International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.1476
(05/2000)

Performance objectives for narrow-band digital channels using geostationary satellites to serve transportable and mobile earth stations in the 1-3 GHz range forming part of the integrated services digital network

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2010

RECOMMENDATION ITU-R M.1476*

Performance objectives for narrow-band digital channels using geostationary satellites to serve transportable and mobile earth stations in the 1-3 GHz range forming part of the integrated services digital network

(Question ITU-R 112/8)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that performance objectives for digital mobile-satellite service (MSS) channels using narrow-band modulation and geostationary satellites should include an allowance for inter-system and intra-system interference levels for systems operating in the 1-3 GHz range, as well as comply with the user performance requirements;

b) that the bit-error ratio (BER) will vary with time due to the effects of varying propagation conditions including the effects of multipath fading;

c) that reception of signals transmitted to and from mobile earth stations at most locations may be substantially degraded by location and orientation dependent on signal propagation impairments which determine spatial performance;

d) that digital MSS channels may be used in global or spot coverage beams as part of a worldwide MSS, in which case stringent satellite power constraints are expected;

e) that the performance objectives of the MSS for services which form part of the integrated services digital network (ISDN) should be defined considering the ITU-T Recommendations concerning ISDN performance objectives (ITU-T Recommendations G.821 and G.826) with an appropriate consideration for the effect of propagation conditions in the MSS;

f) that performance objectives for MSS which are not connected via the ISDN will be the subject of other ITU-R Recommendations,

recommends

1 that in both forward and return directions of transmission, through the service and feeder links, the combined radio-link performance objectives for MSS digital channels forming part of the ISDN are as follows:

1.1 the combined MSS radio link unavailability due to propagation should provisionally be not more than 0.1% of the time, where the definition of available time and unavailable time is given in ITU-T Recommendation G.821, and provided for clarity in § 2, Annex 1 of this Recommendation;

1.2 a BER better than 9×10^{-7} after error correction for more than 99% of the available time;

* Radiocommunication Study Group 8 made editorial amendments to this Recommendation in 2004 in accordance with Resolution ITU-R 44.

2 that the method given in Annex 2 may be used as a guideline for the system designer, for apportioning the overall unavailability between the feeder link and service link parts;

3 that the following Notes are an integral part of this Recommendation.

NOTE 1 – An analysis linking the available and unavailable time defined by ITU-T Recommendation G.821 to unavailability due to propagation of MSS channels is provided in Annex 1.

NOTE 2 – For data communications, error control techniques are generally provided as an integral part of the modem. Additional end-to-end error control measures may be implemented to enhance performance for specific user applications. However, for the purpose of this Recommendation, the effects of these user application techniques are not included in the performance objectives.

NOTE 3 – The effects of obstruction and shadowing of the direct propagation path are not considered in the performance objectives defined above. Digital mobile-satellite channels used by vehicular land mobile earth stations are more susceptible to reduced spacial availability due to shadowing and obstruction.

NOTE 4 – Spatial availability is defined as the cumulative probability of link availability arising from the joint distribution of location and orientation dependent random losses in the link.

NOTE 5 – For maritime and aeronautical earth stations at low elevation angles operating through the digital mobile-satellite channel, the BER performance objectives given in *recommends* 1 might be achieved for a lower percentage of the time.

NOTE 6 – In the case of backup using a previous generation satellite the BER performance objectives given in *recommends* 1 might be achieved for a lower percentage of the time.

NOTE 7 – The effects of aggregate interference from other systems and services should be taken into account in ensuring that the overall performance objectives of the digital MSS channel are met.

NOTE 8 – A BER objective better than 1×10^{-6} for more than 99% of the available time (reflecting propagation conditions) is apportioned between the MSS link and the other components forming part of the end-to-end ISDN link. With reference to the hypothetical reference connection (HRX) given in Fig. 1 of ITU-T Recommendation G.821, 90% of the performance objectives (errored seconds (ES), sererely errored seconds (SES)) are apportioned to the MSS radio link since it is the most significant contributor to BER degradation. Therefore, the BER performance apportioned to the MSS radio link is 9×10^{-7}, during the available time.

NOTE 9 – Further study is required for the necessity of short-term performance criteria to define the associated BER thresholds and percentages of time.

Annex 1

Methodology for calculating unavailability of the MSS radio link based on the unavailability defined for the ISDN in ITU-T Recommendation G.821

1 Introduction

For fixed services (FS) and fixed-satellite services (FSS), quality objectives for the ISDN are defined by ITU-T Recommendation G.821. For MSS, on the other hand, availability is the main quality objective so far and it is assessed by the statistics of C/N versus a threshold C/N which corresponds to a specified BER in probability. In the mobile ISDN era where mobile-satellite communication systems will be incorporated in the global ISDN system, however, circuit quality of MSS should be defined so as to keep consistencies with the FS and FSS.

