RECOMMENDATION ITU-R S.735-1*

Maximum permissible levels of interference in a geostationary-satellite network for an HRDP when forming part of the ISDN in the fixed-satellite service caused by other networks of this service below 15 GHz

(1992-1993)

The ITU Radiocommunication Assembly,

considering

a) that emissions from the earth stations as well as from the space station of a geostationary-satellite network in the fixed-satellite service (FSS) may result in interference to another such network when both networks operate in the same bands;

b) that it is desirable that the interference in networks in the FSS caused by transmitters of different networks in that service should be such, as to give a reasonable orbit utilization;

c) that the system designer should control the overall performance of a network and be entitled to provide a quality of service that meets ITU recommended performance criteria which are expressed in terms of a bit error ratio (BER);

d) that it is necessary to protect a network of the FSS from interference by other such networks;

e) that to allow an operator to exercise control over the quality of service there needs to be a limit on the aggregate interference a network must be able to tolerate from emissions of all other networks;

f) that to limit the aggregate interference from all other networks, there needs to be a limit on the interference a network should be expected to tolerate from any one other network;

g) that it is desirable that the increase in interference from other satellite networks should be a controlled fraction of the total noise that would give rise to a bit error ratio, as set out in Recommendation ITU-R S.614;

h) that the levels of interference between geostationary-satellite networks in the FSS below 10 GHz are not expected to exhibit a large variation with time, and under these conditions it is preferable to define the permissible interference limit as a fraction of the pre-demodulator noise power, as this allows multiple interference entries to be superimposed on each other on the basis of RF power addition;

j) that in frequency bands between 10 and 15 GHz where very high propagation attenuation may occur for short periods of time, it may be desirable for systems to make use of some form of fade compensation to counteract signal fading;

k) that interference between networks in the FSS may exhibit a non-uniform spectral distribution containing narrow-bandwidth peaks and that narrow-bandwidth carriers are more sensitive to this type of interference,

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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).

recommends

1 that a geostationary network in the FSS operating in the frequency bands below 15 GHz should be designed and operated in such a manner that in any satellite hypothetical reference digital path which forms part of a 64 kbit/s ISDN connection the provisions of § 1 of Recommendation ITU-R S.614 can be met when the aggregate interfering power from the earth and space station emissions of all other networks operating in the same frequency band or bands, assuming clear-sky conditions on the interference paths, does not exceed at the input to the demodulator:

1.1 25% of the total system noise power under clear-sky conditions when the network does not practice frequency re-use;

1.2 20% of the total system noise power under clear-sky conditions when the network does practice frequency re-use;

2 that for a geostationary network in the FSS as mentioned in § 1, the inter-network interference caused by the earth and space station emissions of any one other network operating in the same frequency band or bands should be limited to 6% of the total system noise power under clear-sky conditions;

3 that the maximum level of interference noise power caused to that network should be calculated on the basis of the following values for the receiving earth station antenna gain, in a direction at an angle φ (in degrees) referred to the main beam direction:

$$G = 32 - 25 \log \varphi \quad \text{dBi} \quad \text{for} \quad 1° \le \varphi < 48°$$

$$G = -10 \quad \text{dBi} \quad \text{for} \quad 48° \le \varphi < 180°$$

4 that the following Notes should be regarded as part of this Recommendation:

NOTE 1 – For the calculation of the limits quoted in § 1.1, 1.2 and 2 it should be assumed that the total system noise power at the input to the demodulator is of thermal nature and includes all inter-system noise contributions as well as interference noise from other systems.

For interference not of a thermal nature the permissible level of interference into a digital carrier should be based upon the degradation of the long-term performance objective as given in Annex 1 to Recommendation ITU-R S.614.

NOTE 2 – For this interference calculation, as applied to satellite networks operating in a fading environment, it should be assumed that the carrier power level is reduced, until the system performance coincides with the above BER and percentage of month (see Annex 1 for clarification).

NOTE 3 – It is assumed in this Recommendation that the interference from other satellite networks is of a continuous nature at frequencies below 10 GHz: further study is required with respect to cases where interference is not of a continuous nature above 10 GHz.

NOTE 4 – When interference is characterized by a non-uniform spectral distribution there may be cases where, for design purposes, a greater interference allocation of total system noise may be made to narrow-bandwidth carriers by the system designer. One model developed to address this is presented in detail in Annex 2.

