RECOMMENDATION ITU-R S.1067*,**

Ways of reducing the interference from the broadcasting-satellite service into the fixed-satellite service in adjacent frequency bands around 12 GHz

(1994)

The ITU Radiocommunication Assembly,

considering

a) that the Radio Regulations (RR) have allocations for the fixed-satellite service (FSS) and the broadcasting-satellite service (BSS) in adjacent frequency bands (e.g. 10.7-11.7 GHz and 12.5-13.25 GHz for FSS and 11.7-12.5 GHz for BSS in Region 1, 10.7-12.2 GHz for FSS and 12.2-12.7 GHz for BSS in Region 2 and 10.7-11.7 GHz and 12.2-13.25 GHz for FSS and 11.7-12.2 GHz for BSS in Region 3);

b) that in most cases satellite e.i.r.p. levels in the BSS will be considerably higher than the majority of FSS down-path e.i.r.p.s;

c) that the nature of video modulating signals, the need for high modulation indices and the practical limitations on satellite output filtering in the BSS, are likely to result in significant levels of unwanted emission immediately below the lowest frequency BSS channel and immediately above the highest;

d) that the commonly used interference limits for FSS carriers should be respected;

e) that the BSS 12 GHz bands are the subject of Plans defined in RR Appendix S30, which allow some guardband at the band edges, but that these guardbands might be utilized for non-broadcasting signals – e.g. Telemetry,

recommends

1 that the method described in Annex 1 may be employed to determine the potential level of interference from BSS space stations operated in adjacent bands;

2 that, to the degree practicable, the interference reduction techniques listed in Annex 2 may be employed in FSS and BSS networks operated in adjacent bands.

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 6.

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

ANNEX 1

Factors concerning the protection of fixed-satellite earth stations operating in adjacent frequency band allocations against unwanted emissions from broadcasting satellites operating in frequency bands around 12 GHz

1 General

The high space station e.i.r.p. required for individual reception in the broadcasting-satellite service may lead to substantial levels of unwanted emissions at frequencies outside the channel occupied by a broadcasting-satellite emission. For the broadcasting-satellite channels closest to the edges of an allocated band, these unwanted emissions may set up power flux-densities in the direction of a fixed-satellite earth station operating near the edges of adjacent fixed-satellite bands which may greatly exceed the levels of interference acceptable to the earth station.

Whether or not such levels of unwanted emissions cause unacceptable interference to fixed-satellite earth stations depends on a number of factors including:

– the orbital spacing between the broadcasting satellite and the fixed satellite and the corresponding fixed satellite earth-station antenna discrimination that may be achieved;

– the level of filtering in the broadcasting-satellite transmitter and the earth-station receiver that may be realized in practice;

– the frequency separation between channels closest to the frequency separating the allocations;

– the interference criterion used in defining the permissible maximum spectral power flux-density; and

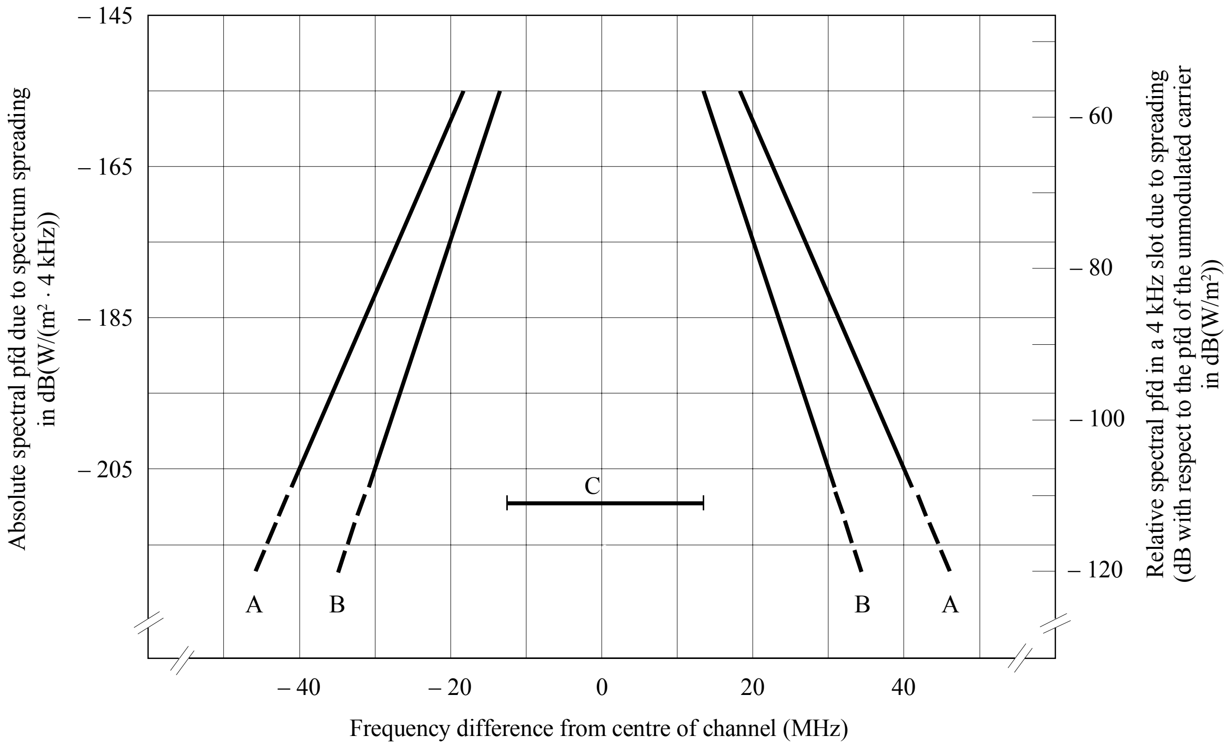
– additional factors providing isolation, such as satellite antenna discrimination.