This Annex discusses various propagation impairments for mobile-satellite systems (such as maritime mobile-satellite service (MMSS), aeronautical mobile-satellite service (AMSS) and land mobile-satellite service (LMSS)) from a viewpoint of the available and unavailable time defined by ITU-T Recommendation G.821, and stresses the importance of the concept that unavailability and degradation during available time are two different measures for evaluation of mobile-satellite communication in the mobile ISDN era.

2 Definition of parameters used in ITU-T Recommendation G.821

To clarify the discussion in this Annex, parameters used in ITU-T Recommendation G.821 are listed below.

– Available time and unavailable time

  A period of unavailable time begins when the BER in each second is worse than 1×10^{-3} for a period of ten consecutive seconds. These ten seconds are considered as the unavailable time. A new period of available time begins with the first second of a period of ten consecutive seconds each of which has a BER better than 1×10^{-3}.

– SES

  One-second period which has a BER worse than 1×10^{-3}.

– ES

  One-second period in which one or more bits are in error.

In ITU-T Recommendation G.821 for ISDN performance objectives, availability is not discussed and only percentages of SES and ES are defined.

3 Relation between availability defined by traditional analysis and ITU-T Recommendation G.821

Table 1 summarizes the characteristics of fading phenomena for various MSS. From this Table, it can be recognized that:

– LMSS propagation environments are most complex due to the variety of fading phenomena, and

– a consideration of availability for MMSS is needed because the fading period of MMSS is comparable with 10 s which is a criteria for available and unavailable time in the ITU-T definition.

TABLE 1

Characteristics of propagation impairments in several MSS communication environments

Service / Characteristics	MMSS	AMSS	LMSS-V (vehicular)	LMSS-P (handheld terminal)
Communication environment	Line-of-sight	Line-of-sight	Line-of-sight Out-of-sight	Line-of-sight (out-of-sight communication is difficult)
Primary factor of fading	Sea reflection fading	Sea reflection fading Ground reflection fading	Shadowing by terrain, buildings and trees Multipath fading	Same as LMSS Shadowing by human body
Typical fade depth(1)	Within 10 dB	Within 8 dB	Varies with environment (more than 20 dB when maximum)	Within 10 dB
C/*M* (2)	More than 6 dB	More than 7 dB	0-20 dB (various)	More than 6 dB
Dominant frequency component of variation	0.5 to several hundred Hz	20 to several hundred Hz	10 to several tens of Hz (multipath fading) Below 1 Hz (shadowing by terrain)	Several Hz or below

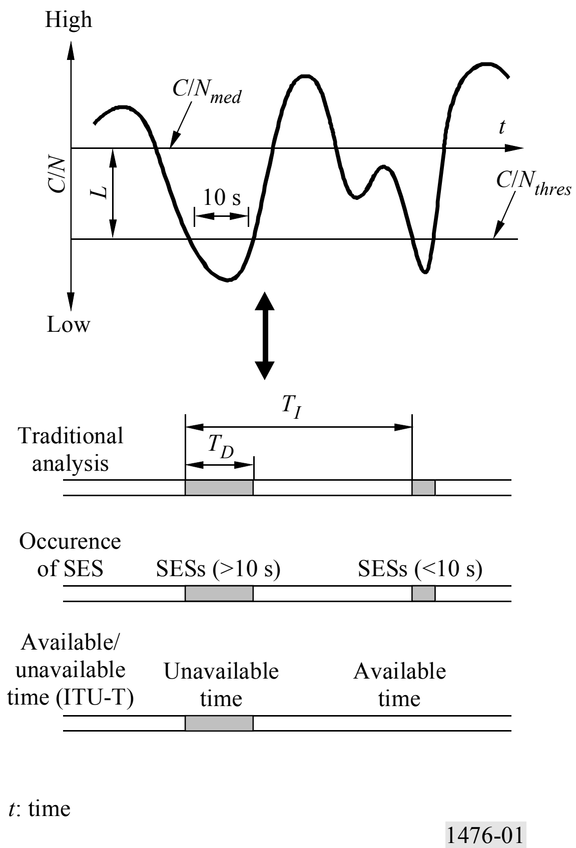
(1) Fade depth: 50-99 percentile fade level.

(2) *C*/*M* ratio of direct wave power, *C*, to average multipath power, *M*.

