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SERIES G: TRANSMISSION SYSTEMS AND MEDIA

Digital transmission systems – Digital networks – Quality
and availability targets

**Error performance of an international digital
connection operating at a bit rate below the
primary rate and forming part of an integrated
services digital network**

ITU-T Recommendation G.821

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION G.821

ERROR PERFORMANCE OF AN INTERNATIONAL DIGITAL CONNECTION OPERATING AT A BIT RATE BELOW THE PRIMARY RATE AND FORMING PART OF AN INTEGRATED SERVICES DIGITAL NETWORK

Summary

This Recommendation defines error performance parameters and objectives for international digital connections operating below the primary rate of the digital hierarchy. The objectives given are independent of the physical network supporting the connection. This Recommendation is based upon bit error and bit error ratio measurements. The events, parameters and objectives are defined accordingly.

Annex A deals with the definition of availability of the connection, and Annex B gives guidelines concerning the interpretation of Table 1.

Appendix I informs about inconsistencies between Recommendations G.821 and G.826.

Source

ITU-T Recommendation G.821 was revised by ITU-T Study Group 13 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 27th of August 1996.

Keywords

Error Performance Parameters, Error Performance Objectives, Errored Second, Severely Errored Second.

FOREWORD

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The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Introduction

This Recommendation takes into account that services are based on the concept of an Integrated Services Digital Network (ISDN).

In digital networks, errors are a major source of degradation in that they affect voice services in terms of distortion of voice, and data type services in terms of lost or inaccurate information or reduced throughput.

In spite of the fact that voice services are likely to predominate the narrow-band ISDN, it is required to transport a wide range of service types and it is therefore desirable to have a unified specification.

An explanation of network performance objectives and their relationship with design objectives is given in Recommendation G.102. [1]

Background

This Recommendation was adopted in 1980 and defined error performance parameters and objectives for ISDN connections operating at a bit rate of 64 kbit/s. Because it was the first Recommendation giving error performance objectives, it found wide application even in areas it was not developed for. One of these applications was error performance evaluation at bit rates higher than 64 kbit/s.

In 1988, Annex D was added to Recommendation G.821, which indicated how to derive error performance data of 64 kbit/s connections taking into account measurements performed at higher bit rates. Practical experience showed, however, that Annex D/G.821 lead in many cases to doubtful results. It became obvious that a Recommendation was needed which dealt with error performance parameters and objectives for higher bit rates.

To fill this gap, Recommendation G.826 [3] was developed and was adopted in 1993. It gives error performance parameters and objectives for constant bit rate digital paths operating at bit rates at and above the primary rate. Recommendation G.826 contains the statement that it "*... is the only Recommendation specifying error performance parameters and objectives at bit rates at or above the primary rate.*" Considering this statement, Recommendation G.821 had to be restricted to bit rates below the primary rate and Annex D/G.821 had to be deleted. On the other hand, the bit rate range between 64 kbit/s and the primary rate was to be covered by Recommendation G.821.

Another problem discovered in the practical use of Recommendation G.821 was the applicability of the Degraded Minute parameter (DM). In practice, this event was hardly detected and it was therefore decided to delete it from Recommendation G.821.

In summary, the following modifications are now included in Recommendation G.821:

- this Recommendation has been restructured in accordance with Recommendation A.15;
- this Recommendation is applicable to bit rates below the primary rate of the digital hierarchy;
- the Degraded Minute parameter is deleted;
- Annex D/G.821 (1988) is deleted;
- otherwise, there are no technical changes to this Recommendation.

After Recommendation G.826 [3] was adopted, work on Recommendation G.821 continued and comparisons between the performance objectives of Recommendations G.821 and G.826 were made. From these comparisons it became apparent that inconsistencies exist between the two Recommendations. Some examples are given in Appendix I of this Recommendation.

Thus, Recommendation G.821 shall be used with some caution until the inconsistencies between it and Recommendation G.826 [3] are removed.

Recommendation G.821

ERROR PERFORMANCE OF AN INTERNATIONAL DIGITAL CONNECTION OPERATING AT A BIT RATE BELOW THE PRIMARY RATE AND FORMING PART OF AN INTEGRATED SERVICES DIGITAL NETWORK

(Geneva, 1980; revised in 1996)

1 Scope

This Recommendation specifies error performance events, parameters and objectives of a $N \times 64$ kbit/s circuit-switched digital connection ($1 \leq N \leq 24$ or ≤ 31 respectively) used for voice traffic or as a "Bearer Channel" for data-type services.

