REPORT 807-3*

UNWANTED EMISSIONS** FROM BROADCASTING-SATELLITE SPACE STATIONS

(Question 1/10 and 11, Study Programme 2E/10 and 11)

(1978-1982-1986-1990)

1. Introduction

Space stations in the broadcasting-satellite service may radiate high levels of e.i.r.p. and consequently the level of the unwanted emissions may produce interference in networks using adjacent and harmonically related bands for other services. This Report considers unwanted emissions from space stations operating in all bands allocated to the broadcasting-satellite service. In particular, some provisional results of studies are given in this Report regarding unwanted emissions from a broadcasting-satellite space station at the lower and upper edges of the 12 GHz band.

2. Possible sources of unwanted emissions from broadcasting satellites

The sources of unwanted emission into adjacent bands from a broadcasting-satellite transponder operating near the edge of a broadcasting-satellite frequency band are:

- radiation due to frequency conversion;
- third-order intermodulation products caused by insufficient suppression of signals in adjacent channels in the satellite transponder branching network;
- thermal noise power generated by the satellite transponder;
- spreading of the signal spectrum due to non-linearities.

In the following, an attempt is made to deduce the variation of the spectral power flux-density (PFD) as a function of frequency difference from the channel centre. The absolute values of the spectral PFD are related to the maximum PFD required for television broadcasting as given, for example, in Report 215.

Another possible source of unwanted emissions, in this case, beyond adjacent bands, is a harmonically related spurious emission from a broadcasting satellite.

2.1 Spurious emission due to frequency conversion

Spurious emissions generated by the frequency conversion process and the local oscillator source need to be taken into account in the implementation of BSS systems.

Tables I and II show for example the down-link frequencies that would be affected by high order frequency conversion products (up to the 10th order) for specific translation frequencies for Region 2. Similar factors also apply in general to Regions 1 and 3.

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* This Report should be brought to the attention of Study Group 1 and the IEC.

** Unwanted emissions consist of spurious emissions and out-of-band emissions. See Nos. 138, 139 and 140 of the Radio Regulations.

Considering the effects of interference caused by spurious components radiated from one BSS channel into another, the protection margins inherent to the BSS down-link plan should not be significantly degraded by such implementation factors. This is only likely to be a significant factor for interference from a co-located satellite, and in the case of certain values of frequency translation between a feeder link and its associated down link. In Regions 1 and 3, taking into account possible power differences between down-link carriers and the possibility of multiple interfering signals, an appropriate limit for the total spurious emission power radiated from any BSS satellite channel falling within any down-link channel is of the order of 55 dB below that of the main carrier; i.e. the carrier from the channel causing the interference. This figure is readily realizable, for example, in the case of a satellite using a 5.6 GHz frequency translation in the Region 1 and 3 Plan with a single frequency conversion stage. Dual frequency translation will reduce the level of in-band spurious emissions. Such techniques can be used if required. The interference level actually required to protect other channels from this source of interference requires further study.

2.2 *Intermodulation products caused by insufficient suppression of signals in adjacent channels*

With a carefully designed branching filter inserted at a relatively linear portion of the transponder, it should be possible to suppress the signal in the adjacent channels so that the intermodulation products falling into the adjacent band are of an acceptable level.

2.3 *Unwanted emission due to thermal noise power generated by the broadcasting-satellite transponder*

Thermal noise in the down link is caused by interaction of the thermal noise and the RF carrier in the high-power amplifier due to non-linearity, by amplification and transmission of receiver noise, and by retransmission of received feeder-link noise.

Figure 1 represents the calculated results [CCIR, 1974-78a] for the thermal noise spectral PFD as a function of frequency. The two curves shown refer to different filtering conditions as noted in the figure.

