RECOMMENDATION ITU-R S.353-8

ALLOWABLE NOISE POWER IN THE HYPOTHETICAL REFERENCE CIRCUIT FOR FREQUENCY-DIVISION MULTIPLEX TELEPHONY IN THE FIXED-SATELLITE SERVICE

(Question ITU-R 27/4)

(1963-1966-1970-1978-1982-1986-1990-1992-1994)

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference circuit is intended as a guide to the design and construction of actual systems;

b) that the cost of establishing and maintaining systems in the fixed-satellite service is critically dependent on the overall signal-to-noise performance requirements;

c) that the total noise power in the hypothetical reference circuit should not be such as would affect appreciably conversation in most telephone calls or the transmission of telephone signalling;

d) that it may be necessary to take account of fading due to meteorological events, particularly rain;

e) that specifications of circuit availability are contained in Recommendation ITU-R S.579;

f) that there may be other sources of noise of short duration;

g) the information presented in Annexes 1 and 2,

recommends

1. that the noise power, at a point of zero relative level in any telephone channel in the hypothetical reference circuit as defined in Recommendation ITU-R S.352 should not exceed the provisional values given below:

1.1 10 000 pW0p psophometrically-weighted one-minute mean power for more than 20% of any month;

1.2 50 000 pW0p psophometrically-weighted one-minute mean power for more than 0.3% of any month;

1.3 1 000 000 pW0 unweighted (with an integrating time of 5 ms), for more than 0.01% of any year;

2. that the following Notes should be regarded as part of the Recommendation.

Note 1 – Noise in the multiplex equipment is excluded from the above. For frequency-division multiplex telephony, noise additional to the above values is introduced by the equipment necessary to translate the satellite baseband to and from the multiplex level required for interconnection to a terrestrial link. In considering the performance of an overall connection, the noise introduced by such equipment should be added to the values given in § 1. The noise allowed by the ITU-T for multiplex equipment is given in ITU-T Recommendation G.222, § 4.

Note 2 – It is assumed that noise surges and clicks from power supply systems and from switching apparatus (including switching from satellite-to-satellite) are reduced to negligible proportions and therefore will not be taken into account when calculating the noise power.

Note 3 – In applying the hypothetical reference circuit and the allowable circuit noise to the design of satellite and earth-station equipment for a given overall signal-to-noise performance, the system characteristics preferred by the ITU-R, as found in its Recommendations, should be used where appropriate; where more than one value is recommended, the designer should indicate the value chosen; in the absence of preferred values, the designer should indicate the assumptions used.

Note 4 – For frequency-division multiplex telephony, it will be assumed that, during the busy hour, the baseband signal can be represented by a uniform-spectrum signal, the mean absolute power-level of which, at a point of zero relative level is equal to $-15 + 10 \log N$ (dBm) for 240 channels or more, and $-1 + 4 \log N$ (dBm)* for number of channels between 12 and 240, N being the number of channels. These formulae apply only to baseband signals without pre-emphasis and using independent amplifiers or repeaters for the two directions of transmission. Further information on the conventional load, in particular in the case of a repeater which is common to both directions of transmission, is given in ITU-T Recommendation G.223.

* It is considered that these formulae give a good approximation in calculating intermodulation noise when $N \geq 60$. For small numbers of channels, however, tests with uniform-spectrum random noise are less realistic, due to the wide difference in the nature of actual and test signals.

Note 5 – Compandors are sometimes used in achieving a performance considered equivalent to that of § 1.1 with typical compandor gain values of approximately 10 dB for speech-like signals.

Note 6 – The noise power indicated in § 1 above should include interference noise (see Recommendations ITU-R SF.356 and ITU-R S.466) and noise resulting from atmospheric absorption and increased noise temperature due to rain. In certain cases, such as extremely long links and low elevation angles where margins must be higher, additional noise may cause limits of the general objectives to be slightly exceeded. This should not cause serious concern, provided that the provisions of ITU-T Recommendation G.222, § 2.6, are met.

Note 7 – The value given in § 1.3 on occasion may be exceeded due to solar interference in the beam of the antenna but this noise is assumed to result in unavailability of the circuit. Detailed information is given in Appendix 2 of Recommendation ITU-R S.733.