2 References

The following Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision: all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

- [1] CCITT Recommendation G.102 (1980), *Transmission performance objectives and Recommendations.*
- [2] CCITT Recommendation G.801 (1984), *Digital transmission models.*
- [3] ITU-T Recommendation G.826 (1996), *Error performance parameters and objectives for international constant bit rate digital paths at or above the primary rate.*
- [4] ITU-T Recommendation I.325 (1993), *Reference configurations for ISDN connection types.*
- [5] CCITT Recommendation I.340 (1988), *ISDN connection types.*
- [6] CCITT Recommendation G.921 (1988), *Digital sections based on the 2048 kbit/s hierarchy.*

3 Abbreviations

For the purposes of this Recommendation, the following abbreviations are used:

BER	Bit Error Ratio
ES	Errored Second
ESR	Errored Second Ratio
HRDP	Hypothetical Reference Digital Path
HRX	Hypothetical Reference Connection
ISDN	Integrated Services Digital Network
SES	Severely Errored Second
SESR	Severely Errored Second Ratio

4 Definitions

Within the scope of this Recommendation, the following definitions apply:

4.1 Digital connections

The performance objectives are stated for each direction of a $N \times 64$ kbit/s circuit-switched connection ($1 \leq N \leq 24$ or ≤ 31 respectively) used for voice traffic or as a "Bearer Channel" for data-type services.

Recommendation I.325 [4] gives reference configurations for the ISDN connection types listed in Recommendation I.340 [5]. In the context of error performance of 64 kbit/s circuit-switched connection types and the allocation of performance to the connection elements, an all digital hypothetical reference configuration (HRX) is given in Figure 1. It encompasses a total length of 27 500 km and is a derivative of the standard hypothetical reference configuration given in Figure 1/G.801 [2] and of the reference configuration given in Figure 3/I.325.

4.2 Error performance events and parameters

4.2.1 Events

Error performance parameters are derived from the following events:

4.2.1.1 errored second (ES): It is a one-second period in which one or more bits are in error.

4.2.1.2 severely errored second (SES): It is a one-second period which has a bit error ratio $\geq 1 \cdot 10^{-3}$.

4.2.2 Parameters

It should be noted that total observation time (S_{total}) is split into two parts, namely, time for which the connection is deemed to be available (S_{avail}) and that time when it is unavailable (S_{unavail}). Error performance should only be evaluated whilst the connection is in the available state. See Annexes A and B.

Parameters are:

4.2.2.1 errored second ratio (ESR): The ratio of ES to total seconds in available time during a fixed measurement interval.

4.2.2.2 severely errored second ratio (SESR): The ratio of SES to total seconds in available time during a fixed measurement interval.

4.3 Functions of error performance objectives

The performance objectives aim to serve two main functions:

- a) to give the user of national and international digital networks an indication as to the expected error performance under real operating conditions, thus facilitating service planning and terminal equipment design;
- b) to form the basis upon which performance standards are derived for transmission equipment and systems in an ISDN connection.

The performance objectives represent a compromise between a desire to meet service needs and a need to realize transmission systems taking into account economic and technical constraints. The performance objectives, although expressed to suit the needs of different services are intended to represent a single level of transmission quality.

Since the performance objectives are intended to satisfy the needs of the digital network, it must be recognized that such objectives cannot be readily achieved by all of today's digital equipment and systems. The intent, however, is to establish equipment design objectives that are compatible with the objectives in this Recommendation.

It is further urged that all technologies, wherever they appear in the network, should preferably be designed to better standards than those indicated here in order to minimize the possibility of exceeding the end-to-end objectives on significant numbers of real connections.

The objectives relate to a very long connection and recognizing that a large proportion of real international connections will be shorter, it is expected that a significant proportion of real connections will offer a better performance than the limiting value given in clause 5. On the other hand, a small percentage of the connections will be longer and in this case may exceed the allowances outlined in this Recommendation.

NOTE – Controlled slips, which may be perceived as short bursts of errors, are not included in the calculations of the error performance objectives in this Recommendation. Therefore, users should be aware that error performance measurements which include controlled slip effects may produce poorer performance than would be indicated by this Recommendation. Users are directed to Recommendation G.822, which specifies the controlled slip rate objectives, for guidance in estimating the possible effects on their applications.