2 Estimated levels of unwanted emissions from 12 GHz broadcasting satellites

The levels of spectral power flux-density (pfd) given in Fig. 1 correspond to a beam-centre e.i.r.p. from the broadcasting satellite of 64 dBW, which has been taken because the values of e.i.r.p. associated with approximately 90% of the frequency assignments made in the broadcasting-satellite Plan for Regions 1 and 3 lie in the range of 64 ± 1.5 dBW. More study is required to establish which curve between the two shown, may appropriately represent the operational conditions. The signal used in the calculation of curve A in Fig. 1 was on 100% saturated colour bars. Such a signal is not used in normal broadcasting.

FIGURE 1

Typical out-of-band envelopes of the radio-frequency spectrum radiated by a TV broadcasting satellite



A: envelope for 100% colour-bar baseband signal, modulator AC coupled
B: envelope for line 330 insertion test signal, modulator AC coupled
C: nominal channel bandwidth (27 MHz)

Note 1 – For the left-hand scale, it is assumed that the satellite e.i.r.p. corresponds to a pfd of –94 dB(W/m²) at the centre of the beam for an unmodulated carrier.

Note 2 – Minimum energy dispersal of ±7.9 kHz is assumed.

Note 3 – Pre-emphasis according to Recommendation ITU-R F.405 is assumed.

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3 Worst-case maximum permissible levels of spectral power flux-density at the interfered-with receivers

Examples of fixed-satellite systems using the bands adjacent to the Region 1, 11.7-12.5 GHz broadcasting-satellite service band are given in Table 1, along with calculations of the worst-case maximum permissible pfd at the interfered-with fixed-satellite service earth station receiver. The criterion used in these calculations was that the overall interference due to unwanted emissions should be at a level 10 dB below the thermal noise level of the interfered-with system. The probable benefit of antenna directivity has not been included in the calculations. Moreover, no account was taken of the spectral shape of either the unwanted emissions, nor of the interfered-with received signal. Under these assumptions, the maximum permissible spectral power flux-density of unwanted emissions in the band below 11.7 GHz is seen to be about –200 dB(W/(m^2 · 4 kHz)) for a narrow-band fixed-satellite signal and –195 dB(W/(m^2 · 4 kHz)) for a maritime satellite feeder link. In the band above 12.5 GHz, the limit is –171 dB(W/(m^2 · 4 kHz)) for a narrow-band data satellite-link. The frequency at which the maximum power flux-density from the broadcasting-satellite is specified will be called the “protected frequency”. For narrow-band signals it will be the centre frequency of the narrow-band fixed-satellite channel in question.

TABLE 1

Examples of systems in the 10.7-11.7 GHz and 12.5-12.75 GHz bands in Region 1 and the maximum pfd limits of unwanted emissions from broadcasting satellites to protect them

Parameter	System		
	10.7-11.7 GHz		12.5-12.75 GHz
	Maritime satellite to earth station link	Fixed-satellite to earth station link	Fixed-satellite to earth station link (data carrier)
Boltzmann’s constant (dB(W/(Hz · K)))	–228.6	–228.6	–228.6
Receive noise temperature (K)	300	100	100
Receive thermal noise level(1) (dB(W/4 kHz))	–167.6	–172.6	–172.6
Maximum interference level in a 4 kHz bandwidth into receiver (dB(W/4 kHz))	–177.6	–182.6	–182.6
Gain of receive antenna (dBi)	60	60	45.8
Effective maximum allowable pfd at the interfered-with receiver (dB(W/(m^2 · 4 kHz)))	–194.6	–199.6	–185.4

(1) A level of interference of 10 dB below thermal noise level is assumed.

When considering the use of narrow-band signals in the upper part of the 10.7-11.7 GHz band, the foregoing maximum permissible spectral power flux-densities apply directly. However, when wideband carriers are used in the upper part of the 10.7-11.7 GHz band, the relatively rapid roll-off characteristics of out-of-band emissions from broadcasting-satellite space stations will tend to reduce the effect of interference on such carriers.