Note 8 – The objectives set out in this Recommendation are performance objectives, as distinct from availability objectives.

Note 9 – It may be necessary to make special provision regarding the performance of inter-satellite links. The extent of this provision is a matter requiring further study.

Note 10 – Short interruptions (less than 10 s) shall be treated as equivalent to the case where noise power of a circuit is more than 10^6 pW0 unweighted.

Note 11 – It is desirable that systems be planned on the basis of propagation data covering a period of at least four years. The performance recommended to be met in “any year” should be based on the cumulative propagation statistics for all the complete years for which reliable data are available. The performance recommended to be met for “any month” should be based on the propagation data corresponding to the “worst month of the year taken from the monthly statistics for all the years for which reliable data are available”. The “worst month” should be calculated in accordance with Recommendation ITU-R PN.581.

Note 12 – This Recommendation applies only when the system is considered available in accordance with Recommendation ITU-R S.579.

Note 13 – In order to comply with the values given in § 1, for systems operating above 10 GHz, it may be advantageous to make use of fade countermeasures strategies and techniques for which basic guidance is provided in Recommendation ITU-R S.1061.

ANNEX 1

Form of the hypothetical reference circuit and allowable noise standards for frequency-division multiplex telephony

1. Form of the hypothetical reference circuit

The concept of the hypothetical reference circuit (HRC) has been used by the ITU-T in developing the requirements for making international connections for telephony and television and has been typically associated with terrestrial systems. This topic is discussed in ITU-T Recommendation G.222 along with the associated standards of noise performance. The HRC applicable to the fixed-satellite service (FSS) is given in Recommendation ITU-R S.352 which includes provisions for the possibility of the use of diversity at the higher frequency bands where rain attenuation is a factor in the performance.

The HRC is applicable to all types of analogue transmissions and generally comprises a single, geostationary-orbit satellite link although a satellite-to-satellite link can be used.

With respect to television, the definition and characteristics of reference chains comprising one or more hypothetical reference circuits and corresponding to different services, have been studied by the ex-CMTT and are reflected in Recommendations ITU-R S.354 and ITU-R CMTT.567.

2. Allowable noise standards

2.1 General considerations

The noise standards for international connections for analogue telephony services are established by the ITU-T taking into account the need to provide a minimum quality for the longest connections considered reasonable and, from this minimum quality for the end-to-end connection, an allowance for each portion of the circuit can be determined.

The current status of this work is that specifications exist for the basic HRC which apply to terrestrial systems, the length being 2 500 km and the total noise allowance being 10 000 pW0p including the multiplex. This specification was made in 1963 and it seemed appropriate at the time to consider the satellite link as the equivalent of a single HRC with a proviso that multiplex noise was excluded. This latter provision accounts for the fact that only a single multiplexing operation is a normal part of a satellite link.

Four such international connections were deemed to make up the longest connections. Hence it was implicit that this part of a connection could have a total noise of 40 000 pW0p. Additionally, the local part of the circuit could be considered to add another 10 000 pW0p for an end-to-end total of 50 000 pW0p or –43 dBm0p. This level of noise has generally been accepted as the level where user difficulties begin to be of concern even though noise of twice this level is found to be acceptable by as many as half the users.

2.2 Allowable noise in the HRC: frequency-division multiplex telephony

2.2.1 Factors influencing the allowable noise

The total noise of a typical HRC of 10 000 pW0p for terrestrial links is translated into a distance dependant factor of 3 pW0p/km, after making an allowance of 2 500 pW0p for the multiplex and the specified length of 2 500 km. The total of 4 such HRCs providing an international connection of 10 000 km was probably reasonable in 1963, however, such a length is not consistent with present practice. For example, the ISDN hypothetical reference connection is 27 500 km and ISDN performance is based on that concept. At the same time, the practice of system designers of terrestrial systems has long been to use an objective of 1 pW0p/km instead of 3 pW0p/km. This objective allows for twice as many HRCs in a connection without exceeding the 40 000 pW0p limit for the long haul portion of the connection. This assumes that the multiplex contribution is maintained at 2 500 pW0p for each HRC. The effect is to increase the length of a connection, which meets the overall requirement, to over 20 000 km, which is more representative of modern communications.