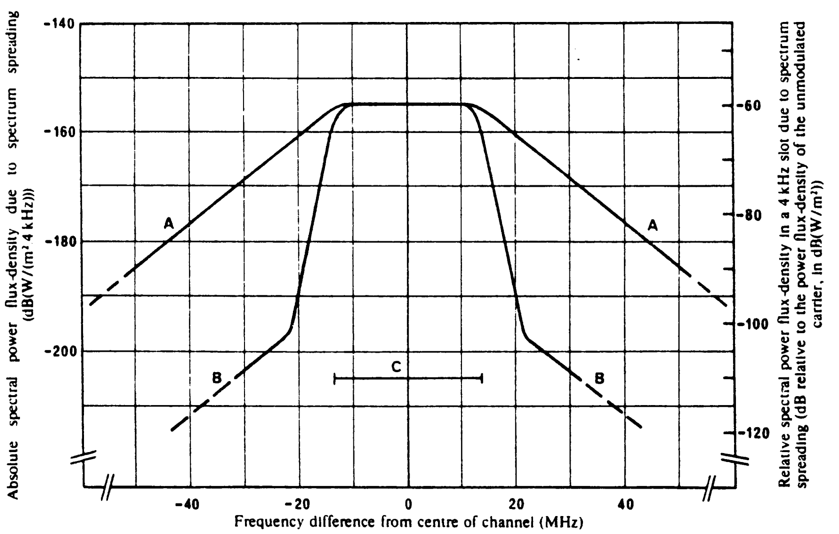

FIGURE 1 — *Typical envelopes of the thermal noise power spectrum radiated by the high-power output amplifier of a broadcasting satellite*

Curves A : Transponder with typical filtering

B : Estimated performance of transponder with additional filter before power amplifier

C : Nominal channel bandwidth (27 MHz)

Note. — The spectra shown by curves A and B assume the presence of an rf-carrier corresponding to a power flux-density of −94 dB(W/m²) at the centre of the beam area and a carrier-to-noise power ratio of about 20 dB at the transponder output. In the absence of a carrier, the thermal noise spectrum envelopes increase by about 9 dB.

2.4 *Spreading of the spectrum of the radio-frequency signal due to non-linearities*

Band limiting on the feeder link and in the transponder leads to carrier envelope variations at the input to the transponder high power amplifier. This is typically a saturated amplifier which causes AM/PM conversion, so the envelope variations will generate RF intermodulation products, some of which will fall out of band. The transponder output filter is likely to have limited loss, so it will be unlikely to be very effective in removing out-of-band intermodulation products near to the band edge.

This intermodulation will be reduced by increasing the bandwidth of the feeder link and of the transponder preceding the high power amplifier, but this will increase the system noise bandwidth (see § 2.3).

The actual spectrum radiated by the satellite largely depends upon the television signal transmitted. In Fig. 2 computer calculated results on this subject [CCIR, 1974-78a] are presented for illustrative purposes. The signal used in the calculations of Fig. 2, curve B, was a television test signal in line 330, with a peak-to-peak deviation of 13 MHz. The signal used in the calculation of Fig. 2, curve A, consisted of 100% saturated colour bars. It should be noted that such a signal is not used in normal broadcasting. A sound sub-carrier with a peak-to-peak deviation of 5.6 MHz was associated with both television signals.