The error performance objectives detailed in clauses 5 and 6 apply to a $N \times 64$ kbit/s circuit switched connection (as defined in clause 4.1).

However, it is recognized that in practical situations objectives of this Recommendation will need to be evaluated from measurements made on paths operating at higher bit rates. For that purpose, Recommendation G.826 [3] – which specifies error performance objectives for international constant bit rate digital paths at or above the primary rate – shall be used.

5 Performance objectives

The performance objectives for an international ISDN connection as identified in 4.1 are shown in Table 1. It is intended that international ISDN connections should meet all of the requirements of Table 1 and of clause 6. The connection fails to satisfy the objective if any of the requirements is not met.

TABLE 1/G.821
Error performance objectives for international ISDN connections

Performance classification	Objective (Notes 1, 2)
Severely Errored Second Ratio	< 0.002
Errored Second Ratio	< 0.08
NOTES 1 The ratios are calculated over the available time. The observation time has not been specified since the period may depend upon the application. A period of the order of any one month is suggested as a reference. 2 Annex B illustrates how the overall performance should be assessed.	

6 Apportionment of overall objectives

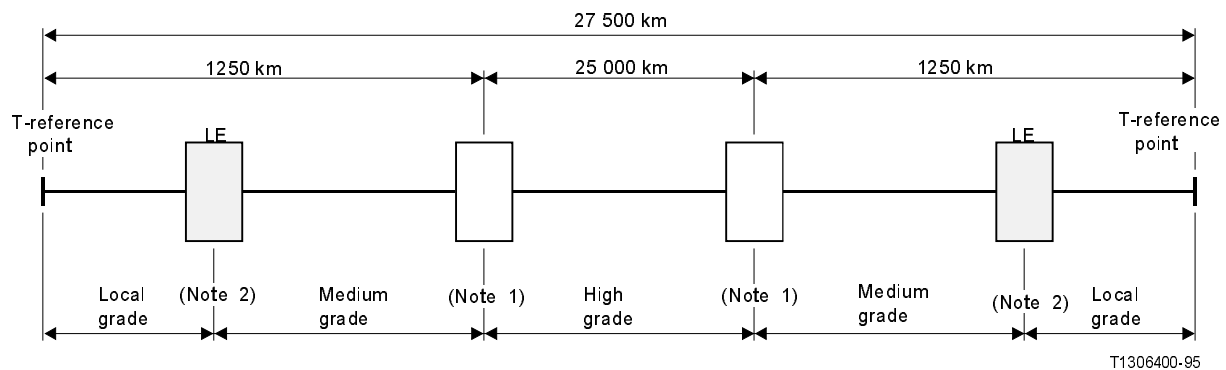
Since the objectives given in clause 5 relate to an overall connection, it is necessary to subdivide this to constituent parts. This clause outlines the basic principles and strategy for apportioning the performance objectives.

The overall apportionment philosophy involves the use of two slightly different strategies, one applicable to the errored seconds requirement and the other applicable to the severely errored seconds requirement.

6.1 Basic apportionment principles

Apportionment is based on the assumed use of transmission systems having qualities falling into one of a limited number of different classifications.

Three distinct quality classifications have been identified representative of practical digital transmission circuits and are independent of the transmission systems used. These classifications are termed local grade, medium grade and high grade and their usage generally tends to be dependent on their location within a network (see Figure 1).



NOTES

1 It is not possible to provide a definition of the location of the boundary between the medium and the high grade portions HRX. Note 4 to Table 2 provides further clarification of this point.

2 LE denotes the local exchange or equivalent point.

FIGURE 1/G.821
Circuit quality demarcation of longest HRX

The apportionment of the permitted degradation is given in Table 2. The derived network performance objectives are given in subsequent subclauses.