Figure 1 shows an example of flat fading in which the *C*/*N* value changes with time. Since noise level *N* can be regarded as constant in the ordinary case, the variation of *C*/*N* is equivalent to that of the received level. Also, *C*/*N* and BER correspond to each other, the variation of *C*/*N* in Fig. 1 can be regarded as a variation of BER, (here, BER is defined as a probability, not the BER in one second mentioned above. We will therefore write the former BER_{prob} and the latter BER_{sec} to distinguish them). We denote the median (nominal) value of *C*/*N* as C/N_{med}, and the threshold *C*/*N* value at which BER_{prob} becomes the threshold BER as C/N_{thres}, for example 1×10^{-3}.

FIGURE 1

Definition of available and unavailable time based on traditional analysis and ITU-T Recommendation G.821



According to the traditional analysis, unavailability is defined as:

$$UA_{trad} = \frac{\text{(Sum of duration in which } C/N \text{ is smaller than a threshold)}}{\text{(Total time)}} \times 100\% \quad (1)$$

On the other hand, unavailability defined by ITU-T Recommendation G.821 is given by equation (2):

$$UA_{ITU\text{-}T} = \frac{\text{(Sum of unavailable time defined by ITU-T definition)}}{\text{(Total time)}} \times 100\% \quad (2)$$

These two unavailabilities differ depending on the speed of variation, etc. The criteria for UA_{trad} is a C/N value for a specified BER_{prob} and the criteria for $UA_{ITU\text{-}T}$ is SES. In this way, the criteria for each unavailability are different. The relation between BER_{sec} and BER_{prob} can be expressed as follows:

$$BER_{sec}(t_i) = \int_{t_i - 0.5}^{t_i + 0.5} BER_{prob}(C/N(t))\, dt \quad (3)$$

To regard a BER_{sec} as a SES, it is necessary that the condition at which $BER_{prob} < 1 \times 10^{-3}$ is contained in the second $t_i - 0.5 < t_i < t_i + 0.5$. The relation between L which corresponds to the difference between C/N_{med} and C/N_{thres}, and its percentage of time p is different under each propagation environment, and is expressed as a function of environmental parameters and system parameters.

In a fading environment where the mean duration of signal fade is relatively shorter than 10 s, there may be two conditions where the unavailable time occurs:

a) Mean period of variation is shorter than one second, and BER_{sec} obtained from equation (3) is worse than a specified value for a period of 10 consecutive seconds.

b) Variation is calm and the signal fade (or C/N degradation) exceeds the threshold value for more than 10 s.

For AMSS, condition a) may be the dominant factor, while for MMSS condition b) may be the dominant factor. In the latter case, the relation between unavailability UA_{trad} defined by the traditional analysis and $UA_{ITU\text{-}T}$ defined by ITU-T Recommendation G.821 can be approximated by equation (4):

$$UA_{ITU\text{-}T} \approx \frac{\int_{\tau_0}^{\infty} \tau\, f(\tau; <T_D(p)>)\, d\tau}{\int_{0}^{\infty} \tau\, f(\tau; <T_D(p)>)\, d\tau}\, UA_{trad} \tag{4}$$

$$p = 100 - UA_{trad} \quad \%$$

where τ_0 represents the criteria for fade duration (10 s for availability/unavailability criteria), and f represents a probability distribution function of fade duration T_D as a function of threshold level L which corresponds to a p percentile fade level.

In the case described by equation (4), UA_{trad} always exceeds $UA_{ITU\text{-}T}$ ($UA_{trad} > UA_{ITU\text{-}T}$), and unavailability defined by ITU-T becomes smaller than that defined by the traditional analysis. This is only a matter of definition, and there is no change in the quality of actual MMSS communication.

4 Unavailability in MMSS fading environments

In this section MMSS unavailability is discussed as a case study of the previous section. In MMSS, sea reflection fading is the primary factor in propagation impairments. Many studies have been carried out on this phenomenon, and have revealed its characteristics. In previous studies, the following characteristics have been identified.

4.1 Fading spectrum

The fading spectrum (spectrum of intensity variation) can be approximated by the following second order Butterworth characteristic:

$$W(f) \propto \left(1 + \frac{9f^4}{f_{-10}^4}\right)^{-1} \tag{5}$$

Here, f_{-10} represents the –10 dB spectral bandwidth. This bandwidth depends on frequency, elevation angle, sea surface condition, ship velocity, etc., and its value varies over a wide range. Its characteristics are summarized in Fig. 2.