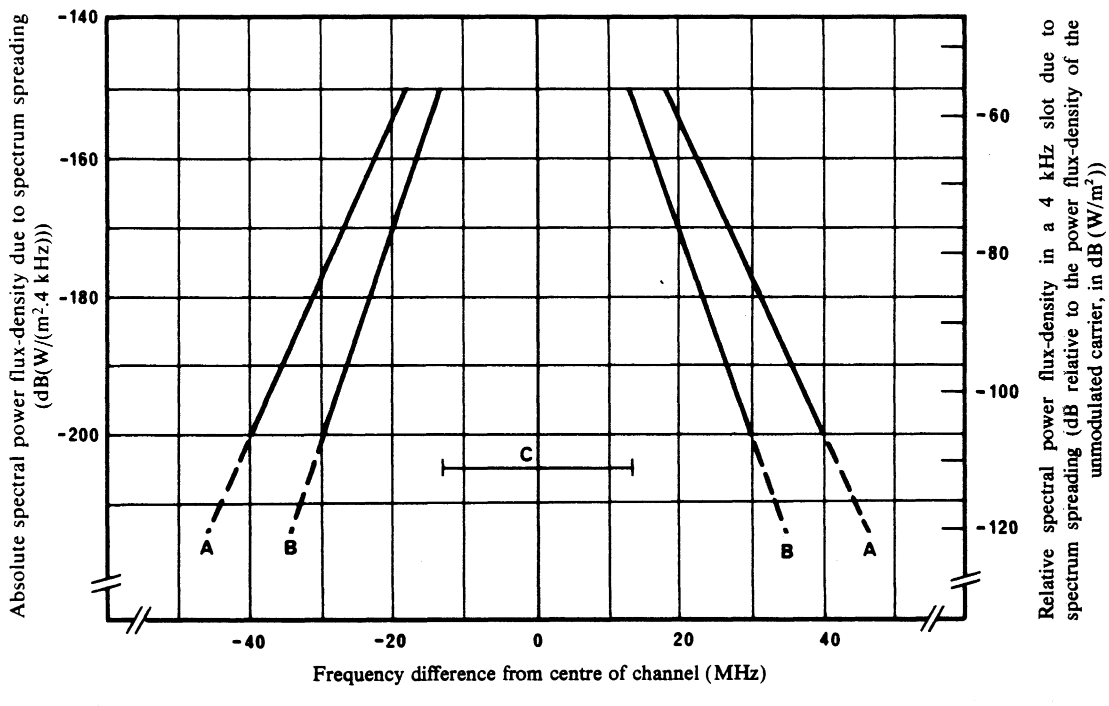

FIGURE 2 – *Typical out-of-band envelopes of the radio-frequency spectrum radiated by a television broadcasting satellite*

Curves A: envelope for 100 per cent 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 e.i.r.p. of the satellite corresponds to a power flux-density of -94 dB(W/m^2) at the centre of the beam for an unmodulated carrier.

Note 2. – Minimum energy dispersal of $\pm$ 7.9 kHz is assumed.

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

Additional data showing power spectral density envelopes of television signals based upon laboratory measurements in the United States of America [CCIR, 1978-82a] are shown in Annex I. The signal used in these measurements was an FM carrier with a digital (4-PSK) audio sub-carrier (693 kbit/s data rate at a sub-carrier frequency of 5.5 MHz) with a 75% NTSC colour bar. Measurements for both 18 MHz and 27 MHz bandwidths were made with several different signal deviations (including over-deviation). No energy dispersal waveform was used, nor was any significant RF filtering applied.

2.5 *Spurious emissions due to harmonics*

Annex II notes the harmonics of the various bands allocated to the broadcasting-satellite service and other space services which operate at those frequencies. Studies in the USA have shown that if spurious emissions at harmonics of the fundamental frequency are of the order of 60 dB below the level of the fundamental interference to other services operating at these frequencies may not be significant [CCIR, 1978-82b].

General criteria for protection include: power level, fraction of total sky covered and percentage of time exceeded. Protection is usually achieved by geographical sharing; "line-of-sight" sharing is difficult, but maximum allowable line-of-sight e.i.r.p.s are given in Fig. 3.

The likelihood of harmful interference to the services shown in Annex II has not been assessed except for the case reviewed in § 3.3. Further study is necessary.

3. **Protection of other services from unwanted emissions**

Guard bands necessary to protect the services operating in adjacent bands from unwanted emissions of 12 GHz broadcasting satellites in Regions 1 and 3 are discussed in § 3.9 of Annex 5 to Appendix 30 (ORB-85) to the Radio Regulations.

For space stations in the broadcasting-satellite service in other bands, adjacent services may similarly be protected by establishing appropriate guard-bands. The width of these guard bands will depend on future decisions concerning the minimum levels to be protected, on current filter technology (e.g. roll-off in dB/MHz) and on the bandwidth of the emission from the broadcasting-satellite service.

Also, the width of the guard-bands depends upon equitable application of the principle of sharing the burden of protection, that is, services in adjacent bands should employ designs affording a maximum feasible protection from interference outside the bandwidth required for satisfactory service (see for example No. 301 of the Radio Regulations).

Studies in the USA have shown that unwanted emissions immediately outside the allocated band can be reduced by filters with a roll-off of, for example, 2 dB/MHz, which could continue to an attenuation of 80 dB, depending on filter design, but such attenuation may not be realized at frequencies far removed from the carrier.

3.1 *Fixed-satellite service*

Report 712 addresses the protection of fixed-satellite earth stations operating in adjacent bands against unwanted emissions from 12 GHz broadcasting-satellite space stations and gives the values of maximum allowable power flux-density (PFD) at the edge of the band that would produce no more than 500 pW0p of interference in the worst channel of an FDM-FM carrier in the fixed-satellite service whose space station is co-located and serves the same area.

