RECOMMENDATION ITU-R M.1475

METHODOLOGY FOR DERIVATION OF PERFORMANCE OBJECTIVES OF NON-GEOSTATIONARY MOBILE-SATELLITE SERVICE SYSTEMS OPERATING IN THE 1-3 GHz BAND NOT USING SATELLITE DIVERSITY

(Question ITU-R 87/8)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that non-geostationary mobile-satellite service (non-GSO MSS) systems in the 1-3 GHz band are being planned for implementation or being implemented;

b) that performance objectives would be specified for the hypothetical reference digital path (HRDP) given in Recommendation ITU-R M.827;

c) that performance objectives are designated for GSO MSS systems in Recommendation ITU-R M.1181;

d) that both regenerative and non-regenerative transponders may be used in non-GSO MSS systems;

e) that the methodology for the derivation of performance objectives may be different for regenerative and non-regenerative transponders;

f) that performance objectives for feeder links of non-GSO MSS systems should be determined based on end-to-end performance objectives;

g) that performance objectives are useful for the basis of definition of interference criteria,

recommends

1 that for non-GSO MSS systems with non-regenerative transponders performance objectives should be defined for an end-to-end connection, from which performance objectives may be derived for feeder link and service link in such a way that 10% of unavailable time is allocated to the feeder link;

2 that the method presented in Annex 1 may be used to obtain performance objectives for non-GSO MSS systems with non-regenerative transponders;

3 that for non-GSO MSS systems with regenerative transponders performance objectives may be defined either for an end-to-end connection or for service link and feeder link separately, where Recommendation ITU-R S.614 or ITU-R S.1062 may provide guidance on performance objectives of feeder links.

ANNEX 1

Methodology for the derivation of performance objectives for non-GSO MSS systems with non-regenerative transponders

1 Derivation of performance objective

1.1 Definition of performance objective

A performance objective is defined by a threshold value of the end-to-end performance and an acceptable percentage of time as the following definition: "Percentage of time when the bit error ratio (BER) without forward error correction (FEC) is worse than BER_{th} shall be X% (e.g. 0.1%, 1%, 10%, etc.) or less", where BER_{th} and X(%) are the end-to-end performance threshold BER and the percentage of unavailable time, respectively. This BER should be averaged over a period of Z s. (The quantity is for further study.)

1.2 Link threshold value of performance objectives

Recommendation ITU-R M.1181 which deals with availability of GSO-MSS stipulates the threshold value of performance BER_{th}, for mobile voice traffic, is 4×10^{-2} (without FEC). It should be noted that the threshold value of performance depends on the type of applications offered by the particular MSS system (e.g. voice, fax, data and for mobile, vehicular and semi-fixed).

1.3 Percentage of available and unavailable time

Due to inherent properties of MSS systems, which includes the time variant conditions of MSS service link shadowing and mobility of user terminals, it may be realistic to use the value given in Recommendation ITU-R M.1181 for GSO MSS systems, that is, available time percentages (X%) between 90% to 95% for non-GSO MSS systems.

2 Basic concept and assumptions

2.1 Threshold C/N_T

The carrier-to-noise power ratio for the end-to-end link may be estimated from the performance objective defined by the BER_{th}. As an example, the end-to-end threshold $(C/N_T)_{th}$ (where "th" stands for threshold) for mobile voice traffic employing QPSK modulation is assumed to be 7 dB, for a threshold BER of 4×10^{-2} without FEC. It should be noted that the $(C/N_T)_{th}$ value of 7 dB is higher than the theoretical value to cope with various practical degradation (e.g. modem implementation margins). Furthermore, for other MSS, such as transportable data delivery service, the BER requirement is more stringent (see Recommendation ITU-R M.1181) leading to a $(C/N_T)_{th}$ requirement of at least 15 dB.

2.2 Degradation of C/N_T and service link and feeder-link margin

2.2.1 Definitions

The total carrier-to-noise power ratio is denoted by C/N_T. Hence, it is possible to write the end-to-end C/N_T of the non-GSO MSS system as:

$$C/N_T = \left\{ [(C/N_T)_s]^{-1} + [(C/N_T)_f]^{-1} \right\}^{-1} \qquad (1)$$

where C is the receive carrier power and N_T is the sum of the noise power N (excluding interference) and the interference power, I, (i.e. $N_T = N + I$). The suffixes s and f indicate the service link and feeder link, respectively.

