REPORT 917-2*

PERMISSIBLE LEVELS OF INTERFERENCE INTO TELEPHONE CHANNELS IN THE MARITIME MOBILE-SATELLITE SERVICE

(Question 86/8)

(1982-1986-1990)

1. Introduction

Consideration is given in this report to the possible effects of interference on telephone channels in the maritime mobile-satellite service using frequency modulation and 2.1 syllabic companding. Particular attention is given to the shore-to-ship direction, and to the effects of interference on satellite channel quality and capacity.

This report mainly addresses systems utilizing 1.5/1.6 GHz frequencies for links with ship earth stations, 4/6 GHz frequencies for feeder links, and satellites with Earth-coverage antennas. Considerations and results for other types of systems may be significantly different. The analytical approach used to develop an interference budget is only partially consistent with the approach presented in Report 1179, with the principal differences being in the method for accommodating interference within the overall noise budget and in the amounts of degradation that are assumed to be permissible from interference occurring in the feeder links and the links at 1.5/1.6 GHz. Further study is required in these and other areas.

2. Sources of interference

Interference may enter the channels of a maritime satellite network via the receivers of the 4/6 GHz feeder links (i.e. at coast earth stations and at the satellite), and also via the receivers of the 1.5/1.6 GHz links between ships and the space station (i.e. at ship earth stations and at the satellite). Most of this interference is expected to originate from the transmitters of stations in those services which share the same frequency bands as the maritime mobile-satellite service. Potential sources of interference therefore include the fixed-satellite service operating at 4/6 GHz, and terrestrial services operating at 4/6 GHz and 1.5/1.6 GHz. Further potential sources of interference into a maritime mobile-satellite network are the links of another maritime mobile-satellite system. In the case of the 1.5/1.6 GHz links, the intereference mechanism arises because of the relatively broad beamwidth of ship earth station antennas and their resultant poor discrimination characteristics. Such interference can therefore be reduced only by an efficient design of maritime mobile-satellite systems; this will be an important consideration in the design of future systems. On the 4/6 GHz feeder links, coast earth station antenna discrimination characteristics are superior to those for ship earth stations at 1.5/1.6 GHz. Nevertheless, interference from other satellite systems in the 4/6 GHz bands might be a critical factor in coordinating suitable geostationary satellite orbit positions for space stations in maritime mobile-satellite systems.

---

* The Director, CCIR, is requested to bring this Report to the attention of the International Maritime Satellite Organization (INMARSAT) and Study Group 4.

3. Performance objectives for telephony

Performance objectives for telephone channels in the maritime mobile-satellite service are given in Recommendation 547, in terms of the permissible subjectively-equivalent noise power. As an example, the permissible subjectively-equivalent noise power in a telephone channel for a speech level of -20 dBm0 is assumed to be 25 000 pW0p. Tests conducted with typical voice modems (Report 752) indicate that the 25 000 pW0p objective can be achieved with a carrier-to-noise density ratio (C/N_0) of between 52 and 53 dBHz.

4. Typical satellite link characteristics

In terms of satellite output power requirements and system capacity, transmission parameters in the shore-to-ship direction are far more critical than in the ship-to-shore direction, and hence are the only ones considered here. Table I shows the main noise contributions on the shore-to-ship link, assuming satellite characteristics which are typical of those being considered for maritime mobile-satellite systems (Report 760). No allowance has been made for interference in Table I.

TABLE I — *Typical parameters for shore-to-ship transmission*

Parameter	Value
Up-path C/N_0 (thermal noise) with 5° coast earth station elevation (dBHz)	70
Coast earth station C/I_0 (intermodulation noise) (dBHz)	75
Satellite C/I_0 (intermodulation noise) (dBHz)	63.8
Down-path C/N_0 (thermal noise) with 10° ship antenna elevation angle (dBHz)	53.5
Overall $C/(N_0+I_0)$ for satellite link (dBHz)	53
Satellite nominal e.i.r.p. required to achieve overall $C/(N_0+I_0)$ channel objective (dBW)	18.1 per carrier