At 12.5 to 12.75 GHz, a value for a specific FSS system is shown as -171.2 dB(W/(m^2 · 4 kHz)). No such limit is defined for the 12.1 to 12.2 GHz frequency band.

TABLE I – *Space-to-Earth frequencies in BC-SAT Region 2 affected by harmonic mixing product of* $(9f_{LO} - 2f_{FL})$

Space-to-Earth frequency (GHz)	Local oscillator frequency (GHz)	Feeder-link frequency (GHz)
12.11	5.19	17.30
12.13	5.20	17.33
12.16	5.21	17.37
12.18	5.22	17.40
12.20	5.23	17.43
12.23	5.24	17.47
12.25	5.25	17.50
12.27	5.26	17.53
12.30	5.27	17.57
12.32	5.28	17.60
12.34	5.29	17.63
12.37	5.30	17.67
12.39	5.31	17.70
12.41	5.32	17.73
12.44	5.33	17.77
12.46	5.34	17.80
12.48	5.35	17.83
12.51	5.36	17.87
12.53	5.37	17.90
12.55	5.38	17.93
12.58	5.39	17.97
12.60	5.40	18.00

TABLE II – *Space-to-Earth frequencies in BC-SAT Region 2 affected by harmonic mixing product of* $(6f_{LO} - f_{FL})$ and $(3f_{FL} - 8f_{LO})$

Space-to-Earth frequency (GHz)	Local oscillator frequency (GHz)	Feeder-link frequency (GHz)
12.50	5.00	17.50
12.52	5.01	17.53
12.53	5.01	17.54
12.55	5.02	17.57
12.57	5.03	17.60
12.58	5.03	17.61
12.60	5.04	17.64
12.62	5.05	17.67
12.63	5.05	17.68
12.65	5.06	17.71
12.67	5.07	17.74
12.68	5.07	17.75