As an example of a broadband system in the 10.7-11.7 GHz band, some calculations have been made for a 20 MHz 612 channel carrier used in the INTELSAT system.

For the calculations it was assumed that an effective single entry interference noise contribution of about 500 pW0p should be tolerable due to out-of-band interference.

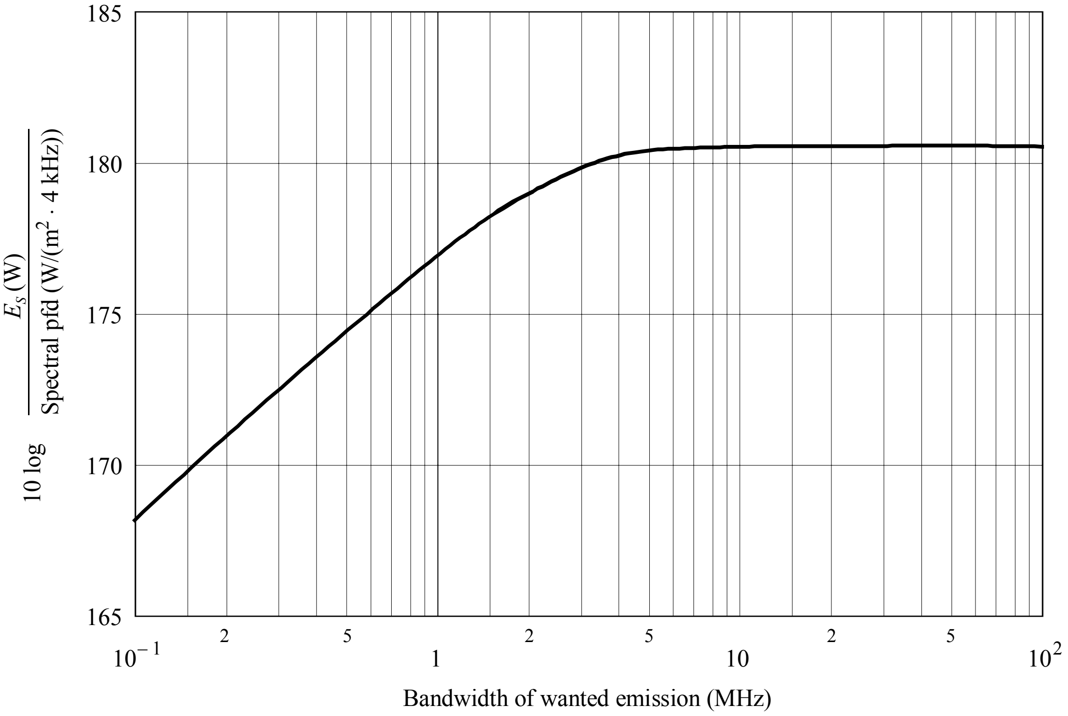
Taking the worst case, where the interference spectrum is represented by curve A of Fig. 1, the required carrier-to-interference ratio for the example considered, was found to be 25.6 dB. Then, taking an average e.i.r.p. density of 16.4 dB(W/MHz) for the INTELSAT system, together with the relationship between cumulative interference e.i.r.p. and band-edge power flux-density given in Fig. 2, the values of maximum permissible unwanted band-edge spectral density may be derived. The results are given in Fig. 3 as a function of the bandwidth of the wanted carrier.

FIGURE 2

The ratio of E_S to the interference spectral pfd at the edge of the broadcasting-satellite frequency allocation, as a function of the wanted carrier bandwidth

where:

E_S: maximum permissible cumulative interference e.i.r.p. within the bandwidth of the wanted carrier which is located at the edge of the band occupied by the FSS, a guardband of 4 MHz being allowed.



Note 1 – This curve was calculated using the interference spectrum envelope represented by curve A of Fig. 1.