5. Effects of interference

In considering the effects of interference, it is useful to recall the permissible interference limits for the fixed-satellite service. For the fixed-satellite service, the total noise power allowance under clear-sky conditions is 10 000 pW0p (Recommendation 353), of which 25% can be contributed by interference from other networks in the fixed-satellite service (Recommendation 466) and a further 10% can arise from interference from terrestrial line-of-sight radio-relay systems (Recommendation 356). The total permissible interference noise contribution can thus be as much as 35% of the total noise power, or 3500 pW0p. In considering the applicability of such limits to the maritime mobile-satellite service, it should be noted that satellite output stages in current maritime mobile-satellite systems are severly power-limited in the satellite-to-ship path, and hence the contribution of interference to the total permissible noise power could have a significant effect on channel quality or system capacity. In order to compensate for this, speech processing is now used in maritime mobile-satellite systems, and hence the interference (which is assumed to be noise-like), as well as internal system noise, must be considered in terms of its subjective effect.

Future satellites might not be so power-limited, making an overall noise objective of 10 000 pW0p attainable and resulting in performance comparable to that of the fixed-satellite service. Consequently, it is reasonable to allocate no more than 3500 pW0p to interference from other systems to a maritime mobile-satellite system.

6. Noise power budget

From the above considerations, a possible noise power budget can be derived as shown in Table II. Values of C/N_0 corresponding to the noise allocations in Table II assume linear relationships between subjectively-equivalent noise power and pre-detection RF noise power.

TABLE II — *Noise power allocations for telephone channels*

Noise source	Equivalent C/N_0 (80% of the time) (dBHz)		Noise budget (subjectively-equivalent noise power) (pW0p)	
Satellite link:				
up-path thermal		70(1)		
coast earth station intermodulation products		75(1)		
satellite intermodulation products		63.8(1)		
down-path thermal		53.5(1)		
Total satellite link:		53		21 500
Interference:				
satellite systems	62.4		2 500	
terrestrial services	66.4		1 000	
total interference		60.9		3500
Total channel noise:		52.4		25 000

(1) Typical parameters for shore-to-ship direction.

The total satellite link noise power of 21500 pW0p has not been broken down in Table II for the various components of the link. In addition, the total interference noise power allocation of 3500 pW0p is assumed to apply in both directions of transmission to all sources of interference on both up and down links. Individual allocation of either satellite link or interference noise would be determined by the particular maritime-satellite system being considered and by the relationship between up-path and down-path noise which would differ for each direction of transmission. This allocation of interference noise requires further study.

It can be seen from the down-path C/N_0 in Table II that the interference allowance necessitates an addition 0.6 dBW of satellite e.i.r.p. in order to maintain an overall channel quality of 53 dBHz. This corresponds to a capacity loss of about 13%.

7. Provisional permissible interference protection criteria

It has been assumed in Table II that interference allocations for other satellite systems and the terrestrial services are the same as the corresponding protection criteria adopted for the fixed-satellite service. Assuming further that the same criteria can be applied for single-entry interference, the following provisional interference protection criteria might be used for the maritime mobile-satellite service:

7.1 *Interference from satellite services:*

- total interference from satellite systems should not exceed 2500 pW0p in the hypothetical reference circuit for more than 20% of any month;
- interference from a single satellite system should not exceed 800 pW0p in the hypothetical reference circuit for more than 20% of any month.

7.2 *Interference from terrestrial services:*

- total interference from terrestrial systems should not exceed 1000 pW0p in the hypothetical reference circuit for more than 20% of any month;
- interference from a single terrestrial station should not exceed 333 pW0p in the hypothetical reference circuit for more than 20% of any month.

In Annex I, detailed consideration is given to the potential problem of interference from fixed service transmitters operating in part of the frequency band 1550-1645.5 MHz, to satellites operating in the maritime mobile-satellite frequency band 1626.5-1645.5 MHz.