NOTE 5 – For networks using 8 bit PCM encoded telephony see Recommendation ITU-R S.523.

NOTE 6 – In some cases it may be necessary to limit the single entry interference value to less than the value quoted in § 2 above in order that the total value recommended in § 1 may not be exceeded. In other cases, particularly in congested arcs of the geostationary-satellite orbit, administrations may agree bilaterally to use higher single entry interference values than those quoted in § 2 above, but any interference noise power in excess of the value recommended in § 2 should be disregarded in calculating whether the total value recommended in § 1 is exceeded.

NOTE 7 – There is an urgent need for study of the acceptability of an increase in the maximum total interference noise values recommended in § 1.

NOTE 8 – Although this Recommendation has an upper frequency limit of 15 GHz, in the frequency range from 10 to 15 GHz short-term propagation data are not available uniformly throughout the world and there is a continuing need to examine such data to confirm an appropriate interference allowance to meet § 1.2 and 1.3 of Recommendation ITU-R S.614.

NOTE 9 – There is a need for urgent study to be given to the interference noise allowances appropriate to systems operating at frequencies above 15 GHz.

NOTE 10 – The interference criteria of this Recommendation apply only to the transmission of digital services that fall under the provisions of ITU-T Recommendation G.821 and Recommendation ITU-R S.614. Further study by Radiocommunication Study Group 4 is required regarding the performance objectives and appropriate interference criteria for other than 64 kbit/s digital transmissions within an ISDN connection as information on the performance requirements for such services becomes available to it.

NOTE 11 – The principles of this Recommendation may also be applied to digital-satellite networks providing long-term performance objectives different from those in Recommendation ITU-R S.614. This is a subject for further study.

NOTE 12 – Special attention may have to be given to digital carriers with narrow bandwidths when they are being interfered with by analogue TV transmissions. For such cases with artificial energy dispersal at the frame rate the protection ratios given in Recommendation ITU-R S.671 apply. This is a subject for further study.

NOTE 13 – Attention should also be drawn to the interference from TDMA systems when, due to burst overlapping at the transponder input of an interfered-with system, the BER is increased relative to that of a synchronous burst allocation.

NOTE 14 – In order to promote orbit efficiency, satellite networks operating in heavy rain environments are encouraged to use some form of fade compensation.

NOTE 15 – This Recommendation is closely related to Recommendation ITU-R S.614, a fact that needs to be considered in any future revisions to either of these two Recommendations.

NOTE 16 – Annexes 1 and 2 provide information on the permissible level of interference into an ISDN satellite digital path.

ANNEX 1

Considerations on the permissible level of interference into an ISDN satellite digital path

The development of a Recommendation on the permissible level of interference into an ISDN satellite digital path is essential if satellite networks are to have some basis on which to undertake coordination, or for system designers to include some margin for interference in their link calculations.

It was noted in the preparation of this Recommendation that there were two ways of interpreting the noise level referred to in Recommendation ITU-R S.523 which is dealing with maximum permissible levels of interference in an FSS 8 bit PCM telephony system.

The expression used in § 1.1 of Recommendation ITU-R S.523 is:

"the interference power level should not exceed 25% of the total noise power level at the input to the demodulator which would give rise to a bit error ratio of 1×10^{-6}".

The point discussed was the total noise power level to be applied in the Recommendation when the operating carrier level is higher than that which corresponds to BER of 10^{-6}. One way is to reduce the carrier level as shown in Fig. 1a so that BER becomes 10^{-6}. The other way is to increase the noise as shown in Fig. 1b to the level with which BER of 10^{-6} is obtained. Through the discussions in recent meetings, it was agreed that the former interpretation was appropriate.