TABLE 2/G.821

**Allocation of the objectives
for the three-circuit classifications (Note 1)**

Circuit classification	Allocation of the objectives given in Table 1
Local grade (2 ends)	15% block allowance to each end (Notes 2, 5 and 6)
Medium grade (2 ends)	15% block allowance to each end (Notes 3, 5 and 6)
High grade	40% (equivalent to conceptual quality of 0.0016% per km for 25 000 km) (Notes 4, 7 and 8)
<p>NOTES</p> <ol style="list-style-type: none"> 1 The allocation principle given in this table is applicable to ESR and half of the SESR according to 6.3a). 2 The local grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length. 3 The medium grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length. The actual length covered by the medium grade part of the connection will vary considerably from one country to another. Transmission systems in this classification exhibit a variation in quality falling between the other classifications. 4 The high grade apportionment is divided on the basis of length resulting in a conceptual per kilometre allocation which can be used to derive a block allowance for a defined network model (e.g. Hypothetical Reference Digital Link). For practical planning purposes of links in network models, link allowances based on the number of 280 km sections nominally 280 km (as specified in Table 2/G.921 [6]) can be used in place of the per kilometre allocation specified in this Recommendation. For longer sections which are not an exact integer multiple of 280 km, the next highest integer multiple is used. 5 The local grade and medium grade portions are permitted to cover up the first 1250 km of the circuit from the T-reference point (see Figure 1) extending into the network. For example, in large countries this portion of the circuit may only reach the Primary Centre whilst in small countries it may go as far as the Secondary Centre, Tertiary Centre or the International Switching Centre (see Figure 1). 6 Administrations may allocate the block allowances for the local and medium grade portions of the connection as necessary within the total allowance of 30% for any one end of the connection. 7 Based on the understanding that satellite error performance is largely independent of distance, a block allowance of 20% of the permitted errored second objectives is allocated to a single satellite HRDP employed in the high-grade portion of the HRX. 8 If the high-grade portion of a connection includes a satellite system and the remaining distance included in this category exceeds 12 500 km or if the high-grade portion of a non-satellite connection exceeds 25 000 km, then the objectives of this Recommendation may be exceeded. The occurrence of such connections is thought to be relatively rare and studies are continuing in order to investigate this. The concept of satellite equivalent distance (the length of an equivalent terrestrial path) is useful in this respect and it has been noted that a value in the range 10 000 to 13 000 km might be expected. 9 For subscriber premises installation, between the T-reference point and terminal equipment, no specific requirements are given. However careful attention should be paid to the choice of the subscriber equipment since the overall performance of the connection depends heavily, not only on the network performance, but also on the quality of the terminal installation. 	

The following general assumptions apply to the apportionment strategy that follows:

- in apportioning the objectives to the constituent elements of a connection, it is the Ratios ESR and SESR that are subdivided;
- the error ratio threshold is not subdivided;
- an equal apportionment of the objectives applies for the errored seconds requirement;
- no account is taken of the error contribution from either digital switching elements or digital multiplex equipments on the basis that it is negligible in comparison with the contribution from transmission systems.

These quality classifications for different parts of the connection are considered to represent the situation for a large proportion of real international connections. Administrations are free to use whatever transmission systems they wish within their own networks and these other arrangements are considered as being completely acceptable provided that the overall performance of the national portion is no worse than it would have been if the standard ITU-T arrangements had been employed.

It should be noted that a small percentage of connections will be longer than the 27 500 km HRX. By definition the extra connection length will be carried over high-grade circuits and hence the amount by which such connections exceed the total allowance envisaged in this Recommendation will be proportional to the amount by which the 25 000 km section is exceeded. Administrations should note that if the performance limits in the various classifications could be improved in practical implementations, the occurrence of these situations could be significantly reduced.

6.2 Apportionment strategy for the errored seconds requirement

The apportionment of the permitted degradation, i.e. 0.08 ESR, is given in Table 2. The derived network performance objectives are given in Table 3.

TABLE 3/G.821
Allocation of Errored Second Ratio objective

Circuit classification (see Figure 1)	Network performance objectives ESR
Local grade	0.012
Medium grade	0.012
High grade	0.032

6.3 Apportionment strategy for the severely errored seconds requirement

The total allocation of 0.002 SESR is subdivided into each circuit classification (i.e. local, medium, high grades) in the following manner:

- a) 0.001 SESR is divided between the three circuit classifications in the same proportions as adopted for the other objective. This results in the allocation as shown in Table 4.

TABLE 4/G.821

Allocation of Severely Errored Second Ratio objective

Circuit classification	Allocation of SESR objectives
Local grade	0.00015 block allowance to each end (Note 6 to Table 2)
Medium grade	0.00015 block allowance to each end (Note 6 to Table 2)
High grade	0.0004 (Notes 1, 2)
NOTES	
1 For transmission systems covered by the high grade classification each 2500 km portion may contribute not more than 0.00004 SESR.	
2 For a satellite HRDP operating in the high grade portion there is a block allowance of 0.0002 SESR (see also Note 7 to Table 2).	