The use of satellites, with their distance independent performance, and their ability to provide connections of as much as 17 000 km with a single link, makes it clear that such links having the noise level corresponding to a single HRC will provide for improved end-to-end performance in many cases.

The satellite HRC has a short-term noise limit that would also have to be adjusted so that margins would be still reasonable. This is quite feasible to do for the 6/4 GHz bands where the actual margin requirements are small (of the order of 3 dB or less). For this case then, the current short term allowance of 50 000 pW0p for 0.3% of the month is easily met as would be the 0.1% of the month specified in ITU-T Recommendation G.222.

For the 14/11 GHz bands, this is not the case and the short-term value will be affected depending upon the margin used. For example, on a link designed to a long term value of 10 000 pW0p with 10 dB of margin, the short term noise could reach a level of 100 000 pW0p, which, while still a usable circuit for many users, exceeds the current limits. The ITU-T itself would prefer this value for the short term allowance but it would be too difficult to measure, and therefore adopted the 50 000 pW0p number.

The subject of increased noise is also discussed in Annex 2 from a slightly different point of view; however, the same general conclusions are reached.

Finally, still in the context of the 14/11 GHz bands, the results of an analysis are provided in the following, which highlights the impact of introducing the concept of availability as far as performance compliance with ITU-T Recommendation G.222 is concerned.

A standard link concept is used for the analysis to correspond to the current practice of other terrestrial systems of allowing 1 pW0p/km for design, or a link of 10 000 km. The operational locations for such links are typically at 40° latitude and 25° elevation angle. The climates for these latitudes exhibit rain rates, for 0.01% of the time, between 30 and 60 mm/h. A value of 50 mm/h is chosen for the analysis. Calculations of the rain attenuation are made in accordance with the methods of Radiocommunication Study Group 3 (ex SG 5).

The 10 000 pW0p requirement for 20% of any month is interpreted as applying to the worst month i.e. for the poorest propagation month. The definition of the worst month is provided in Recommendation ITU-R PN.581. The same interpretation is applied to the 50 000 pW0p clause.

Propagation availability factor (as defined in Annex 1 to Recommendation ITU-R S.579) is taken as 10% of the duration of fade which results in reaching the system threshold. Two cases are shown in Fig. 1, one at 50 000 pW0p and one at 100 000 pW0p. The margin in the first case is 7 dB and is 10 dB for the second.

The performance for the path expressed in terms of the available time will meet all of the ITU-T Recommendation G.222 performance objectives for the climate and latitudes assumed in this study. For low antenna elevation angles and higher rain rates, it may be more difficult to meet ITU-T Recommendation G.222.