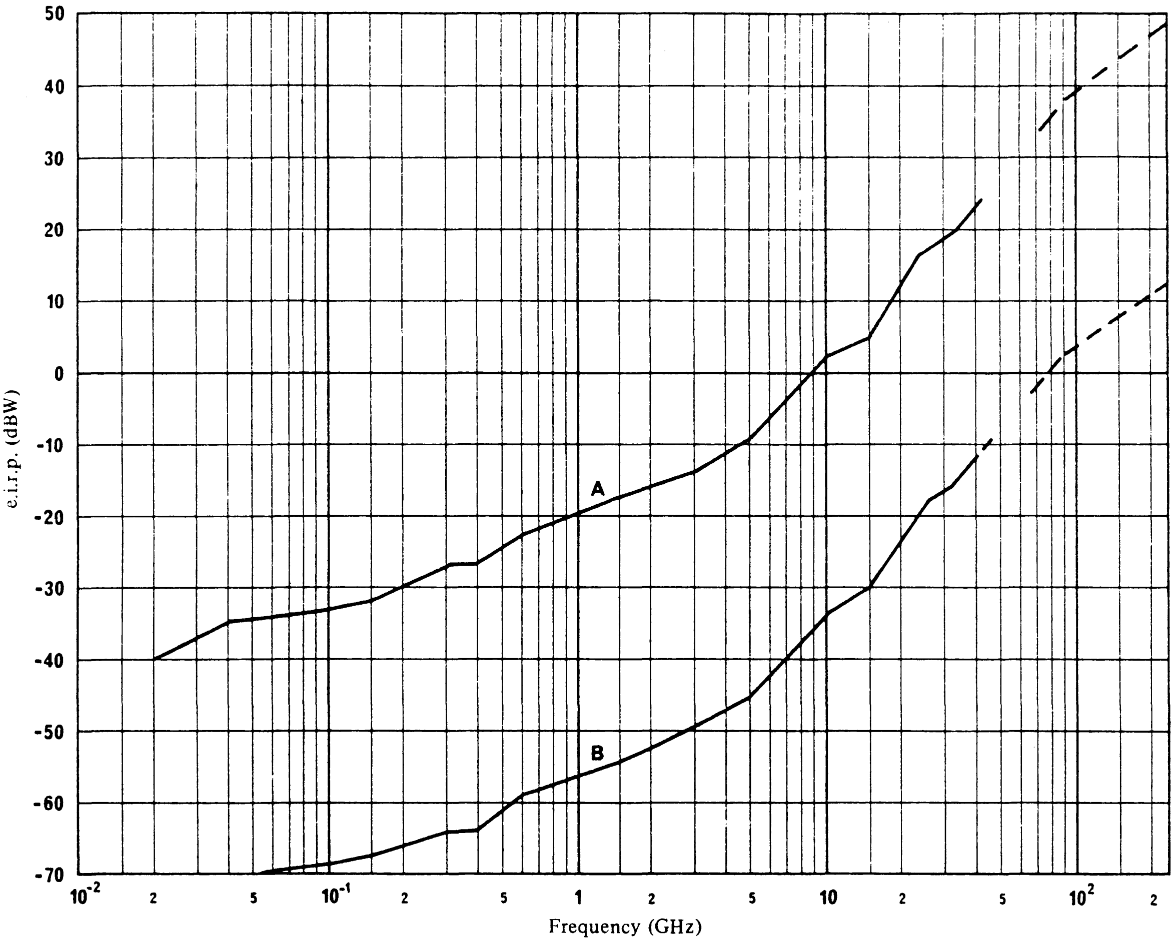

FIGURE 3 – *Maximum allowable e.i.r.p. for sharing transmitters within line-of-sight of a radioastronomy observatory*

Curves A: space transmitter in geostationary orbit

B: terrestrial transmitter at 600 km

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:

a) provide for adequate angular separation between the orbit location of satellites in the broadcasting-satellite service and the fixed-satellite service;

b) 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;

c) 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 fixed-satellite service.

In the interests 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 b) 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 under a) and c) above, can be developed.

3.2 *Fixed and mobile services*

Unwanted emissions from broadcasting satellites into fixed and mobile services are discussed in Report 789.

3.3 *Radioastronomy service*

Studies have shown that harmonic radiation from certain channels of Regions 1 and 3 broadcasting satellites into radioastronomy bands need to be suppressed with appropriate output filters [CCIR 1982-86a]. Unwanted emissions, expressed as radiated spectral density in any direction to Earth, in the 23.6 GHz to 24 GHz band (channels 5 to 15 in the Plan for Regions 1 and 3) shall be less than −70 dB(W/Hz) and in the 36.4 to 36.5 GHz band (channels 22 to 24 in the Plan for Regions 1 and 3) less than −65 dB(W/Hz), based on the protection requirements set forth in Report 224.

When calculating the magnitude of unwanted emissions, frequency dispersal gain of 61 dB/Hz is assumed for the 24 GHz band based on 2 × 600 kHz, and 63 dB/Hz for the 36 GHz band based on 3 × 600 kHz.

These radiations levels would ensure a world-wide protection of radioastronomy observations against harmonic radiation of broadcasting satellites, provided the gain of the radioastronomy antenna in the direction of broadcasting-satellite positions is no greater than that of an isotropic antenna.

Typically, about 60 dB of harmonic suppression will be required to ensure this protection. Transmit filters of conventional design can provide this protection with little weight or performance penalty.

3.4 *Space operations service*

Consideration is currently being given to accommodating the space operation signals of broadcasting satellites in Regions 1 and 3 within the guard bands at the edges of the bands allocated to satellite broadcasting or to feeder links. These signals may suffer interference from the out-of-band residual spectrum of television signals emitted or received by the broadcasting satellites. In the case of the feeder link, the main source of interference is the signal on the channel adjacent to these guard bands (channel 1 or channel 40). In the case of the down link, the problem is more complex. The television signal on the adjacent channel is also a potential source of interference but other sources exist, in particular the intermodulation products created in satellite repeaters between television signals on different channels (e.g. channels 39 and 40). These may affect the telemetry band.

Tests on these risks of interference, conducted in France [CCIR, 1982-86b], have provided the necessary conditions to ensure a good transmission of space operation signals. Report 1076 concerning the space operation service takes into account the principal results of these tests.

4. Conclusions

It is concluded that the unwanted emissions from a broadcasting-satellite space station may not be negligible and, in the case of adjacent band interference, are caused primarily by thermal noise and by frequency modulation of the carrier by the video waveform chosen. The results presented in this Report can be used, where appropriate, to deduce the width of possible guard bands between the 12 GHz band and adjacent bands used for other services. However, caution should be used to avoid applying the results to conditions differing from those presented herein. Additional study and measurements are required on this subject. If it is practicable to use RF filters or narrowband multiplexers at the output of the broadcasting-satellite transponders which have sharp channel-edge decay rates, then the guard bands could be reduced (WARC-79).

