addition, Resolution 42 of WARC ORB-88 incorporated the concept of interim systems in the Region 2 plan.

This Resolution provides for interim systems that could be operated by administrations for up to ten years, with characteristics that differ from the assignments to those administrations in their use of higher e.i.r.p.s, in their modulation characteristics, in their coverage areas or combinations thereof, or in the sense of polarization. These differences could increase the possibility of unacceptable interference (see annex to Resolution 42).

Similarly, as suggested in Resolution 519 of WARC ORB-88, a future competent conference should consider the introduction of some sort of interim BSS systems in Regions 1 and 3 as well.

Studies [CCIR, 1986-90a] have shown that the pfd limits set forth in Resolution 42 may not be adequate to protect all FSS networks employing digital transmissions as discussed in Report 873. Therefore, when establishing any such interim system procedures in Regions 1 and 3, due account should be taken of sharing between BSS systems and FSS networks.

Further studies were based on somewhat different characteristics and specific criteria for the FSS systems. Figure 1 shows the resulting required topocentric angular separations between broadcasting satellites and fixed satellites for each of the FSS systems considered.

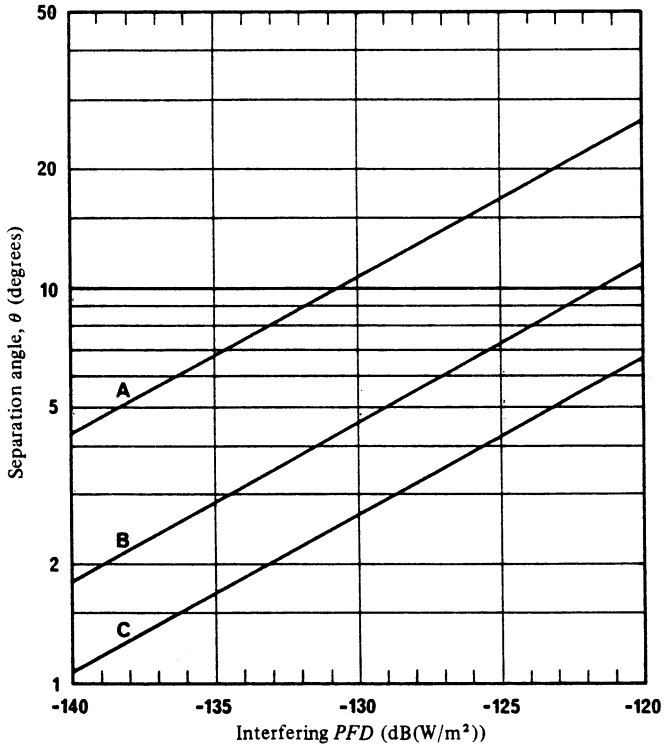

FIGURE 1 – *Separation angle as a function of interfering power flux-density*

$$25 \log \theta = C/I - C/T - 10 \log T + PFD - 11.3$$

Curves A : SCPC-PSK (C/I = 18 dB, C/T = −172 dB(W/K), T = 200 K)

B : FDM-FM (C/I = 28 dB, C/T = −150 dB(W/K), T = 100 K)

C : Wide-band data (N/I = 14 dB, T = 500 K, B = 2.4 MHz)

It is observed that SCPC systems usually will require more protection than wide-band systems.

In the areas around the Bering and Denmark Straits, it is likely to be extremely difficult to achieve significant service area separation, so that satellite position separation will be the only source of discrimination, and may be inadequate in any case to provide adequate protection margins. Thus co-frequency inter-regional sharing in this area may be impossible to achieve. This is clearly not a favourable sharing condition. One way of alleviating the problem would be to agree to use FSS receiving earth stations with a 10 dB lower side-lobe sensitivity where they are located closest to the Region 2 BSS service area. On the BSS side it may be possible to use a very steep BSS satellite antenna side-lobe decay [CCIR, 1982-86a] so as to allow FSS earth stations in Region 1 to relax their side-lobe sensitivity, from the above stringent value, rapidly towards more normal values with increasing distance from the Region 2 BSS service area. In the areas where West Africa and Eastern South America are closest, some service area discrimination due to space station antenna patterns is achievable, depending on the coverage areas chosen. Coverage areas for both FSS serving West Africa and BSS serving Eastern South America should be chosen taking this possibility into consideration. In addition, carefully chosen shaped-beam spacecraft antennas can improve the sharing situation.

Figure 2 shows how the side-lobe sensitivity can be relaxed with distance for various assumed BSS satellite constituent beamwidths ("beamlet" widths).