8. Conclusions

A preliminary assessment of the effects of interference on telephone channel quality and capacity in the maritime mobile-satellite service has been made, with respect to satellite systems currently being planned. It is proposed that the permissible level of interference in a telephone channel should not exceed 3500 pW0p for more than 20% of any month. Allocations for individual interference entries have been suggested. These allocations and other aspects of interference into a maritime mobile-satellite network require further study.

ANNEX I

INTERFERENCE TO FREQUENCY MODULATED TELEPHONE CHANNELS IN THE MARITIME MOBILE-SATELLITE SERVICE FROM THE FIXED SERVICE AT 1.6 GHz

1. Introduction

In this Annex consideration is given to the potential problem of interference to frequency modulated telephone channels in the maritime mobile-satellite service from transmitters of the fixed service at 1.6 GHz.

At the WARC-79, the frequency band 1626.5-1645.5 MHz was allocated for use by the maritime mobile-satellite service (Earth-to-space direction), the allocation being effective from January, 1982 (previously the band was limited to 1636.5-1644 MHz). However, the band 1550-1645.5 MHz which overlaps it was also allocated for use by the fixed service in 17 countries on an equal primary basis (see No. 730 of the Radio Regulations).

This shared allocation with the fixed service gives rise to two potential interference problems. Firstly, interference from ship earth-station transmitters to receivers of the fixed service, and second, interference from fixed service transmitters into maritime mobile-satellite receivers.

This Annex addresses the second potential problem and considers a number of techniques, including e.i.r.p. limitations which might be applied to fixed service transmitters in order to protect maritime mobile-satellite receivers from unacceptable interference. It also discusses other possible means of reducing the interference.

2. Permissible interference levels into a maritime mobile-satellite system

There is not as yet a CCIR Recommendation on permissible interference levels. However, Report 917 considers a possible interference noise budget, and, based on interference limits applied to the fixed service proposes provisional protection criteria for that part of the total interference emanating from terrestrial sources. These are:

- total interference from terrestrial systems should not exceed 1000 pW0p in the hypothetical telephone reference circuit of a satellite system for more than 20% of any month;
- interference from a single terrestrial station should not exceed 333 pW0p in the hypothetical telephone reference circuit for more than 20% of any month.

On the basis that the required overall C/N_0 is 52.4 dBHz as shown in Table II of the main text, and that this corresponds to a subjectively equivalent noise power of 25 000 pW0p, then the single entry interference of 333 pW0p becomes equivalent to a C/N_0 of 71.1 dBHz, assuming as in Report 917 a linear relationship between subjectively equivalent noise power, and pre-detection RF noise power.

Reference to a typical link power budget for a maritime mobile-satellite system, as shown in Report 760, gives an up-path C/N_0 of 63.4 dBHz due to thermal noise sources from an unfaded link, as compared with the value of 71.1 dBHz for the single-entry interference – a difference of 7.7 dB.

3. Fixed service e.i.r.p. limits

In the INMARSAT system, NBFM modulation is used for voice carriers with a single carrier bandwidth of about 28 kHz, and in this Annex the bandwidth within which interference should be controlled is taken as 30 kHz. Link power budgets appearing in Report 760 give a value of -12.2 dB(K^{-1}) for a typical edge-of-coverage satellite G/T at 1.6 GHz. Based on this, the following calculation derives the maximum permissible e.i.r.p. per 30 kHz towards the satellite from a fixed service transmitter in order to meet the assumed 333 pW0p single-entry interference criterion, and relates to unfaded transmission conditions:

– noise power in bandwidth "B" at the satellite receiver (dBW):	kTB
– interference noise power (equivalent to 333 pW0p) (dBW):	$kTB - 7.7$
– interference noise power into satellite antenna (where G is the gain of the antenna) (dBW):	$kTB - 7.7 - G$
– e.i.r.p. from fixed service transmitter (dBW):	$kTB - 7.7 - G + 188.9$ $kB - G/T + 181.1$
– hence, permissible e.i.r.p. per 30 kHz:	$-228.6 + 44.75 - (-12.2) + 181.1$ $= +9.6$(dB(W/30 kHz)) (see Note)

Note. – Provisional value, which may need to be adjusted based on application of other sharing techniques.