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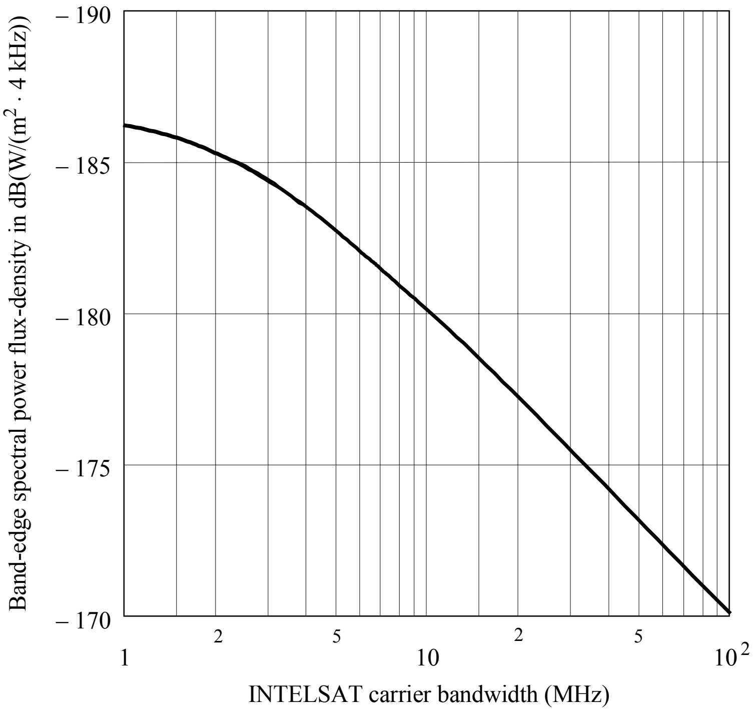
For the particular case of the 20 MHz 612 channel carrier instanced above, which applies where the BSS and FSS spacecraft are co-located, it may be seen that the maximum permissible band-edge pfd would be about –177 dB(W/(m^2 · 4 kHz)). It is considered that a standard of protection based on this 20 MHz carrier would afford reasonable protection for most other carrier sizes, apart from narrow-band carriers. Thus, by avoiding the use of narrow-band carriers in the upper portion of the 10.7-11.7 GHz band, a reasonable beam-edge out-of-band interference pfd would appear to be –177 dB(W/(m^2 · 4 kHz)). In cases where there is some angular separation between the BSS and FSS satellites, this permissible pfd could be raised by the degree of discrimination afforded by the wanted earth station antenna pattern.

FIGURE 3

Maximum permissible band-edge spectral power flux-density due to interfering out-of-band emissions as a function of carrier bandwidth in the INTELSAT-V system

(Based on a single entry producing 500 pW0p of interference noise power and assuming a guard band 4 MHz wide within the allocated FSS band)



Note 1 – This curve was calculated using the interference spectrum envelope represented by curve A of Fig. 1.

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4 Approaches to protecting fixed-satellite earth stations

To achieve compatibility between unwanted emissions from broadcasting-satellite space stations and permissible levels of interference in the fixed-satellite earth stations, a combination of the following provisions may have to be made:

4.1 provide for adequate angular separation between the orbit location of satellites in the BSS and the FSS;

4.2 provide adequate output filtering in the transmitter of the broadcasting-satellite space stations or in the receivers of the fixed-satellite earth stations; or both;

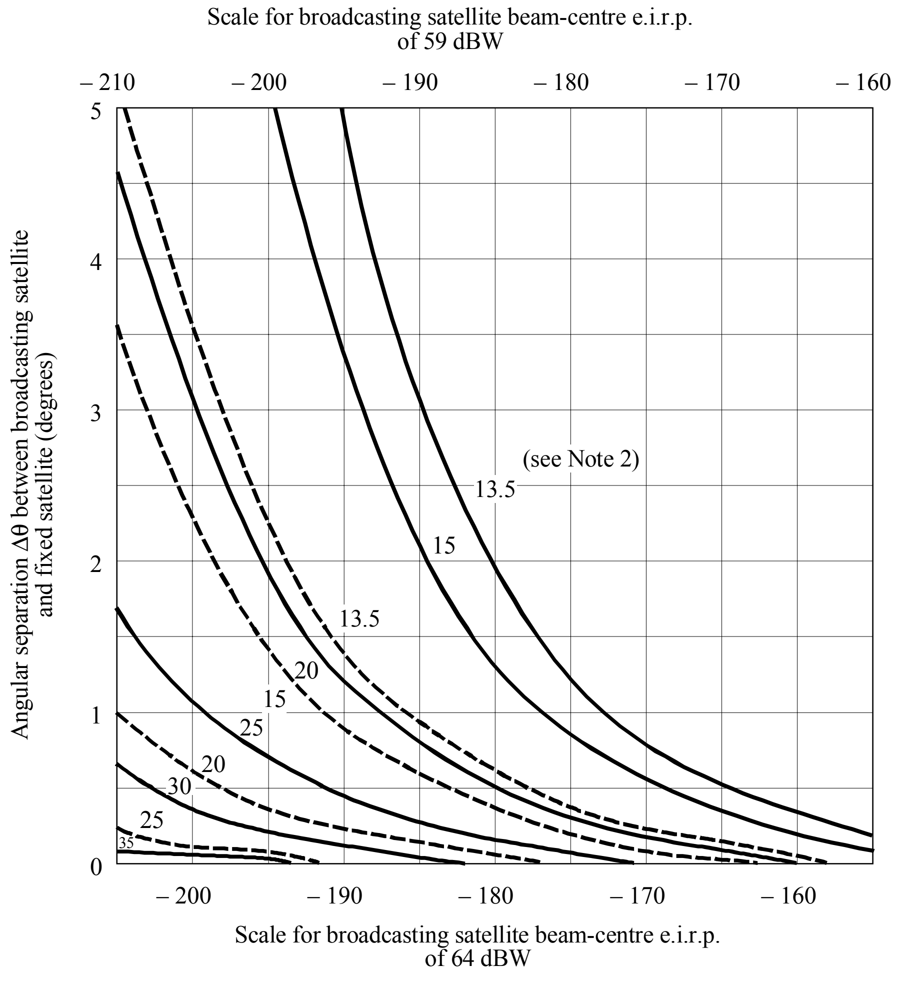
4.3 provide adequate frequency separation between the centre of the lowest channel occupied by an emission from a broadcasting-satellite space station and the previously defined protected frequency of the FSS.