4.2 Mean fade duration $<T_D>$ and mean fade occurrence interval $<T_I>$

The mean values of T_D and T_I when the threshold value is set to a p percentile fade level, L_p, can be expressed by equation (6):

$$\langle T_I\ (p)\rangle \ = \ \frac{\sqrt{3}}{f_{-10}} \exp\left\{m(p)^2/2\right\} \tag{6a}$$

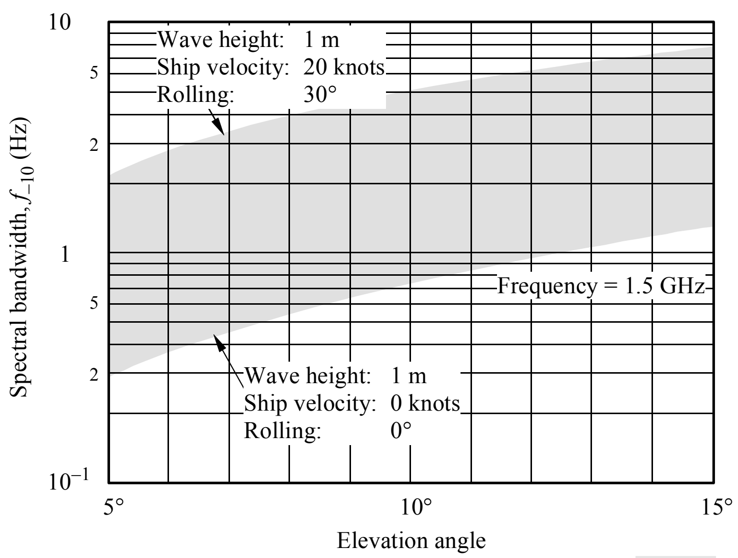
$$\langle T_D\ (p)\rangle \ = \ \langle T_I\ (p)\rangle \left(1 - \frac{p}{100}\right) \tag{6b}$$

Here, the relation between p and m is expressed by equation (7):

$$p \ = \ \frac{100}{\sqrt{2p}} \int_{-\infty}^{m} \exp\left(-t^2/2\right)\ \mathrm{d}t \qquad \% \tag{7}$$

FIGURE 2

Spectral bandwidth of multipath fading due to sea surface reflection in MMSS environments



1476-02

4.3 Probability distribution functions (PDFs) of T_D and T_I

The PDFs of T_D and T_I when threshold value is set to a p ($p = 50$ to 99) percentile fade level L_p can be expressed as exponential distributions of the means $<T_D>$ and $<T_I>$, respectively.

PDF of T_D is expressed by equation (8):

$$f(\tau;\bar{\tau}) = \frac{1}{\bar{\tau}} \exp(-\tau / \bar{\tau}) \tag{8}$$

Substituting equation (8) in (4), the relation between the two unavailabilities in MMSS environments is expressed by equation (9):

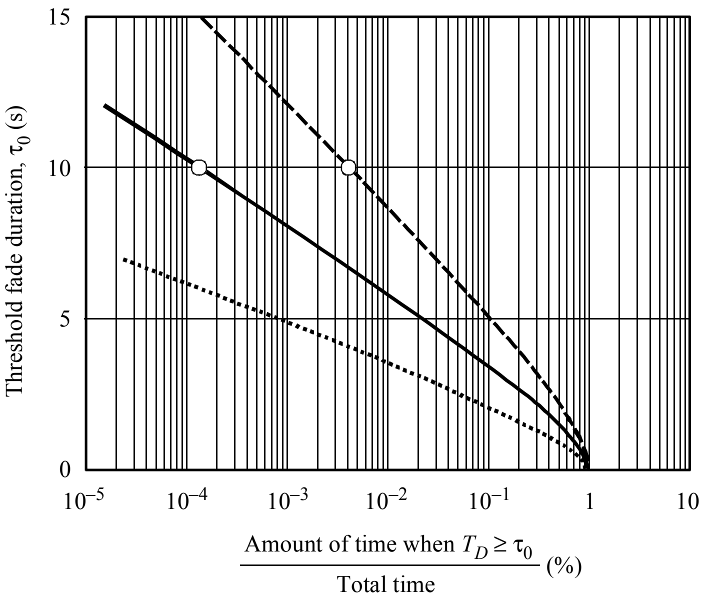
$$UA_{ITU\text{-}T} \approx e^{-\tau_0 / \langle T_D(p) \rangle} \left(1 + \frac{\tau_0}{\langle T_D(p) \rangle} \right) UA_{trad} \tag{9}$$

Since unavailable time becomes likely to occur as the period of variation becomes longer, unavailability for $f_{-10} = 0.5$ Hz (fairly slow within the observed cases), $f_{-10} = 0.3$ Hz (rare case within the observed cases) and $f_{-10} = 0.2$ Hz (may not be observed in the actual communication) are estimated. Figure 3 shows the estimation results for $p = 99\%$ and $p = 99.9\%$ ($BER_{prob} = 1 \times 10^{-3}$). In this Figure, $\tau_0 = 10$ s corresponds to the unavailability according to the ITU-T definition. From the result, it can be concluded that the probability of occurrence of unavailable time is negligible for all MMSS communication environments.