References have also been provided relating to the requirements of the fixed-satellite, fixed, mobile and radioastronomy services in terms of unwanted emissions into adjacent and harmonically related frequency bands, which must be accounted for in the design of the space segment of the broadcasting-satellite system.

REFERENCES

CCIR Documents

[1974-78]: **a.** 11/117 (Italy).

[1978-82]: **a.** 10-11S/139 + Add.1 (USA); **b.** 10-11S/28 (USA).

[1982-86]: **a.** 10-11S/46 (EBU); **b.** 10-11S/9 (France).

ANNEX I

UNWANTED EMISSIONS FROM BROADCASTING SATELLITES – RESULTS OF LABORATORY MEASUREMENTS USING A TRANSPONDER SIMULATOR

1. Introduction

This Annex presents the results of laboratory measurements of the emission characteristics of a satellite transponder with bandwidths and TV signal characteristics typical of systems that could operate in the broadcasting-satellite service (BSS) in Region 2. The results for two different filter bandwidths and several signal deviations are presented.

2. Test parameters

System M/NTSC video on a frequency modulated carrier with a digital (4-PSK) audio sub-carrier was used for the spectrum measurements. Several different video signal deviations were tested, but in all cases the audio sub-carrier was a 693 kbit/s data stream with a nominal bandwidth of 0.8 MHz. The audio sub-carrier was centred at 5.5 MHz in the video baseband.

The composite video baseband was frequency-modulated and bandpass filtered. The output of this filter was up-converted and fed to the satellite simulator. At the output of the simulator, a spectrum analyzer was used to record the signal spectral density. No significant RF filtering was used after the travelling wave tube amplifier (TWTA).

A helix type TWTA was used as the transponder amplifier for these tests. This TWTA is similar to those used on the Intelsat-IV satellites.

All tests were made with the input spectrum generated by a 75% NTSC colour bar signal with pre-emphasis.

3. Test results

The power spectral flux density envelopes of the FM-modulated TV signals are shown in Figs. 4 and 5 (see Note 1). The in-band spectral flux density envelope is shown as a dashed line within the channel bandwidth (see Note 2).

All tests were conducted with the satellite transponder travelling wave tube amplifier operating at saturation. It should be noted that the power spectral flux density envelopes generally exceed the amplitude responses of the respective IF filters. The envelopes reflect the spreading of the spectrum caused by the non-linear operation of the satellite transponder TWTA. The spectrum spreading is significant for the "over-deviation" test conditions.

Note 1. – The absolute spectral power-flux density values shown on each figure are based upon an assumed power-flux density of -105 dB(W/m^2) at the centre of the beam for an unmodulated carrier.

Note 2. – The in-band and out-of-band envelopes shown in Figs. 4 and 5 outline the peak (worst case) values and therefore integration of the curves to determine total power will yield misleading results. Also, it is not advisable to extrapolate the envelope curves beyond the points on the figures.