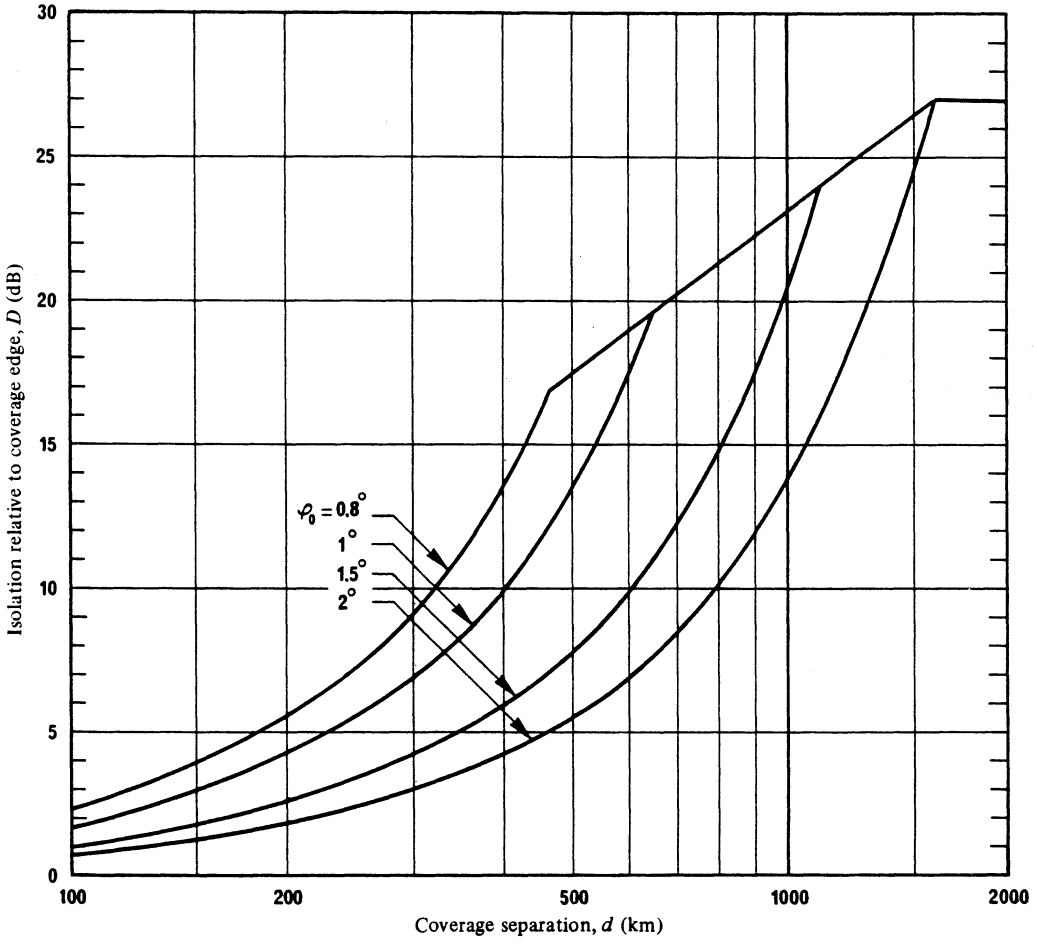

FIGURE 2 – *Coverage edge isolation versus east-west coverage ground separation*

φ_0 : broadcasting satellite constituent beamwidth

Guidelines for actual protection requirements are found in Annex 6 of Appendix 30 (ORB-85) to the Radio Regulations. However the pW0p (interference power) requirements are not readily usable in this equation. Further study is required on the conversion of interference power in pW0p into a usable C/I protection requirement.

4. Use of atmospheric absorption in inter-regional calculations

Appendix 30 (ORB-85) of the Radio Regulations and the Final Acts of the RARC SAT-83, Part I, in their respective Annexes 1 (concerning modifications to the respective Plans) provide the PFD levels from the BSS in one Region into the other which would trigger coordination with respect to the fixed-satellite service. Also, in their respective Annexes 4, they provide the PFD levels from the FSS in one Region into the other which would trigger coordination with respect to the BSS. The calculations in the direction from Regions 1 and 3 to Region 2 (Annex 6, § 2, Part I of the Final Acts of the RARC SAT-83) is based on the use of atmospheric absorption. Resolution No. 9 of the RARC SAT-83 is directed, *inter alia*, towards the use of atmospheric absorption in the reverse direction as well.

A discussion of atmospheric absorption is given in § 5.3 of Report 631.

5. Conclusions

Sharing between services in the different regions is governed by the sharing criteria adopted by the WARC-BS-77 and by WARC-79 (including, in particular, Appendix 30 and Resolutions Nos. 31, 34, 700, 701, 703 and Recommendation No. 708). The system characteristics adopted in the Plans for the broadcasting-satellite service in Regions 1 and 3 by the WARC-BS-77 and in Region 2 by the RARC SAT-83 impose restrictions on the use of certain orbital positions near and between the space stations of the Plans for certain sensitive fixed-satellite services. These restrictions can be alleviated to some degree by special design of the broadcasting-satellite antenna.

REFERENCES

CCIR Documents

[1978-82]: **a.** 10-11S/27 (USA); **b.** 10-11S/131 (USA).

[1982-86]: **a.** 4/230(10-11S/141) (Canada).

[1986-90]: a. 10-11S/168 (INTELSAT).