RECOMMENDATION ITU-R S.1063*

Criteria for sharing between BSS feeder links and other Earth-to-space or space-to-Earth links of the FSS

(Question ITU-R 210/4)

(1994)

The ITU Radiocommunication Assembly,

considering

a) that under the Radio Regulations (RR) the Earth-to-space links used as feeder links to satellites in the broadcasting-satellite service (BSS) are part of the fixed-satellite service (FSS);

b) that the frequency and technical characteristics of such feeder links may depend on the technical characteristics of systems using the broadcasting satellite, but that risks of interference with satellites in the FSS providing links between specified points on the Earth should also be taken into account;

c) that the system constraints of the BSS may affect the efficiency with which the FSS frequency bands are used for links between earth stations;

d) that the following Earth-to-space FSS frequency bands have been identified for use by BSS feeder links; 10.7-11.7 GHz (Region 1), 14.5-14.8 GHz (all Regions except Europe), 17.3-17.8 GHz (Region 2 also allocated to the BSS), 17.3-18.1 GHz (Regions 1 and 3), 18.1-18.4 GHz (all Regions by RR Nos. S5.520 and S5.521), 24.75-25.25 GHz (Regions 2 and 3), 27.5-30.0 GHz (all Regions);

e) that certain BSS feeder links are planned as in RR Appendix S30A to pair with the BSS Plan of RR Appendix S30,

recommends

1 that when considering sharing between the FSS and BSS feeder links:

1.1 the requirements and constraints of both systems should be taken into account;

1.2 reducing the required bandwidth of the feeder links should be considered;

1.3 suitable interference calculations should be performed and results compared against required protection ratios;

2 that the factors and examples given in Annex 1 be considered to help facilitate § 1.

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

ANNEX 1

Criteria for sharing between BSS feeder links and other Earth-to-space or space-to-Earth links of the FSS

1 Introduction

Frequency bands allocated to the BSS are, by definition, in the space-to-Earth direction. Feeder links to broadcasting satellites, operating in any frequency band must, under the current provisions of the Radio Regulations, use the Earth-to-space allocations of the FSS. For the purpose of this Annex, the term "fixed-satellite service" is as defined in the Radio Regulations, but excludes feeder links to broadcasting satellites.

The World Administrative Radio Conference (Geneva, 1979) (WARC-79), and subsequently the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92), allocated a number of Earth-to-space bands for use by feeder links for the BSS. These bands are: 10.7-11.7 GHz (Region 1), 14.5-14.8 GHz (all Regions except Europe), 17.3-17.8 GHz (Region 2, this band is also allocated to the BSS), 17.3-18.1 GHz (Regions 1 and 3), 18.1-18.4 GHz (all Regions by RR Nos. S5.520 and S5.521), 24.75-25.25 GHz (Regions 2 and 3), 27.5-30.0 GHz (all Regions).

Since, however, the uplink requirements of the BSS, particularly around 12 GHz, are expected to be fairly substantial and feeder links for broadcasting satellites may be drawn from any fixed-satellite Earth-to-space allocation (though subject to coordination in bands not exclusively designated for feeder links), and since the higher frequency bands for that purpose may be unattractive to some administrations, the problem of using Earth-to-space allocations by both the FSS and the BSS remains a matter of concern.

The simultaneous use of the 14 to 14.5 GHz band by broadcasting-satellite systems and around 12 GHz by the FSS having different space-to-Earth allocations will be a problem in congested parts of the orbit. In addition to individual and community type BSSs in the 12 GHz band, it is envisioned that interactive services (voice, data and video) may be provided through the use of earth stations with small aperture antennas. This may place additional requirements and constraints on both services.

This Annex evaluates the impact of sharing, associated with using fixed satellite allocations for feeder links to broadcasting satellites with regard to the Plans developed by the World Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service, (Geneva, 1977) (Regions 1 and 3) (WARC BS-77), the related subsequent Regional Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service in Region 2 (RARC SAT-R2) (Geneva, 1983), and the BSS feeder-link plan for Regions 1 and 3 developed at the Second Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and on the Planning of Space Services Utilizing It (Geneva, 1988) (WARC ORB-88).

2 Technical and operational characteristics required for feeder links to broadcasting satellites

2.1 Broadcasting-satellite systems around 12 GHz

The WARC BS-77 established certain technical standards which affect the feeder links for Regions 1 and 3. One important requirement is that the reduction in the quality in the downlink due to thermal noise in the feeder link is taken to be equivalent to a degradation in the downlink C/N not exceeding 0.5 dB for 99% of the worst month. To limit the impairment to this value, the C/N on the feeder link must be about 10 dB higher than that required for the downlink C/N, which in this case would mean a feeder link C/N of up to 24 dB, if the modulation indices were the same.