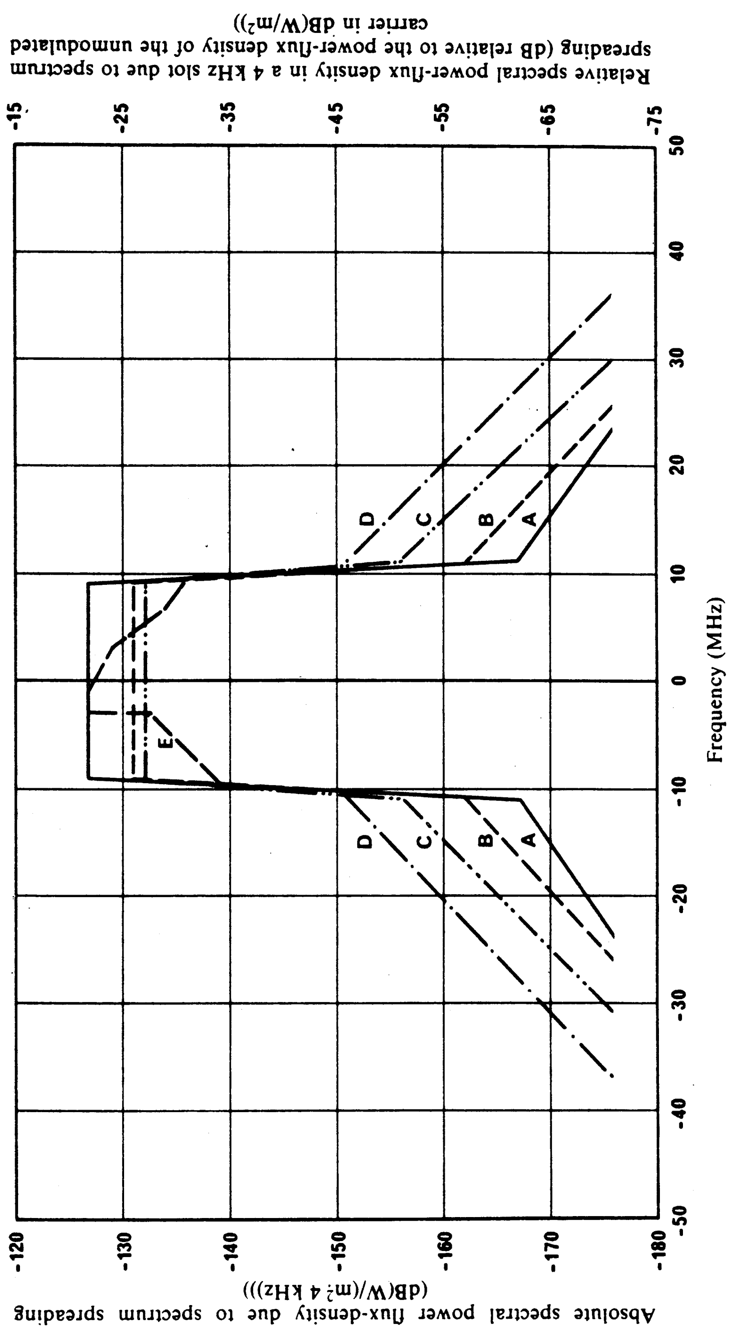

FIGURE 4 – *Power spectral density envelopes for 18 MHz bandwidth*

Curves A: peak deviation = 3.5 MHz
B: peak deviation = 5.6 MHz
C: peak deviation = 8.9 MHz
D: peak deviation = 11.2 MHz
E: in-band spectral flux-density envelope