It should be noted that no allowance has been made for an additional margin of up to 3 dB which may result from the use of linear polarization on fixed service links, and circular polarization on satellites' systems. Also, the value of G/T assumed here (-12.2 dB(K^{-1})) is likely to change.

4. Radio Regulations

Article 27 of the Radio Regulations relates to power limits for terrestrial services sharing frequency bands with space radiocommunications above 1 GHz. Radio Regulations Nos. 2502, 2505, 2506 and 2507 are of particular interest since they relate to the band 1.626.5-1645.5 MHz for the countries mentioned in No. 730. It can be seen that with the power limitations as set out in the above provisions, the e.i.r.p. towards the geostationary-satellite orbit could be at least 35 dBW rising to +47 dBW if the former limit is impracticable.

5. Fixed service characteristics at 1.6 GHz

Information on the characteristics of fixed services in this band may be taken from Report 739 (characteristics of simple radio-relay equipment operating in bands 8 and 9 for the provision of telephone trunk connections in rural areas). Typical systems in the 1500 MHz frequency band are shown as comprising 24 and 60 channel frequency division multiplex carriers.

Typical characteristics of such systems are represented in Table II of Annex II of Report 379. It can be seen from Table II that the power of the residual carrier approaches within 0.49 dB and 1.81 dB of the unmodulated carrier power for the 24 and 60 channel systems respectively. Hence, to meet the e.i.r.p. limits derived in § 3, the e.i.r.p. of the fixed-service system towards a maritime mobile satellite would need to be no more than 10.1 dBW (24 channel system) and 11.4 dBW (60 channel system) as compared with the power limitations quoted by the Radio Regulations (see § 4).

6. Discussion

It is recognized that the limits of e.i.r.p. proposed in § 5 (10.1 dBW for 24 channel and 11.4 dBW for 60 channel radio-relay systems, and which are principally attributable to carrier spikes), if directed at maritime mobile satellites in the geostationary-satellite orbit, would impose severe restrictions on the fixed service, e.g. distances between typical repeater stations would be restricted to less than 3 km for an unmodulated carrier level of around 10 dBW; it is also recognized that modification to existing fixed-service systems would be very difficult to implement.

It should be noted however that maritime mobile satellites will occupy relatively few locations in the geostationary-satellite orbit. Consequently, a considerable improvement in the interference position would be achieved if fixed-service transmitters avoided pointing the main lobe of their antenna radiation pattern towards those arcs of the geostationary-satellite orbit occupied by maritime mobile satellites.

Secondly, it is suggested that an improvement in the potential interference position could be effected by use of these additional techniques:

- by applying energy dispersal to the radio-relay system at a frequency below the lowest baseband frequency, at an appropriate deviation and with a suitably high periodicity. This would have the effect of spreading the unwanted energy, and particularly that of the residual carrier, over a wide bandwidth, and would thus enable the fixed system e.i.r.p. to be increased by the improvement factor obtained, without increasing the effective interference level (see Report 384);
- by greater carrier suppression either by employing suppressed carrier modulation on the radio-relay system, or by increasing the modulation index so as to reduce the level of residual carrier. The e.i.r.p. of the fixed-service transmitter could then be increased by an amount equal to the additional carrier suppression;
- by careful frequency coordination between the systems concerned, to avoid assigning fixed-service carriers coincident with satellite transponder channels.

An additional improvement in the interference position may be effected by using a combination of these three techniques.

7. Conclusions

Following a preliminary assessment of the potential interference problem due to fixed services operating in those parts of the 1.6 GHz frequency band shared with the maritime mobile-satellite service and which comply with the power limits defined in the relevant provisions of the Radio Regulations, it is concluded that unacceptable interference could be caused to the latter service. Further study is required of the interference problem, both in extent and degree, and possible means to reduce it.