WARC BS-77 also established a value of 30 dB as the total protection ratio to which each broadcasting satellite transmission must be protected. Similarly, with the division of overall performance requirements, the total protection ratio of the feeder link of a broadcasting satellite may have to be of the order of 40 dB, with a single-entry protection ratio which may be as high as 45 dB. Standards for either of these two latter values have not yet been established. For interference caused by the adjacent channels, recent simulation experiments have shown that the operation of broadcasting-satellite power tubes at saturation reduces interference received from the adjacent channels by about 4 dB relative to that observed under reduced-drive conditions of the power tube. This improvement may also benefit adjacent-channel interference planning of feeder links in Regions 1 and 3.

For Region 2, the RARC SAT-R2 concluded that an overall co-channel protection ratio of 28 dB is required, and that is reflected in the development of the Region 2 Plan. Also, it was decided that, for feeder links, a noise temperature increase of 10% at satellite receiver input should be the threshold which, if exceeded by actual interfering emissions, would require coordination.

Further information is to be found in Recommendations ITU-R BO.793, ITU-R BO.794 and ITU-R BO.795 in RR Appendix 30, and in the Final Acts of the RARC SAT-R2 (Geneva, 1983).

3 Feeder link bandwidth requirements

3.1 Downlink allocations

The feeder link bandwidth requirement has to be viewed in the context of the overall bandwidth allocated to the BSS. These are summarized in Table 1.

TABLE 1

Bandwidth allocated to the BSS below 40 GHz

Part of the spectrum	Amount of bandwidth (MHz)	
700 MHz	170	
2.5 GHz	190	
12 GHz	800	(Region 1)
	500	(Region 2)
	500 + 250	(Region 3)
17 GHz	500	(Region 2)
21 GHz	600	(Regions 1 and 3)

3.2 Reduction of bandwidth required for feeder links to 12 GHz broadcasting satellites

Substantial bandwidth has been allocated to the BSS for its space-to-Earth links, and it is foreseen that these bands will ultimately be used extensively for television with frequency re-use obtained by means of high-gain satellite transmitting antennas and the use of cross-polarization techniques. A similar measure of frequency re-use will, no doubt, be obtained in the feeder link direction by means of high-gain satellite receiving antennas, but it is doubtful whether this technique can provide a significantly greater degree of frequency re-use in the feeder link than in the downlink, in parts of the world where broadcasting coverage areas are relatively small. The usage of the fixed-satellite Earth-to-space bands for broadcasting satellite feeder links could be reduced if means could be found for a further measure of frequency re-use in the feeder link. Four possible ways of achieving this have been identified:

– Feeder link frequency re-use using the higher directivity of the transmitting earth-station antenna, relative to broadcast receiving antennas.

– Dual polarization.

– Alternative modulation methods for the feeder links.

– Integrated sound-vision systems.

4 Feasibility of sharing allocations to the FSS (Earth-to-space) with feeder links for the BSS

4.1 Use of the 14.0 to 14.5 GHz band

An example is used to demonstrate interference by a broadcasting-satellite service feeder-link transmission to a satellite with INTELSAT-V characteristics, and the reverse situation of interference by a fixed-satellite service uplink transmission to a broadcasting-satellite feeder link. The interfering signals are assumed to be co-frequency and co-polarized.

The following are the system assumptions made in the example for the two interfering signals:

Regarding the broadcasting-satellite uplink transmissions:

Satellite receive antennas beamwidths:	1°, 2°, 4°
Satellite receiving system noise temperature:	3 000 K
Transmit earth station diameter:	2, 4, 8 m
Uplink carrier/noise ratio:	25 dB
RF bandwidth:	27 MHz
Energy dispersal:	600 kHz peak-to-peak

These assumptions result in the following consequential system parameters (at 14 GHz):

TABLE 2

Satellite receiving system		Transmit earth station			
Antenna beamwidth (degrees)	Beam edge G/T (dB(K^{-1}))	e.i.r.p. (dBW)	Power into antenna (W)		
			2 m	4 m	8 m
1	6	72.7	380	97	24
2	0	78.7	1 500	380	97
4	–6	84.7	6 000	1 500	380

Regarding the INTELSAT system, three representative transmission types will be assumed, with the following characteristics:

TABLE 3

Type	Modulation	Capacity	e.i.r.p. (dBW)	Protection ratio (dB)
A	FDM-FM	24 channels	69	29(1)
B	FDM-FM	972 channels	81	33(1)
C	CQPSK-TDMA	120 Mbit/s	82	30(2)

(1) To produce 600 pW0p of noise power in the worst channel due to interference from an analogue FM-TV transmission.

