

REPORT ITU-R M.760-3

**Link power budgets for a maritime
mobile-satellite service**

(1978-1982-1990-2004)

1 Introduction

The purpose of this Report is basically twofold:

- to list the parameters which must be taken into account when determining link power budgets for a future maritime mobile-satellite system, and the conditions under which these parameters apply;
- to provide examples of link power budgets to illustrate the application of these parameters.

Link power budgets are required in order to determine the likely power requirements and physical characteristics of the space sector (satellite) and the Earth sector (coast earth stations and ship earth stations). The overall design for a future system will rely to a great extent on the experience acquired in the development and operation of existing and planned maritime satellite systems, and hence considerable guidance on the choice of suitable power budget parameters can be obtained by reference to the INMARSAT system [Inmarsat, 1978; MARISAT, 1977].

The link budget examples given in this Report relate to analogue systems with global coverage by a satellite system utilizing a shaped beam. The example mobile standards used are derived from those of the analogue INMARSAT Standard A system. Examples of link budgets for digital systems are presented in Report ITU-R M.921.

2 Power budget philosophy

The philosophy adopted in this Report is to assume a “reference” system configuration from which corresponding parameters for other configurations may be derived. From the propagation viewpoint, the channel quality obtained with a maritime satellite system will be strongly dependent on the satellite elevation angle, and so it would appear reasonable to adopt the elevation angle as one of the parameters on which to base the reference system. The reference configuration for the power budgets is assumed here to apply at satellite elevation angles of 5° for coast earth stations and 10° for ship earth stations; corresponding parameters and resultant channel qualities for elevation angles other than these may then be derived.

A further criterion adopted here is to assume that parameters for the Earth sector are the same as for existing, or planned, systems: in particular, INMARSAT standard-A ship earth stations are assumed.

3 Telephony channel parameters

Telephony is expected to be the dominant service in terms of system power requirements and hence the power budgets are based on a telephony channel.

For the purpose of presenting information on link budget examples in this Report, as a reference it has been assumed that an overall carrier-to-noise density ratio (C/N_0) of 53 dB/Hz should be achieved for at least 80% of the time in both directions of transmission, with satellite elevation

angles of 5° at coast earth stations and 10° at ship earth stations and with no multipath fading on ship/satellite links. This objective has been used as the reference configuration for the power budgets, as shown in the extreme right-hand column of Tables 1 and 2. The current ITU-R telephone channel quality objective for telephone channels in the maritime mobile-satellite service corresponds to an overall C/N_0 of about 52 to 53 dB/Hz (see Recommendation ITU-R M.547).

In addition to the reference configuration, example power budgets are shown in Tables 1 and 2 for ship elevation angles of 5° and 10° when multipath fading occurs on ship/satellite links. The fading parameters are assumed to be applicable to conditions obtaining for at least 99% of the time. However, insufficient experimental data is available to reliably establish required fading margins for any confidence level.

Single-channel-per-carrier operation in frequency division multiple access is envisaged for telephony, with narrow-band frequency modulation and speech processing (e.g. 2:1 syllabic companding). With C/N_0 of 53 dB/Hz at the demodulator input, a suitable receiver noise bandwidth would be 30 kHz with 50 kHz channel spacing; the corresponding carrier-to-noise ratio (C/N) would be about 8 dB.

Threshold extension demodulators, with a nominal threshold of around 50 dB/Hz, would be required to ensure a graceful degradation of speech quality with reducing signal level.

4 Space sector parameters

The space sector configuration assumed here is based on global coverage in both shore-to-ship and ship-to-shore directions of transmission. Assumptions regarding the characteristics of the 1.5/1.6 GHz antenna and the intermodulation noise performance of the transponders are summarized below.

4.1 1.5/1.6 GHz antenna

The critical transmission path, from the viewpoint of satellite power requirements, is that in the satellite-to-ship direction at 1.5 GHz. Efficient use of the available satellite power for Earth coverage may be obtained by assuming a shaped beam antenna [Wood and Boswell, 1974; Lancrenon *et al.*, 1976]. The trade-off between beam-centre and beam-edge gain with this antenna provides an almost constant received flux density at the Earth's surface for all elevation angles, and thus optimizes system performance for those ship earth stations at the edge of the coverage area where propagation effects are at their most severe. Similar compensation may also be provided on the up-path at 1.6 GHz.

4.2 Intermodulation noise performance

The satellite amplifier carrier-to-intermodulation-noise density ratio (C/I_0) in Table 1 for the shore-to-ship link is shown to be a limiting factor in determining the resultant C/N_0 and therefore must be optimized against amplifier output power. For typical amplifiers and suitable frequency plans that minimize intermodulation noise in occupied channels, a C/I value of about 19 dB in a 30 kHz bandwidth may be reasonably achieved with significant satellite amplifier loading. This results in the assumed C/I_0 of 63.8 dBHz for the shore-to-ship direction.