2.2.2 The concept of satellite equivalent distance

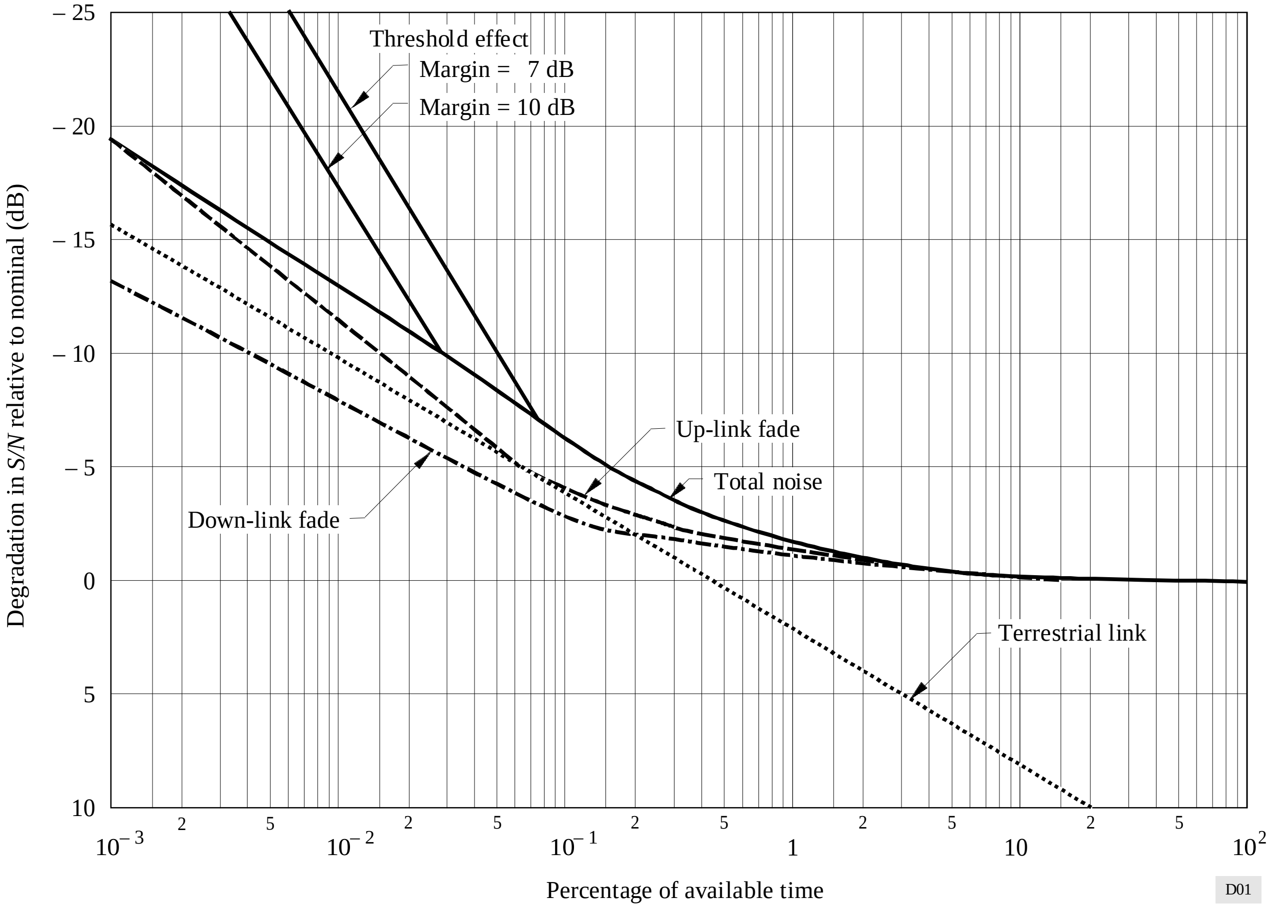
For the purposes of ISDN, the distance independence of satellite links was recognized by the use of a satellite equivalent distance to permit the use of the same performance degradation/km applied to other transmission systems. In the long distance, high quality portion of the HRX for ISDN, half of the noise allocation was assigned to satellite HRDPs which can be translated to an equivalent distance of 12 500 km. Although application of this concept to the analogue case could result in an increased allocation of noise for a satellite HRC without violating the overall end-to-end performance of connections made using a satellite link, there are many situations using a satellite link where better performance is desirable.

2.2.3 Propagation availability

Recommendation ITU-R S.579 covers the subject of availability of the HRC and includes all outages which persist for longer than 10 s. In particular, propagation fades which are the major source of degradation to satellite circuits, have been studied to establish a relationship between fading level and the duration. For the fade levels which are typical for satellite system designs, a value of 0.1 has been determined to be appropriate for the ratio of available to unavailable time for propagation fades. This factor has more impact at the higher frequencies.

FIGURE 1

14/11 GHz noise performance as a function of available time



2.2.4 Use of syllabic compandors

The use of syllabic compandors has been largely confined to up-grading poor quality circuits on older cable systems, where the economics rule out replacement of the system. Such compandors give a subjective improvement in a voice channel which can be as much as 18 dB, but suffer from various stability problems which rule against their widespread use. The latter have been solved by digital implementation and in recent years they have been increasingly used on satellite circuits where the economics would not permit circuits without them.

The use of syllabic compandors on satellite circuits can improve the utilization of either or both, power and bandwidth. They have been shown to provide 10-12 dB of improvement in voice channel quality for speech-like signals. However, the use of syllabic compandors on circuits where the signals are constant, such as data circuits, will not realize any improvement and care must be taken to ensure that the available satellite link signal-to-noise ratio is adequate for the data signals.

There has been increased usage in recent years with none of the problems of the early days and for many cases, syllabic compandors are a valid solution to providing circuits which meet the requirements of ITU-T Recommendation G.222.