(2) Minimum permissible for a single entry from any high power transmission contained within the occupied band of 72 MHz.

Assuming coincident or overlapping 14 GHz space station receive antenna coverages of both a broadcasting satellite and an INTELSAT-V, and assuming further that the earth stations transmitting to the broadcasting satellite meet the ITU-R reference earth-station antenna pattern; compliance with the required protection ratios given above would necessitate the geocentric angular separations, as given in Table 4, between the broadcasting-satellite and an INTELSAT-V.

The advantages of decreased broadcasting satellite receiving antenna beamwidth in reducing interference conditions are clearly shown, however, the reduced coverage could prevent transmission to the broadcasting satellite from certain areas within the boundaries of the service area, or from outside the service area.

TABLE 4

Characteristics of the broadcasting-satellite system		Spacings for interfered-with satellites INTELSAT carrier types (degrees)		
		A	B	C
Satellite antenna receive beamwidth (degrees)	Transmitting earth station antenna diameter (m)	24 channels FDM-FM	972 channels FDM-FM	Q-CPSK 120 Mbit/s
1	2 4 8	5.0 2.9 1.7	2.4 1.4 < 1.0	1.7 < 1.0 < 1.0
2	2 4 8	8.7 5.0 2.8	4.2 2.4 1.4	2.9 1.7 < 1.0
4	2 4 8	15.1 8.7 5.0	7.2 4.2 2.4	5.0 2.9 1.7

Present INTELSAT planning provides for an appreciable number of FDM-FM carriers of only 24 channels capacity with numerous FDM-FM carriers having capacities anywhere between 24 and 972 channels. The geocentric angular separations required between a broadcasting satellite and an INTELSAT-V are, for such carriers, appreciable. They might be achievable if broadcasting satellites were spaced from each other by twice the above angles, but that would result in only just one fixed-service satellite location alternating with one broadcasting satellite location. Where a ratio of n fixed-service satellites to one broadcasting satellite would be desirable, the broadcasting-satellite spacing would have to be further increased by $n - 1$ times the spacing required between the fixed-service satellites.

One could, with the INTELSAT system, take advantage of the fact that it provides currently only limited uplink (14 GHz) coverage and use for broadcasting-satellite feeder links, satellite receive beams of less than 1° beamwidth, and transmit earth stations of greater than 8 m antenna diameter to alleviate the problem, but this could be a severe constraint on the broadcasting-satellite service and may not be acceptable. Alternatively, one might align carrier frequencies between broadcasting-satellite feeder links and INTELSAT-V carriers, or attempt to realize some uplink polarization discriminations.

In the other direction, interference from fixed-satellite service earth stations into broadcasting satellites is far from negligible. With the parameters for the INTELSAT 972-channel carrier and an assumed required single entry protection ratio of 45 dB in the broadcasting-satellite service feeder links, the following geocentric satellite separations would be required at 14 GHz.

TABLE 5

Broadcasting satellite received beamwidth (degrees)	Satellite spacings for different INTELSAT transmit earth-station diameters (degrees)		
	8 m	12 m	16 m
1	11.6	8.8	6.8
2	6.7	5.0	4.0
4	3.8	3.0	2.3

The system parameters given in this section for the FSS are those of INTELSAT-V. Other systems in the FSS, particularly those intended for domestic and regional service, may require greater spacings than those indicated in the tables.

In this case an increase in the sensitivity of the broadcasting-satellite receiver correspondingly increases its sensitivity to interference from transmissions of earth stations in the FSS, and may result in increased satellite spacing requirements.

It may be concluded that interference problems could arise between uplinks of FSS systems and feeder links to broadcasting satellites when they use a common frequency band. However, specific solutions to these problems may be available through frequency coordination and the use of appropriate technology. It is concluded that individual cases of sharing between networks in the FSS and broadcasting satellite feeder links require detailed examination, taking into account the projected design and operating parameters. Two additional examples are given of studies for Regions 1 and 3.

4.1.1 Example 1

An analysis carried out by Japan calculated the interference for particular cases in the band 14.0-14.5 GHz between uplinks to fixed satellites serving Region 3 having the characteristics shown in this Annex for INTELSAT-V and feeder links to broadcasting satellites in Region 3 operating according to the 12 GHz Plan shows the following results:

– For the technical parameters used in the study, the worst value of the carrier-to-interference ratio (C/I) on broadcasting-satellite feeder links interfered with by uplinks to INTELSAT-V in the Indian Ocean Region would be greater than the assumed protection ratio of 45 dB. The worst value of the C/I of uplinks to INTELSAT-V interfered with by feeder links to the broadcasting satellite would be greater than 31 dB required for interference noise power of 400 pW0p (changed to 600 pW0p by Recommendation ITU-R S.466) in a 24-channel FDM-FM system.