In the interest of minimizing *a priori* constraints on system design in both services, it may be undesirable or impractical to rely on filtering requirements alone, as outlined under § 4.2 above; however, a relationship between pertinent system parameters including orbit spacing between satellite locations and frequency separation between "protected frequency" and channel centre frequency, as outlined in § 4.1 and 4.3 above, can be developed.

This relationship is shown in Fig. 4 where the required satellite spacing is plotted versus the power flux-density of unwanted emission at the protected frequency of the fixed-satellite earth station, with frequency separation as a parameter. The curves were derived from information regarding the out-of-band emissions from broadcasting-satellite space stations as given by curves A and B of Fig. 1 for a broadcasting-satellite channel with a channel bandwidth of 27 MHz.

FIGURE 4

Angular spacing and frequency separation to protect fixed-satellite earth stations from unwanted emissions from adjacent-band broadcasting satellites



Note 1 – The channel bandwidth of the broadcasting-satellite signal is 27 MHz.

Note 2 – The numbers on curves indicate Δf: frequency separation between fixed-satellite protected-frequency and broadcasting-satellite channel centre frequency (MHz).

Note 3 – The solid curves are based on curve A of Fig. 1. The dashed curves are based on curve B of Fig. 1.

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The absolute level of the unwanted emissions at the fixed-satellite earth station depends, of course, upon the e.i.r.p. of the broadcasting-satellite. Separate abscissa scales are given in the Figure for e.i.r.p.s of 64 dBW and 59 dBW corresponding to clear weather power flux-densities of about -99 dB(W/m^2) and -104 dB(W/m^2), respectively, at the centre of the broadcasting-satellite service area.

The level of unwanted emissions also depends on the type of television signal carried by the broadcasting-satellite space station, on the location of the fixed-satellite earth station, relative to the broadcasting-satellite service area, and on the gain and side-lobe pattern of the earth-station receiving antenna. The solid curves in Fig. 4 were drawn for the worst-case situation in which the broadcasting-satellite signal was a 100% modulated colour-bar transmission (see curve A in Fig. 1). The dashed curves were drawn for the case in which the broadcasting-satellite signal is a line-330 insertion test signal transmission (see curve B in Fig. 1). In both cases, it was assumed that the fixed-satellite earth location is located at the centre of the broadcasting-satellite service area. The earth-station antenna gain was assumed to be 60 dB and its side-lobe pattern to be given by $32 - 25 \log \varphi$. If the earth station is located outside the coverage area of the broadcasting-satellite, additional interference protection is realized from the angular discrimination of the broadcasting-satellite space station transmitting antenna.

5 Protection by compatible satellite spacing and/or frequency separation (co-coverage)

5.1 Case 1: Both orbit spacing and frequency separation

Using the curves of Fig. 4, it is possible to calculate the combinations of orbital spacing $\Delta\theta$ and frequency separation Δf that will reduce the levels of unwanted emission from a broadcasting-satellite to the maximum permissible level at the protected frequency. The results of such calculations are displayed in Fig. 5 where $\Delta\theta$ is plotted versus Δf for values of maximum permissible pfd ranging from –210 to –160 dB(W/(m^2 · 4 kHz)). Separate families of curves, labelled A and B, are given for the two types of broadcasting-satellite test signals corresponding to curves A and B, respectively, in Fig. 1.

By interpolation it can be seen that, to achieve the interference criterion of –177 dB(W/(m^2 · 4 kHz)) from a 64 dBW e.i.r.p. broadcasting-satellite with 100% colour-bar modulation, for satellite spacing of more than 2°, the required frequency separation is less than half the bandwidth of the broadcasting-satellite, and there is no unused spectrum. With a 59 dBW e.i.r.p. satellite, a maximum separation of about 1° would suffice to reduce the unused spectrum to zero.