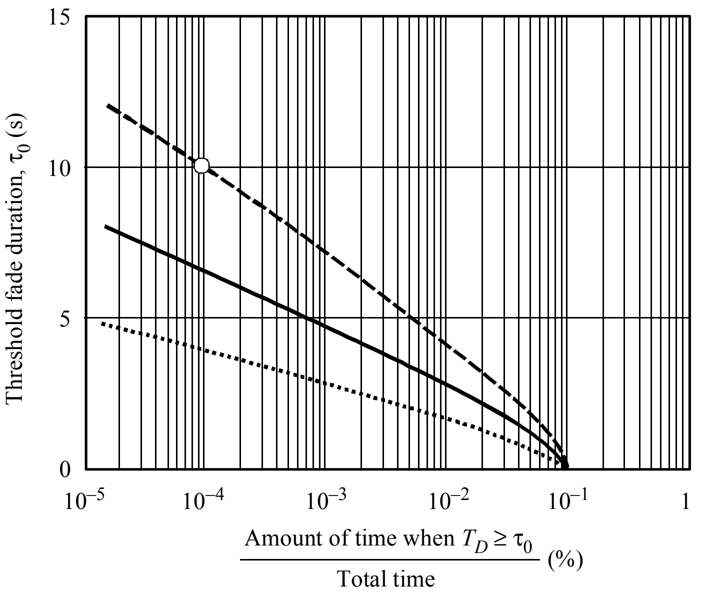
Although the above discussion is a rough estimation, it may be concluded that duration of sea reflection fading in an MMSS environment does not exceed 10 s and availability according to the ITU-T definition is 100%. Needless to say, the quality of MMSS communication circuits is not high even if availability is 100%. The quality of communication circuits should be defined by another definition such as occurrence probability of SES during the available time.

FIGURE 3

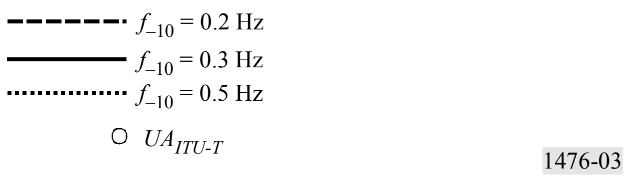
Relations between two unavailabilities based on the traditional analysis and ITU-T Recommendation G.821 in MMSS environments



a) p (= 100 – UA_{trad}) = 99%



b) p (= 100 – UA_{trad}) = 99.9%



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5 Conclusion

This Annex has discussed various propagation impairments for mobile-satellite systems from a viewpoint of the available and unavailable time defined by ITU-T Recommendation G.821. The unavailability of MMSS due to sea reflection fading was examined. As a result, it was concluded that unavailability and degradation during available time should be considered separately as the different measures in the evaluation of mobile-satellite communication.

Annex 2

A method for allocating the overall percentage of time for which the link is available between the service link and feeder link

Generally individual uplinks and downlinks are so designed that the overall percentage of time for which the link is available is to a large extent determined by the service link. This means that the service link is subject to a much tighter power constraint.

The percentage of time for which the end-to-end link is available may be achieved by allocating percentages of available time to the corresponding uplink and downlink using Table 2.

TABLE 2

Direction of transmission	Radio path	Percentage of time for which the link is available
Forward	Feeder uplink	$100(1 - 0.1(1 - A))$
	Service downlink	$A/A_{f,u}$
Return	Feeder downlink	$100(1 - 0.1(1 - A))$
	Service uplink	$A/A_{f,d}$

A: overall radio-link time availability

$A_{f,u}$: forward feeder uplink time availability

$A_{f,d}$: return feeder downlink time availability

For example, an end-to-end link availability requirement of 90% could be achieved with a service link availability requirement of 90.9%, and a feeder-link availability requirement of 99%.

In the described allocation method the feeder link is ascribed 10% of overall link unavailability. Ascribing a larger unavailability to the feeder link will result in a significant increase in the service link availability requirement. Conversely, reducing the unavailability ascribed to the feeder link will result in little or no change to the service link requirement, i.e. the overall link availability is dominated by the service link.