– As for the interference situation between the assumed international fixed satellite positioned at 65° E and the broadcasting satellites, 15 m earth-station antennas of the fixed-satellite system would cause interference to the broadcasting satellites in the orbital range from 62° E to 74° E. Therefore, the required orbital separation for protecting the broadcasting-satellite feeder links may be about 10°. On the other hand, interference from broadcasting-satellite earth stations to space stations in the FSS would arise only from the feeder link earth stations to those broadcasting satellites nearest to the fixed satellite within 3° separation.

– As for the interference situation between the broadcasting satellites and the assumed domestic or sub-regional FSS satellites, located within the broadcasting-satellite positions, the interference to the broadcasting satellites would be dominant. As a result, use of 4.5 m earth-transmitting antennas in the fixed-satellite system would cause interference to the broadcasting satellites which are located within about 30° from the fixed satellites with protection ratios of less than 45 dB.

If different transmission characteristics and orbital locations were assumed for INTELSAT-V, some of which may soon be employed (SCPC, 12-channel carriers, 66° E longitude position etc.), they might lead to different conclusions concerning the required orbital separation between fixed and broadcasting satellites using the 14.0-14.5 GHz band in the Earth-to-space direction. Further study is necessary to take into account the range of system parameters that might be used.

4.1.2 Example 2

The study conducted by the French Administration in this example assumed the fixed-satellite orbital position located between two broadcasting satellites spaced 6° apart, and an FSS service area partially overlapping one of the BSS service areas. For this study and a particular set of assumptions, it was concluded that even in the case of FSS networks using high-capacity FDM-FM carriers, adequate protection from interference to the FSS from the BSS feeder link cannot be assured unless the FSS satellite is placed near to those positions for which interference is minimum. The choice of these positions may entail severe constraints incompatible with the requirements of the FSS (such as the service arc). Furthermore, the use of a band shared between broadcasting-satellite feeder links and the uplinks of the FSS over an entire Region would presuppose that sharing is feasible at least for certain orbital positions, irrespective of the possible characteristics of the systems, however, it has been seen that in the case of SCPC or low-capacity channels in the FSS, it is impossible to find a position that suits the purpose. The allocation of the 17.3-17.8 GHz band in Region 2 for BSS (space-Earth) links by the WARC-92 generates the need for further study here.

4.2 Use of the 14.5-14.8 GHz frequency band

WARC ORB-88 adopted a Plan for BSS feeder links in the 14.5-14.8 GHz band. This Plan, which appears in RR Appendix S30A contains assignments to 19 countries in Africa and Asia, uses 17 orbital locations between 37° W and 128° E and divides the band into 14 channels spaced 19.18 MHz apart.

The results of two studies into sharing between the FSS and BSS feeder links in this band are summarized in this section. These studies were carried out as part of the ex-CCIR preparation for WARC-92. Since that Conference decided that use of the band by the FSS should remain restricted to BSS feeder links, this section is included merely to illustrate the feasibility of 14/11 GHz band sharing.

BSS feeder link transmission parameters were taken as those published in RR Appendix S30A. Two types of FSS carriers were assumed, FM-TV and digital (IDR – 64 kbit/s and 8 448 kbit/s).

The interference analysis was based on the assumption of co-channel, co-coverage interference and no account was taken of polarization discrimination.

The key results showed that:

– an orbital separation of more than 2.5° is sufficient to protect the BSS feeder link assignments from the FSS under worst case co-coverage and co-frequency conditions;

– for smaller orbital separations between FSS and BSS satellites, FSS TV could use the bands with constraints on the uplink earth station locations within the BSS coverage area;

– the required orbital separations could be reduced if frequency separation is maintained between FSS TV and BSS assigned channel frequencies, and this appears to be possible;

– the FSS carriers with higher bit rates can use the band 14.5-14.8 GHz in a way similar to FSS TV;

– the sensitive carriers of the FSS can use the band by frequency planning the carriers around the BSS TV carriers and/or by avoiding certain contours of the BSS satellite antenna, depending on the orbital separation between the satellites.

To summarize, the studies show that coexistence of the FSS and WARC ORB-88 BSS feeder link assignments in the band 14.5-14.8 GHz is feasible. The constraints on FSS networks using this band are not onerous. For a new network to be positioned in most of the GSO, the constraints can be avoided altogether with appropriate choice of orbital location. For networks with limited orbital flexibility, the measures required are likely, in general, to be no greater in severity as compared to those experienced in normal coordination between FSS networks in current bands.