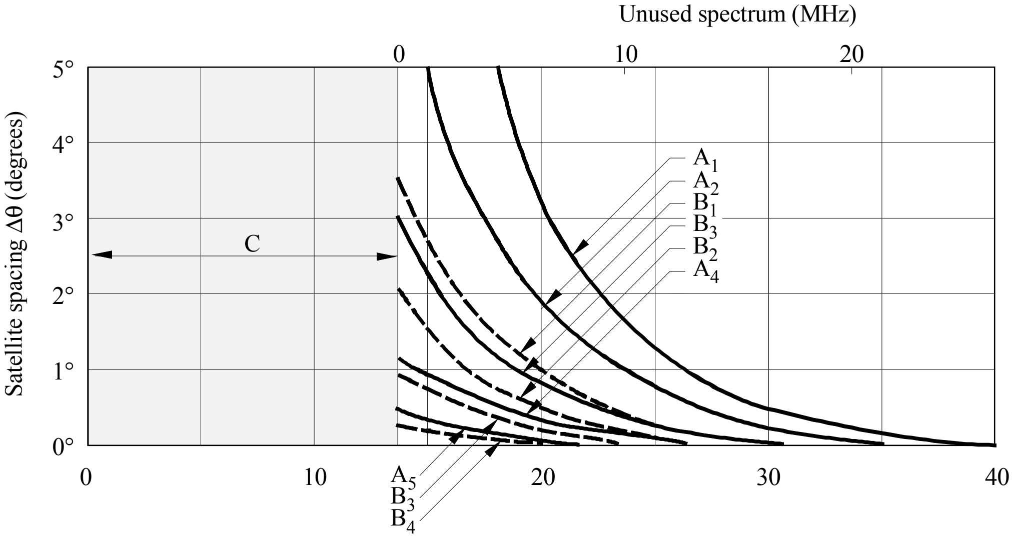
If the line-330 insertion test signal corresponding to curve B in Fig. 1 is assumed, smaller angular and frequency separations would meet the interference limits.

5.2 Case 2: Co-located satellites ($\Delta\theta = 0$)

If, in order to avoid placing any constraints on either service in the location of its satellites, the possibility of co-located satellites is assumed, the reduction of unwanted emission to the permissible values may have to be achieved by frequency separation alone. In this case, the values of maximum permissible power flux-density mentioned in § 3, together with the curves given in Fig. 1, can be used directly to deduce the frequency separation between the centre frequency of the bottom (or top) channels in the broadcasting-satellite band and the fixed satellite protected frequency. For convenience, these curves are reproduced in Fig. 6a), in which it should be noted that 13.5 MHz of the required separation contains the essential spectrum of the broadcasting-satellite emission.

FIGURE 5

Trade-off between satellite spacing (Δθ) and frequency separation (Δ*f*) for various maximum permissible pfds



A: 100% modulated colour-bar transmission (solid curves)
B: line-330 insertion test signal transmission (dashed curves)
1: 264, e.g. pfd = –200 dB(W/(m² · 4 kHz)) from a 64 dBW satellite
2: 259, e.g. pfd = –200 dB(W/(m² · 4 kHz)) from a 59 dBW satellite
3: 249
4: 239
5: 229
C: half-bandwidth of broadcasting-satellite channel (13.5 MHz)

Note 1 – The letter and number on a curve, respectively, identify the type of baseband signal assumed for the broadcasting-satellite emission and the difference $E_S - pfd$, between the satellite e.i.r.p. E_S (dBW) and the resultant, unwanted emission level, pfd (dB(W/(m² · 4 kHz))) at the fixed-satellite earth station.

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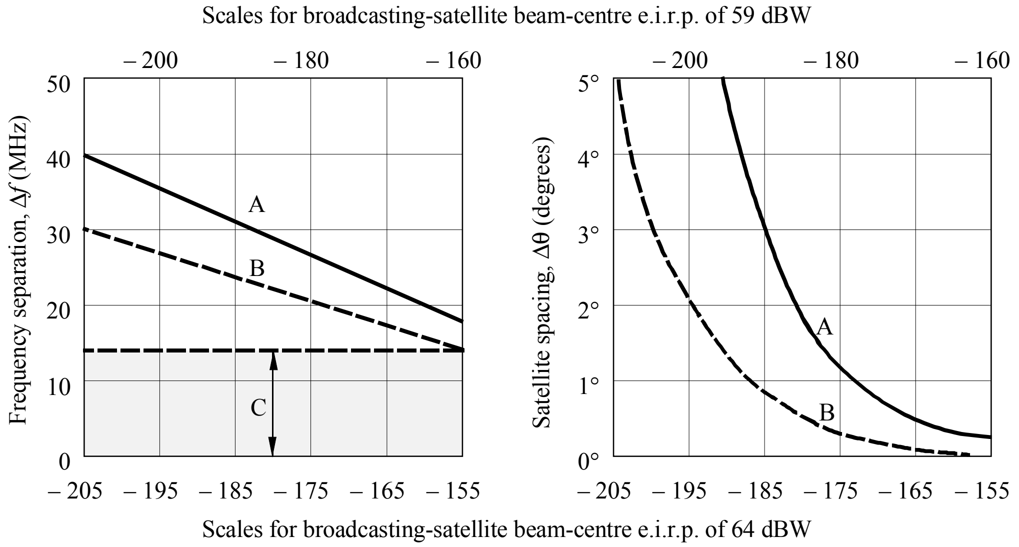
5.3 Case 3: No unused spectrum (Δ*f* = 13.5 MHz)

In certain cases, uplink interference problems will preclude the co-location of 12 GHz broadcasting-satellites and fixed-satellites in the adjacent bands. For this reason, it is of interest to consider the other special case in which the reduction of unwanted emissions to the permissible levels is achieved by orbital spacing alone.