In the ship-to-shore direction, as given in Table 2, a C/I_0 of 70 dB/Hz has been assumed as the satellite amplifier is not expected to be as power limited as in the shore-to-ship direction.

5 Earth sector parameters

The following ship earth station and coast earth station radio-frequency characteristics have been adopted as the basis for the power budgets:

Ship earth station G/T :	$-4 \text{ dB(K}^{-1}\text{)}$ (Standard-A)
Ship earth station e.i.r.p.:	37 dBW
Coast earth station G/T :	$32 \text{ dB(K}^{-1}\text{)}$
Coast earth station e.i.r.p.:	60 dBW.

5.1 Ship earth station

The assumed G/T of $-4 \text{ dB(K}^{-1}\text{)}$ is a net value which includes allowances for power losses due to pointing accuracy, misaligned polarization ellipses, diplexer and dry radome; an additional allowance is shown in the link budgets for loss due to a wet radome. This sensitivity may be achieved with an antenna of 23 dBi gain and a transistorized receive amplifier of 500 K total system noise temperature. An appropriate antenna would be a paraboloid of 1.2 m diameter, with 60% illumination efficiency, and a beamwidth of approximately 10° to the -3 dB points; an axial ratio of about 2 dB has been assumed. For the purposes of the link budget calculations, the pointing and polarization losses have been considered separately.

No allowance has been made in the power budgets for blockage effects from the ship's superstructure; these would depend on the individual ship and could, in theory, be eliminated by choosing an unobstructed site.

5.2 Coast earth station

For a clear-sky G/T of $32 \text{ dB(K}^{-1}\text{)}$ at 5° elevation, a total system clear-sky noise temperature of 100 K has been assumed for the calculation of noise temperature degradation under fading conditions. Fading parameters for 4/6 GHz links are assumed to be applicable to propagation conditions obtaining for 99.99% of the time; the channel quality of the overall links between coast earth stations and ship earth stations is thus mainly determined by the loss parameters on ship/satellite links at 1.5/1.6 GHz.

An appropriate coast earth station's antenna diameter would be 13 m, assuming an illumination efficiency of 60%. The antenna axial ratio has been assumed to be 0.5 dB; for the purposes of the link budget calculations, polarization and pointing losses have been considered separately.

The uplink intermodulation noise from all coast earth station transmit amplifiers has been assumed to result in a total uplink C/I greater than 30 dB in a 30 kHz bandwidth. This assumption is consistent with the current Inmarsat Coast Earth Station Technical Requirements Document and the expected performance of typical frequency plans that could be employed. This results in the C/I_0 value of 75 dB/Hz used in Table 1.

6 Derivation of link margins

The margins necessary to achieve the desired objectives for the satellite links are dependent upon many factors including the satellite characteristics, ship earth station and coast earth station characteristics, weather, sea states and satellite elevation angles. The overall system design should include link margins consistent with the following factors:

- minimum elevation angle considered for service;
- tolerable performance degradation for elevation angles lower than the minimum design point.

The choice of link margins in relation to elevation angle (α) and the system design will affect the performance of the entire system (as seen from the terrestrial network). A system designed to achieve a specified quality for a stated percentage of time, with margins to allow for degradations occurring at low elevation angles, will achieve this quality for much higher percentages of time when calls to and from all ships within the coverage area are considered.

The margins required to compensate for losses other than the basic free space path loss can be grouped into categories of long term (fixed and random losses) and short term.

6.1 Long-term losses

Long-term losses may be defined as those which would tend to last for a period of at least a minute per occurrence.

6.1.1 Fixed long-term losses

Long-term losses which occur with certainty should be included in the path loss for all calculations. The composite margin for these losses (dB) is their sum:

$$L_f = \sum_j L_{f,j} \quad (1)$$

6.1.2 Random long-term losses

Several of the long-term losses tend to occur randomly and are generally independent of each other. The cumulative mean loss ($\bar{L}_l$) and variance (σ_l^2) may be obtained by summing the individual means and variances:

$$\bar{L}_l = \sum_j \bar{L}_{l,j} \quad (2)$$

$$\sigma_l^2 = \sum_j \sigma_{l,j}^2 \quad (3)$$

6.2 Short-term losses

Short-term losses may be defined as those which would tend to last for a period of less than a minute per occurrence. Since the occurrence of a significant short-term fading period may be infrequent, uncertain, or may only occur at certain times of the day, consideration should be given to the fading statistics when establishing fade margins.

Short-term losses tend to be independent of each other and to have different statistical distributions. The cumulative margins needed for these losses may be strongly dependent on elevation angle (α), since the elevation angle independent losses are relatively small or infrequent.

The cumulative mean loss ($\bar{L}_s$) and variance (σ_s^2) for the cumulative short-term losses may be obtained by summing the individual mean losses and variances:

$$\bar{L}_s = \sum_j \bar{L}_{s,j} \quad (4)$$

$$\sigma_s^2 = \sum_j \sigma_{s,j}^2 \quad (5)$$