4.3 Use of the 17.3-18.1 GHz frequency band

In areas of Region 3, where high rainfall rates occur, the use of the upper band may not be desirable due to adverse propagation effects.

The RR Appendix S30A Plan is based on a 5 m antenna at 18 GHz with on-axis gain of 57 dBi, which allows e.i.r.p.s up to 87.4 dBW in the Plan. This requires approximately 1 kW of transmitter power at the antenna input terminal. Noise will be introduced by AM-PM conversion in the earth station HPAs and this has been accounted for in the Plan by allowing 2.0 dB in the feeder link C/N calculations.

5 Use of allocations to the FSS (space-to-Earth) for feeder links serving the BSS

If it were decided to use the reverse-direction approach as provided for in the band 10.7-11.7 GHz in Region 1, i.e. broadcasting feeder link assignments to be made in a space-to-Earth band allocated to the FSS, the following interference modes would ensue:

a) interference from fixed-satellite service space stations into space stations of the BSS, and

b) interference from earth stations transmitting to broadcasting satellites into earth stations receiving from fixed-service satellites.

For interference condition a) above, one may assume the previously introduced parameters for a broadcasting-satellite feeder link which led to a wanted carrier power at the broadcasting-satellite receiver of about –95 dBW. Assuming that a single-entry feeder link protection ratio of 45 dB would be required, the interference power at the broadcasting-satellite receiver input must not exceed a level of –140 dBW. The net attenuation between the output of an interfering fixed-satellite space station transmitter and the broadcasting-satellite receiver, is the free space loss A between the two space stations, less the sum of the antenna gains ΣG (transmit antenna gain of the fixed satellite; receive antenna gain of the broadcasting satellite) of the two kinds of space stations in the direction of each other, i.e. their respective antenna gains at an angle of not less than about 70° off their respective main beam directions. The following inequality applied:

$$P_{FS} + \Sigma G(70°) - A(\varphi) < -140 \qquad \text{dBW} \qquad (1)$$

which, with

$$A = 90 + 20 \log f_{MHz} + 20 \log \varphi \qquad \text{dB} \qquad (2)$$

and the assumption of $f = 11\,000$ MHz yields an equation for the minimum value of the satellite separation angle φ with the two variables P_{FS} (available carrier power at the transmit antenna terminal of the fixed satellite) and ΣG, as follows:

$$\log \varphi = \frac{P_{FS} + \Sigma G - 31}{20} \qquad (3)$$

It can be shown that nearly all these values for the required attenuation (0.01% of the time) would result in site separation distances of less than 100 km, in some cases much less. If, in addition, site shielding were available to provide additional isolation between the sites, even shorter separation distances would be necessary.

Further study is required on the potential effects on radio-relay systems of proposals for both uplinks and downlinks of space systems operating in bands shared with terrestrial services. In addition, it must be studied as to whether this mode of utilization produces operational constraints on feeder links to broadcasting satellites.

6 Conclusions

This Annex has shown that the accommodation of part of the feeder-link requirements of the BSS in one of the Earth-to-space allocations of the FSS heavily used by other FSS carriers may result in some mutual constraints of the two services upon each other since:

– the feeder link requirements for the Plans have to match those of the downlink, the number of required feeder link channels is of the same order of magnitude as that for downlinks, but may be greater, and orbital positions are not subject to choice;

– protection ratio requirements in feeder links to broadcasting satellites may be high, and inter-satellite spacing may have to be appreciable;

– certain orbit locations and/or certain radio-frequency channels may be unavailable to either of these two services;

– inter-network coordination procedures in force in those Earth-to-space allocations to the FSS which are not specifically earmarked for broadcasting-satellite feeder links may not be compatible with the Plan provisions and implementation options.

It is evident that, where BSS feeder link carriers are part of a Plan, the constraints are greater than otherwise and in such cases it would appear preferable for the feeder links to utilize those parts of the spectrum available to them but not to other FSS carriers. However, these constraints are not overwhelming, and technical means to alleviate them are available.

Among the strategies and techniques of reducing the impact on Earth-to-space allocations to the FSS, one worthy of continued consideration is that of sharing with the FSS in frequency bands allocated to the latter in the space-to-Earth direction. However, where such bands are also allocated to terrestrial services, a relatively large number of interference interfaces would exist. Further study is required for the development of appropriate sharing criteria.

Except where BSS feeder links are subject to a plan it is considered that the measures required to allow sharing will be no greater in severity than those used in normal coordination between networks in the FSS.