The curves for this case corresponding to the two test signals previously discussed are shown in Fig. 6b) and may be read directly.

FIGURE 6

Frequency separation for special cases of co-located satellites (Δθ = 0) and zero unused spectrum (Δ*f* = 13.5 MHz)



Maximum permissible spectral pfd in dB(W/(m^2 · 4 kHz))

a) Δθ = 0 *b)* Δ*f* = 13.5 MHz

A: 100% modulated colour-bar transmission (solid curves)
B: line-330 insertion test signal transmission (dashed curves)
C: half-bandwidth of broadcasting satellite channel (13.5 MHz)

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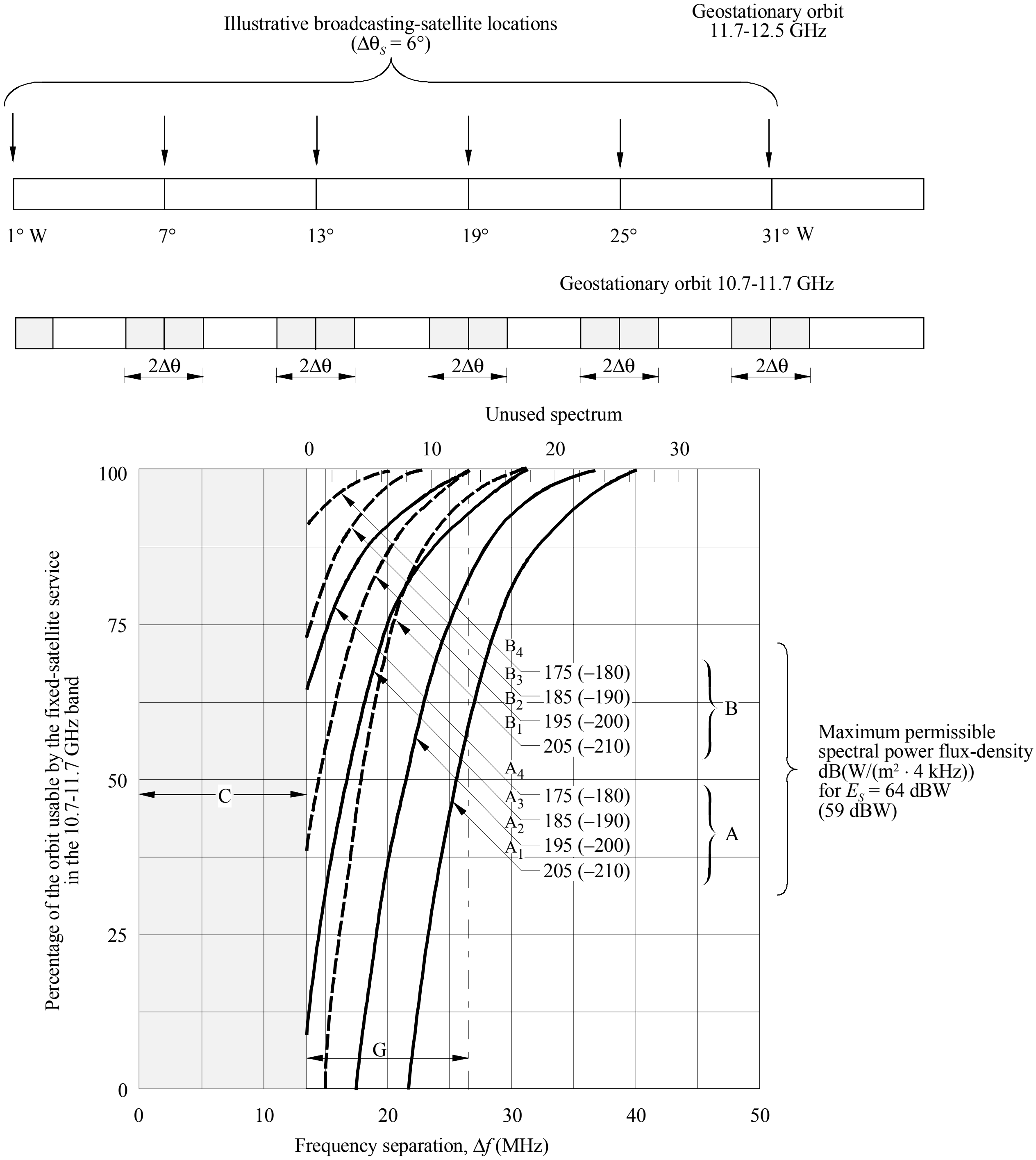
5.4 Discussion