FIGURE 1a

Interpretation based on reduction of signal power

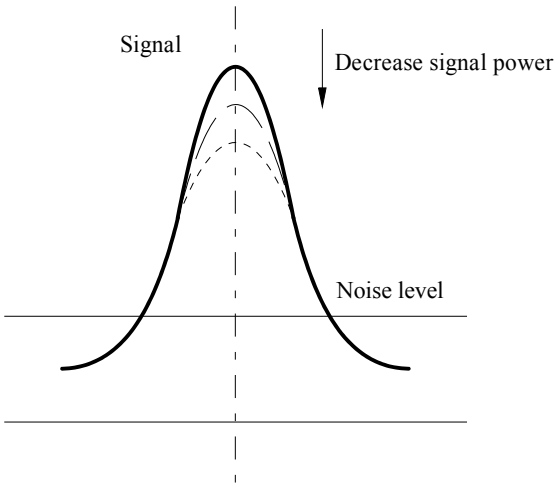
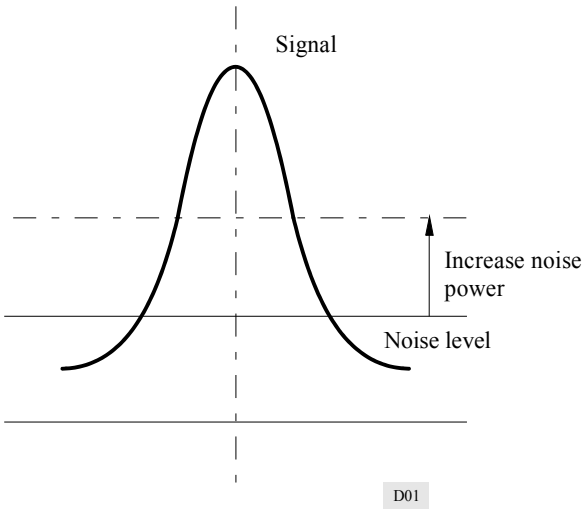


FIGURE 1b

Interpretation based on increase of noise power



In the preparation of this Recommendation there was further discussion on the need to base the permissible interference on the ISDN performance objectives (Recommendation ITU-R S.614), or to base the interference on an *I*/*N* ratio.

The following sections summarize the discussions that led to the development of this Recommendation.

_I_/_N_ method

In the agreed interpretation, i.e. decreasing carrier level as Fig. 1a, the total noise power level corresponds to the operational noise level, and this level does not change whatever the carrier level may be. Since the noise level to be applied to the Recommendation is constant irrespective of the carrier level, there is no longer a need to refer to the BER value in the Recommendation.

Thus, the majority favoured a proposal to describe the permissible interference level simply in terms of the total noise without referring to the BER in the new Recommendation for the 64 kbit/s ISDN application as well as in Recommendation ITU-R S.523.

It should be noted that this method does not preclude the use of *C*/*I* in a coordination. When it is convenient to use the *C*/*I*, the lowest permissible *C*/*I* value can be calculated by taking the ratio of the operational carrier level *C* to the permissible interference *I* derived from the total system noise. In this case the permissible *C*/*I* value depends upon the carrier level of the interfered-with system. However, the absolute value of the maximum permissible level of the interfering carrier is not affected by the carrier level of the interfered-with system.

BER method

On the other hand, the retention of the BER in an interference Recommendation was required, since all interference cannot be assumed to be treated as Gaussian noise. For these exceptions to the interference being treated as Gaussian noise, the BER performance should be used in the calculations of interference. This is particularly true if it is found that in many other cases the effect of the interference is more severe than Gaussian noise. Examples of such exception are: TV into SCPC, TV into intermediate data rate carrier, high capacity FM telephony with energy dispersal into sensitive carriers, and TDMA into digital system when TDMA bursts overlap in time at the interfered-with satellite. Further it was not believed that the various types of interference, including the effects of FEC and the effects of various frequency offset between carriers, have been thoroughly explored at this time.

Finally it was felt that the conservative approach of including BER performance should be retained in an annex with the understanding that this interference Recommendation was based on the assumption that the interference was noise-like in nature.

ANNEX 2

Interference allocation model for narrow-band carriers

1 Satellite carriers of bandwidth less than 12.5 MHz which provide 64 kbit/s connections are more affected by exposed high-power density interference peaks than wider bandwidth carriers.

In these cases an additional allowance for interference can be fixed for design purpose as follows:

– in the case of carriers with bandwidth of less than 2.5 MHz up to 20% can be added to the percentages of total system noise given in *recommends* 1.1, 1.2 and 2;

– in the case of carriers with bandwidth between 2.5 MHz and 12.5 MHz up to X% can be added to the percentages of total system noise in *recommends* 1.1, 1.2 and 2.

The value of X% decreases linearly between 20% and 0% as a function of the bandwidth.

These allowances fixed in a bandwidth dependent manner are based on the interference model explained in the following section.

These allowances can be adopted by satellite operators in designing their systems.