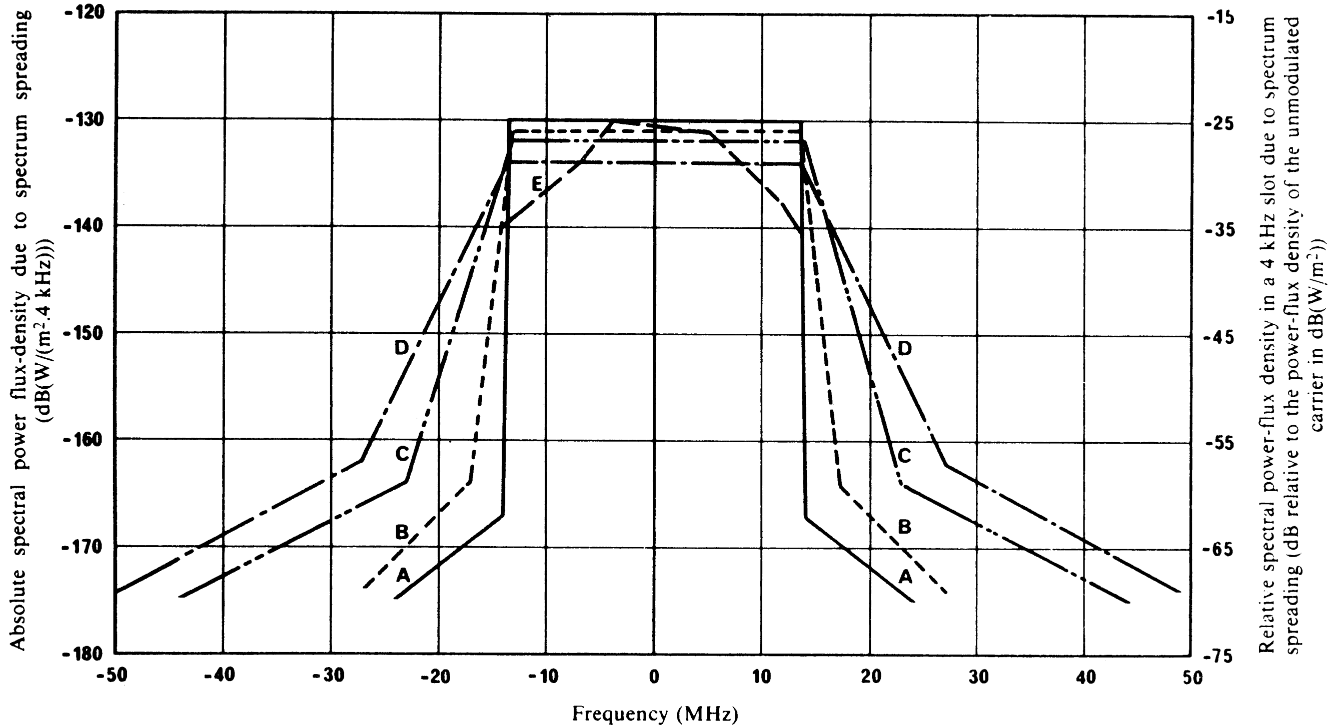

FIGURE 5 – *Power spectral density envelopes for 27 MHz bandwidth*

Curves A: peak deviation = 5.3 MHz
B: peak deviation = 8.4 MHz
C: peak deviation = 13.3 MHz
D: peak deviation = 16.8 MHz
E: in-band spectral flux-density envelope

ANNEX II

SPACE-TO-EARTH AND INTER-SATELLITE SERVICE ALLOCATIONS
AT 2ND AND 3RD HARMONICS OF BROADCASTING-SATELLITE ALLOCATIONS

TABLE III

Fundamental frequency in the BSS	2nd harmonics (services)	3rd harmonics (services)
2.5 – 2.69 GHz	5.0 – 5.38 GHz Fixed-satellite Inter-satellite (see footnote No. 797 of the Radio Regulations)	7.5 – 8.07 GHz Fixed-satellite Meteorological-satellite
11.7 – 12.5 GHz (Region 1) 11.7 – 12.7 GHz (Region 2) 11.7 – 12.2 GHz and 12.5 – 12.75 GHz (Region 3)	23.4 – 25.5 GHz Earth exploration-satellite Radioastronomy	35.1 – 38.25 GHz Earth exploration satellite Space research Fixed-satellite
22.5 – 23.0 GHz (Regions 2 and 3)	45.0 – 46.0 GHz Mobile-satellite Radionavigation-satellite	67.5 – 69.0 GHz Mobile-satellite Radionavigation-satellite
40.5 – 42.5 GHz	81.0 – 85.0 GHz Fixed-satellite Mobile-satellite Broadcasting-satellite	121.5 – 127.5 GHz Earth exploration-satellite Space research Inter-satellite
84.0 – 86.0 GHz	168.0 – 172.0 GHz Inter-satellite	252.0 – 258.0 GHz Mobile-satellite Radionavigation-satellite Radioastronomy

REPORT 1076

CONSIDERATIONS AFFECTING THE ACCOMMODATION OF SPACECRAFT SERVICE FUNCTIONS (TTC) WITHIN THE BROADCASTING-SATELLITE AND FEEDER-LINK SERVICE BANDS

(Question 2/10 and 11, Study Programme 2L/10 and 11)

(1986)

1. Introduction

The Radio Regulations (No. 25) state that spacecraft service functions (TTC) will normally be provided within the service in which the space station is operating. The WARC-BS-77 provided no specific frequency slots for these functions except that it reserved guard bands at the edges of the 11.7 GHz to 12.5 GHz band for Region 1 and 11.7 GHz to 12.2 GHz for Region 3. A compatible frequency plan is assumed for the feeder links in the 17-18 GHz band as well. These guard bands could be used for the TTC space-to-Earth and Earth-to-space assignments.

It should be noted that some countries in Regions 1 and 3 may envisage the exploitation of the 14 GHz band for feeder links in the BSS. The use of guard bands in this frequency region may present difficulties because of sharing constraints with the FSS. Further studies are required.