A consequence of the results presented above is that a set of broadcasting-satellites in the geostationary-satellite orbit might create problems in certain orbital arcs for satellites in the fixed-satellite service operating in adjacent bands, depending on the frequency separation between the closest channel used by the broadcasting-satellite and the protected frequency of the fixed-satellite. This point is illustrated in Fig. 7. Any array of broadcasting-satellites is shown in the 11.7-12.5 GHz band at a spacing of 6°. At each point shown the full 800 MHz allocated to Region 1 is radiated (different channels being received by different countries), from each point the lowest and highest channels are radiated, and adjacent broadcasting-satellites employ opposite polarizations. The curves shown in Fig. 7 are based on Fig. 5 but the vertical axis gives the percentage of orbit "available" to the FSS in the 10.7-11.7 GHz band, relative to all the orbit being "available", availability being defined by the foregoing interference criteria. Depending on the relative positions of the fixed service and the BSS, these additional separation requirements will not necessarily lead to the inability to find a location for another particular fixed-service satellite.

FIGURE 7

Illustrative example of possible effect of unwanted emissions from 12 GHz broadcasting satellites on the orbital arc usable by fixed satellites in adjacent bands



A: 100% modulated colour-bar transmission (solid curves)
B: line-330 insertion test signal transmission (dashed curves)
C: half-bandwidth of broadcasting-satellite channel
G: guardband allowed by RR Appendix S30

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The implications of Fig. 7 will need to be assessed for the different parts of the geostationary orbit in the 10.7-11.7 GHz band. For example, in those parts where a high density of fixed-satellites is anticipated, orbital separation, as shown in Figs. 5 and 6b), may not be feasible for all cases. It may then be necessary to assume no orbital separation as the general case for broadcasting satellites in this part of the orbit.

The above studies did not assume guardbands at the edge of the broadcasting-satellite and fixed-satellite service allocations. The broadcasting plans include centre frequencies for channels 1 and 40 which appear to leave guardbands of about 13.5 MHz. As a result, interference from broadcasting-satellite emissions caused in fixed-satellite service systems operating in adjacent allocated frequency bands may not be as severe as indicated in these studies. On the other hand, these studies did not take into account the possibility of using guardbands for TT&C carriers. Further studies are needed to evaluate whether such an operation will increase the level of unwanted emissions from broadcasting satellites including intermodulation products between TT&C carriers and television carriers. However, where the guardbands are *not* utilized by the BSS spacecraft, Fig. 7 shows that the proportion of the FSS bands affected will be small.

6 Some technical observations concerning frequency band allocations

Based on the frequency study on unwanted emissions, technical problems arise when a broadcasting-satellite service allocation and a fixed-satellite service allocation (in which systems are developed employing global beams, large diameter earth station antennas, sensitive low noise amplifiers and/or narrow-band modulation techniques) are adjacent to each other in the RR Table of Frequency Allocations.

FSS stations located in the service area of a BSS will be subjected to emissions with high power levels from the BSS space stations. These emissions, which are in the band adjacent to the FSS, if received unattenuated, could cause overloading of the FSS earth station low-noise receiver and a consequent increase in the effective system noise temperature. Therefore, attention must be given to this possible situation during the design phase of the FSS earth station.

ANNEX 2

Ways of reducing interference into FSS carriers from BSS channels adjacent to the FSS band

1 FSS satellite operators and designers may be able to utilize, if found feasible, the following techniques to reduce the amount of interference due to out-of-band emissions from BSS end channels:

– try to avoid orbital locations to be about ±1° from the BSS satellite using channels adjacent to the FSS band;

– choose appropriate FSS carriers in the frequency band adjacent to the BSS band;

– use power compensation techniques within the transponder adjacent to the BSS band. Greater power can be assigned to FSS carrier frequencies subject to interference from the BSS end channels;

- use FSS earth station antennas with an improved side-lobe pattern in the orbital plane, e.g. $29 – 25 \log \varphi$ (dB);
- interact with BSS operators using the BSS channels adjacent to the FSS band so as to assess the exact interference situation.

2 On the other hand, BSS satellite operators may be able to utilize, if found feasible, the following techniques to reduce the out-of-band emission into adjacent FSS bands:

- bring into use the lowest and highest frequency BSS channels after using all the other channels in the Plan;
- employ good filtering techniques at the BSS satellite for the lowest and highest frequency channels in the Plan;
- employ reduced satellite e.i.r.p. for end channels consistent with system requirements and with possible interactions with other BSS assignments;
- employ improved BSS satellite transmitting antenna patterns to reduce the amount of energy outside the service area compared with that assumed in the Plan.