2 Model for the allocation of interference

A co-frequency FM-TV carrier with energy dispersal (ED) is the worst interfering signal for narrow-band carriers.

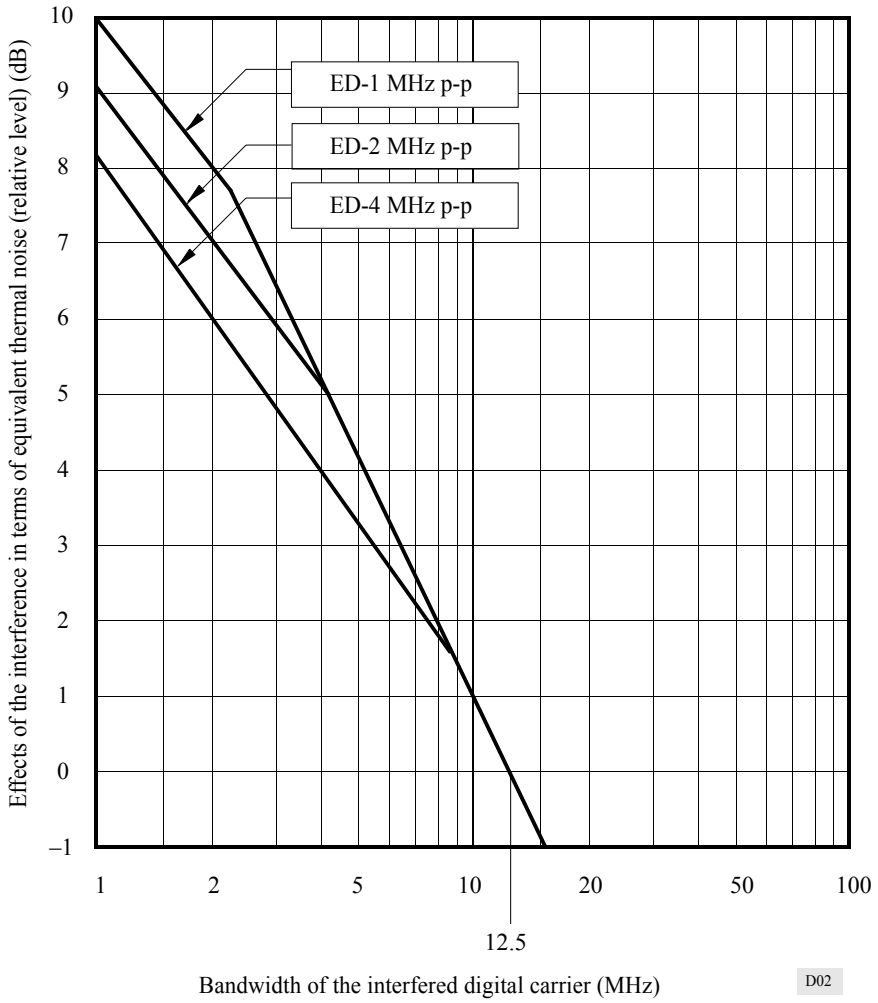
Figure 2 shows the results of a series of measurements. The curves give the amount of thermal noise which would cause the same BER degradation produced by the interfering signals. Curves in Fig. 2, which are rather insensitive of the BER in the interfered channel, are normalized with 0 dB level arbitrarily fixed as 12.5 MHz.

When the bandwidth of a wanted digital carrier is wide enough (above 12.5 MHz, which represents the bandwidth containing most of the energy of one interfering FM-TV carrier) more than one interfering signal, analogue or digital, can fall in that bandwidth. In this case the interference is modelled by a constant power spectral density which causes on average a constant level of degradation independent of the bandwidth.

For bandwidths between 2.5 MHz and 12.5 MHz the interference caused by one co-frequency FM-TV signal with energy dispersal becomes dominant. The worst-case degradation from Fig. 2 has a linear slope with a decay of 7 dB between the points at 2.5 MHz and 12.5 MHz.

FIGURE 2

Interference caused by one co-frequency FM-TV signal with energy dispersal (ED)



Bandwidths below 2.5 MHz correspond to low-rate data carriers which are extremely sensitive to FM-TV interference. In this range of bandwidths where direct interference from co-channel FM-TV is normally avoided by frequency coordination, a constant maximum level of acceptable degradation is adopted in this model as a target for frequency coordination.