2.2.2 C/N_T degradations

Various phenomena give rise to degradations in C/N_T. In the service link and feeder-link bands fading and other effects (e.g. position of the mobile satellite station, de-pointing, de-polarization, atmospheric scintillation, atmospheric absorption, shadowing, etc.), will lower the C receive level. The total interference level, I, will account for intra-system interference and inter-system interference, i.e. $I = I_{Intra} + I_{Inter}$. The contribution to the total interference is provided in Table 1. Here it is also noted that various factors in service link and feeder link give rise to interference, i.e. $I = I_{service\ link} + I_{feeder\ link}$, in such a case the percentage of the interference contributions may be, for example, 90% for the service link and 10% for the feeder link. In regard to the noise level, this is dependent on the G/T and changes to this value are a function of the link dynamics (e.g. user position, receiver gain, rain scattering, etc.). Here, for the sake of simplicity, it is assumed that the contribution of these factors to the end-to-end C/N_T degradation is considered to be statistically independent.

TABLE 1

Types of inter-system and intra-system interferences experienced by non-GSO MSS systems

Link	Intra-system interference	Inter-system interference
Service link	– Inter-spot beam co-channel interference – Intermodulation effects (satellite downlink) – Adjacent channel interference (in the same beam) – Cross polar co-frequency interference	– From other co-channel services – From other co-channel systems – Unwanted emissions from adjacent allocations
Feeder link	– Intermodulation effects (up and downlinks) – Adjacent channel interference – Cross-polar co-frequency interference	– From other co-channel services – From other co-channel non-GSO systems – Interference from unlicensed devices – Unwanted emissions from adjacent allocations

2.2.3 Nominal values of C/N_T and link margins

Based on the above discussions, the link budget will take account of link margins for both service and feeder links to cope with various fading and transmission impairment factors (see § 2.2.2). Appropriate values are assumed to be given for the service link margin, M_s, and the feeder-link margin, M_f, depending on system and operational conditions. Hence with these definitions it is possible to write the following equations:

$$(C/N_T)_{s,nom} = M_s\,(C/N_T)_{s,th}$$
$$(C/N_T)_{f,nom} = M_f\,(C/N_T)_{s,th} \qquad (2)$$

where *th* stands for threshold and *nom* stands for nominal.

2.2.4 Derivation of service link margins

The most important information in deriving the margin for the service link is from the statistical data of shadowing and fading measurements. For example, Recommendation ITU-R M.1188 gives indicative values of fade margins as a function of the required BER_{th}.

The relationship between the fade degradation and percentage of time, can be obtained by the propagation model described in Recommendation ITU-R P.681. For example, in the case of non-GSO MSS satellites, the following link degradation characteristics are determined for the service link operating in a suburban environment with minimum elevation angle of 30°:

$(C/N_T)_s$ degradation ≤ 0 dB	Percentage of time: 50%
$(C/N_T)_s$ degradation ≤ 5 dB	Percentage of time: 90%
$(C/N_T)_s$ degradation ≤ 10 dB	Percentage of time: 95%
$(C/N_T)_s$ degradation ≤ 20 dB	Percentage of time: 99%

2.2.5 Service link and feeder link breakdown of C/N_T

Depending on the link design, the breakdown of the C/N_T into service and feeder links, namely $(C/N_T)_s$ and $(C/N_T)_f$, is determined. For a non-regenerative transponder in nominal conditions (i.e. clear sky), it is generally the case that the $(C/N_T)_f$ is sufficiently higher (e.g. 10 to 20 dB) than the $(C/N_T)_s$. Without specifying the ratio value, here, $(C/N_T)_f$ is assumed to be K times larger than $(C/N_T)_s$, hence:

$$(C/N_T)_{f,nom} = K\,(C/N_T)_{s,nom} \qquad (3)$$

2.3 Apportionment of percentage of unavailable time

The total unavailable time of the end-to-end link has to be distributed appropriately between the service and feeder links. Recommendation ITU-R M.828 gives a definition of the end-to-end availability of MSS systems.

Apportionment of the unavailable time between the service and feeder links is dealt with in Recommendation ITU-R M.1181, where 10% of the unavailable time is allocated to the feeder link. This apportionment has been assumed for non-GSO MSS as well.