3. Summary

The consideration of the factors which bear on the allowances made for the noise in the HRC for the FSS leads to the conclusion that, except for up-dating the provisions of this Recommendation to take account of the concept of propagation availability, use of syllabic compandors and the need to account for rain attenuation at the higher frequencies, the current provisions are reasonable.

ANNEX 2

Noise performance objectives for satellite telephone circuits related to user preferences

1. Introduction

In terrestrial telephone circuits and channels, noise is substantially dependent on the circuit length. This has led to an approach of specifying noise in terrestrial circuits as a function of the distance spanned by the circuit plus a constant noise contribution, that is independent of distance due to those equipment, and interference characteristics that are not distance-dependent.

However, if one examines the philosophy underlying the method of arriving at terrestrial circuit noise standards, the most important feature is the quality of service given to telephone users under average and extreme conditions within the network.

Whilst distances impose a major constraint on transmission performance in terrestrial circuits, satellite circuit noise and attenuation (or loss) are largely independent of distance. Therefore, it would seem more appropriate to determine a value, or range of values, that will provide satisfactory connections irrespective of the distances spanned by the satellite circuits. In the light of these considerations, it may be desirable to examine the feasibility of departing from the noise levels allowed by this Recommendation and the effects of such a departure on the quality of telephone connections via satellite networks for a national service.

2. Possible practical solutions in providing satellite circuits

An analysis and discussion submitted by Australia during the study period 1974-1978 demonstrates that for certain classes of circuits used in a national traffic situation, the standards applied generally to international telephone circuits via satellite can be modified to gain economic advantage, yet provide an adequate service within a country. It will not be possible to take advantage of this for all connections and some special arrangements may be necessary to ensure conformity with international requirements when these “national standard” satellite circuits are to be connected to an international circuit. There are, of course, national traffic situations where standards exceeding those in this Recommendation may have to be applied.

The analysis considered three types of link:

a) conforming with this Recommendation (10 000 pW0p circuits);

b) relaxation of 3 dB (20 000 pW0p circuits);

c) relaxation of 6 dB (40 000 pW0p circuits).

It would be feasible to provide separate transponders for separate types or a mixed arrangement within one transponder. The possible changes in system capacities by departing from the 10 000 pW0p value depend on the system configuration considered, but can offer as much as 100% increase in the total number of channels per transponder in return for 6 dB relaxation from this Recommendation.

It may also be desirable to provide some links with a very low noise contribution to enable very long terrestrial extensions to be permanently associated with them. Such links could perhaps conform to this Recommendation standard. These could then be extended with about 6 500 km of terrestrial transit circuits.

Another possible arrangement is when all traffic to or from international sources is restricted to terrestrial trunks where possible, thus allowing the provision of only type c) circuits with very few of the other types being necessary. This arrangement would have the advantage of simplifying the special international switching arrangements that would be necessary to avoid excessive tandem satellite connections.

Finally, if it is acceptable to use, say, 40 000 pW0p or 20 000 pW0p circuits, rather than the 10 000 pW0p circuit standard, then it will be desirable to re-examine both the total allowance of non-thermal noise (assumed to be constant at 6 000 pW0p) and also, the interference component of this non-thermal noise (assumed to be 2 000 pW0p). Clearly, if the interference, and hence the non-thermal noise contribution, could be increased at the expense of thermal noise, some economic benefits might occur in terms of relaxed co-ordination requirements of the satellite system.

3. Conclusion

Noise objectives in the terrestrial network must recognize the worst and average conditions that may be encountered and which generally are due to the distance factor. Within the constraints of the overall noise standards currently recommended by the ITU-T, standards for satellite circuits can be chosen that should provide equivalent or somewhat better performance than comparable long distance terrestrial connections. Essentially, it is envisaged that the noise allowance for a satellite circuit should correspond to the noise allowance of the terrestrial systems, it notionally replaces. Where special conditions require better circuits, a special arrangement could be made to meet the requirements. It has been shown that this method of establishing the satellite circuit objectives rather than the simple application of this Recommendation standard, leads to a possible increase in a given system's capacity, leading to a reduction in cost per channel for a given system, or a reduction in system costs for a given channel requirement.