The model for the worst-case scenario is shown in Fig. 3. With this model the interference is a bandwidth dependent parameter.

Since the 7 dB factor of Fig. 3 corresponds to a factor of 5 in a linear scale, the following allowanes for single entry interference can be adopted:

– 6% of total system noise for bandwidths above 12.5 MHz;

– 30% of total system noise for bandwidths below 2.5 MHz;

– linear interpolation between 2.5 MHz and 12.5 MHz.

In the case of aggregate interference the following values are derived:

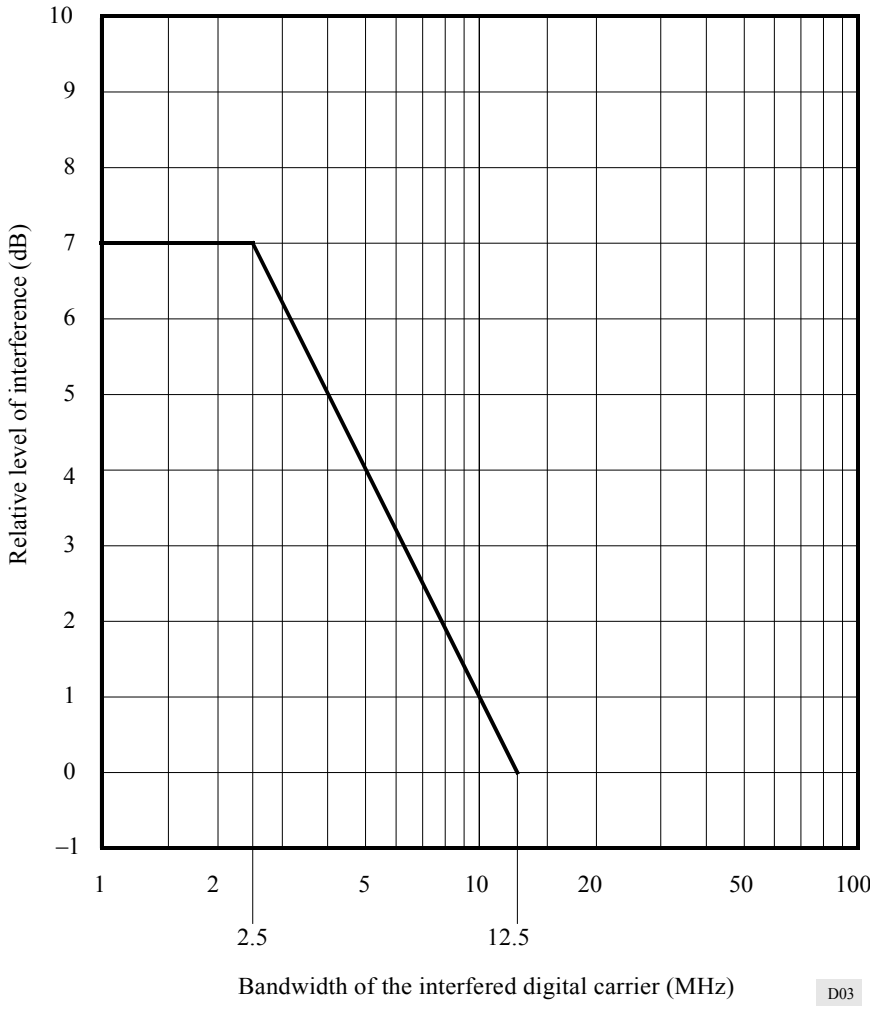
– 15% of total system noise for bandwidth greater than 12.5 MHz (this is based on a 2.5 factor between aggregate and single entry of the thermal noise nature);

– 40% of total system noise for bandwidth less than 2.5 MHz (this assumes the presence of one co-frequency FM-TV carrier and additional interference of thermal nature equivalent to 1.5 times that caused in the absence of FM-TV interference);

– linear interpolation between 2.5 MHz and 12.5 MHz.

FIGURE 3

Interference model



In practice these levels of interference which depend on bandwidth can be slightly rounded to correspond to the simplified statement given in § 1 of this Annex where a 20% additional increase of percentages given in *recommends* 1.1, 1.2 and 2 is required for carrier bandwidths of less than 2.5 MHz for both single entry and aggregate interference. Section 1 of this Annex is the suggested rule for practical use of the bandwidth dependent concept.