2.4 Derivation of C/N_T threshold values for service and feeder links

Based on the above discussion, we now have the following two equations:

In nominal condition:

$$\begin{aligned}(C/N_T)_{nom} &= \left[(C/N_T)^{-1}_{s,nom} + (C/N_T)^{-1}_{f,nom} \right]^{-1} \\ &= \left\{ \left[M_s (C/N_T)_{s,th}\right]^{-1} + \left[M_f (C/N_T)_{f,th}\right]^{-1} \right\}^{-1}\end{aligned} \qquad (4)$$

In threshold condition:

$$(C/N_T)_{th} = \left[(C/N_T)^{-1}_{s,th} + (C/N_T)^{1}_{f,th} \right]^{-1} \qquad (5)$$

From equations (4) and (5), we can resolve for the threshold values $(C/N_T)_{s,th}$ and $(C/N_T)_{f,th}$. After some algebraic manipulations, we get:

$$(C/N_T)_{s,th} = \left[1 + M_f / (M_s\, K)\right]\ (C/N_T)_{th} \qquad (6)$$

$$(C/N_T)_{f,th} = \left[1 + (M_s\, K) / M_f\right]\ (C/N_T)_{th} \qquad (7)$$

where $(C/N_T)_{th}$, has been defined in § 2.1.

2.5 Derivation of performance objectives

2.5.1 Unavailability and threshold allowances

Putting together the unavailability time allowances (see § 1.3 and 2.3) and the link C/N_T threshold allowances (see § 2.4), we have:

For the service link:

– The service link $(C/N_T)_s$ may be lower than $(C/N_T)_{s,th}$ for a time percentage no greater than 0.9 X (%).

For the feeder link:

– The feeder link $(C/N_T)_f$ may be lower than $(C/N_T)_{f,th}$ for a time percentage no greater than 0.1 X (%).

2.5.2 Non-GSO MSS performance objectives

When the above are converted to performance objectives, these become:

For the service link:

– The service link $(C/N_T)_s$ shall be greater than or equal to $(C/N_T)_{s,th}$ for a time percentage greater than or equal to (100 – 0.9 X) (%).

For the feeder link:

– The feeder link $(C/N_T)_f$ shall be greater than or equal to $(C/N_T)_{f,th}$ for a time percentage greater than or equal to (100 – 0.1 X) (%).

3 Example calculation

3.1 Performance objective and unavailability

As an example, for the case of non-GSO MSS systems employing QPSK modulation and for the case of mobile voice application, we assume the following (see also § 1.3 and 2.1):

– The percentage of total available time when the end-to-end threshold $(C/N_T)_{th}$ is higher than 7 dB shall be 95%.

Hence, this can be rewritten as:

– The percentage of total unavailable time when the end-to-end threshold $(C/N_T)_{th}$ is lower than 7 dB shall not be greater than 5%.

Hence the value $X = 5\%$, as used in the definitions of § 2.5.

Then based on § 2.3, the $X = 5\%$ unavailable time is apportioned between service link and feeder link as the ratio 90% and 10% respectively, and the service link and feeder link total unavailable time become 4.5% for the service link and 0.5% for the feeder link.

3.2 Threshold C/N_T values

Assuming that the service link degradation is that of § 2.2.4 (see Recommendation ITU-R P.681), the value of the service link margin becomes $M_s = 10$ dB (which is also consistent with Recommendation ITU-R M.1188). The link margin for the feeder link is assumed equal to $M_f = 3$ dB, which will account for all the carrier impairments as described in § 2.2.2.

Also, it is assumed that $(C/N_T)_f$ is 10 dB higher than $(C/N_T)_s$ at the nominal clear sky condition (i.e. ($K = 10$).

Substituting these values in equations (6) and (7) we get:

$$(C/N_T)_{s,th} = 7.09 \quad \text{dB} \quad \text{for the service link}$$

$$(C/N_T)_{f,th} = 24.09 \quad \text{dB} \quad \text{for the feeder link}$$

3.3 Unavailability and threshold objective

The unavailability and threshold objectives derived from the above equations are of a practical use for the service and feeder links of non-GSO MSS systems employing QPSK modulation for the mobile satellite voice service. These objectives are respectively:

$(C/N_T)_{s,th} \leq 7.09$ dB for a percentage time up to 4.5%

$(C/N_T)_{f,th} \leq 24.09$ dB for a percentage time up to 0.5%

3.4 Performance objectives

Hence the performance objectives become:

$(C/N_T)_{s,th} \geq 7.09$ dB for more than 95.5% of time

$(C/N_T)_{f,th} \geq 24.09$ dB for more than 99.5% of time