- b) The remaining 0.001SESR is a block allowance to the medium and high grade classifications to accommodate the occurrence of adverse network conditions occasionally experienced (intended to mean the worst month of the year) on transmission systems. Because of the statistical nature of the occurrence of worst month effects in a world-wide connection, it is considered that the following allowances are consistent with the total 0.001 SESR figure:
- 0.0005 SESR to a 2500 km HRDP for radio relay systems which can be used in the high grade and the medium grade portion of the connection;
 - 0.0001 SESR to a satellite HRDP.

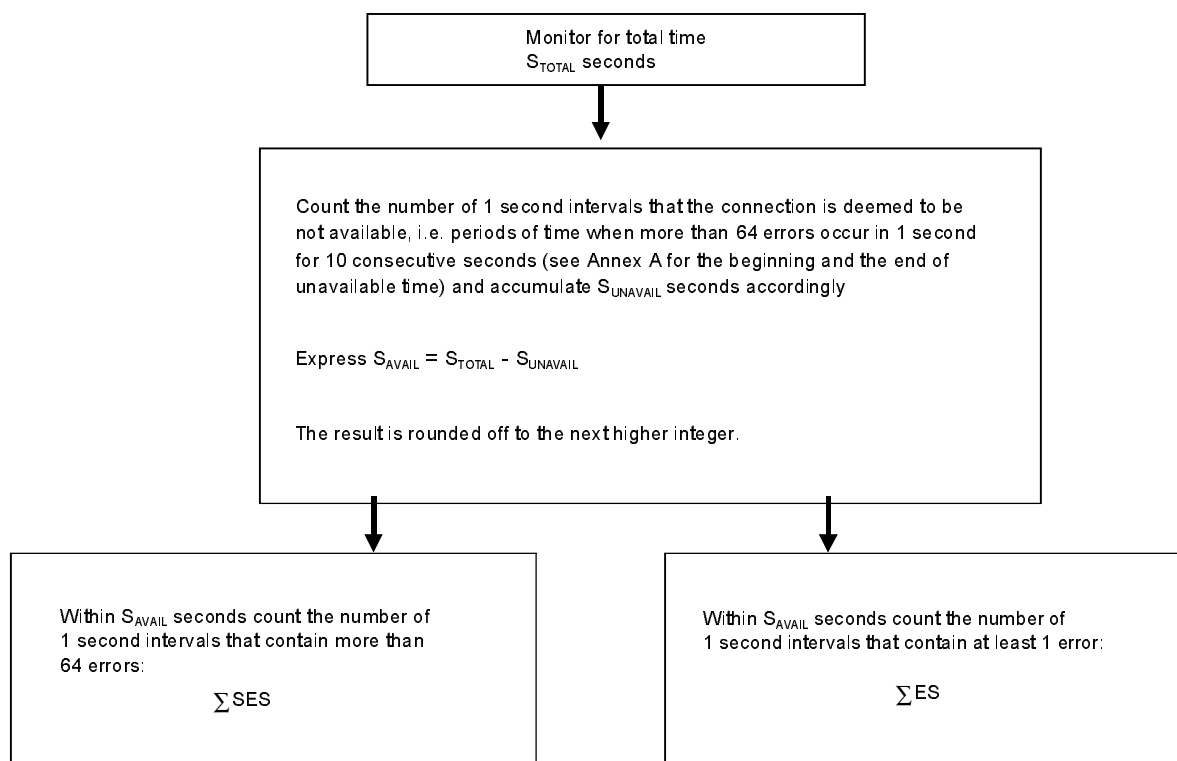
Annex A**Available and unavailable time**

A period of unavailable time begins when the bit error ratio (BER) in each second is worse than $1 \cdot 10^{-3}$ for a period of ten consecutive seconds. These ten seconds are considered to be 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 10^{-3} .

Definitions concerning availability can be found in the E.800-Series Recommendations.

Annex B

Guidelines concerning the interpretation of Table 1



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Performance classification (see Table 1/G.821)	Objective
SESR	$\frac{\sum SES}{S_{Avail}} < 0.002$
ESR	$\frac{\sum ES}{S_{Avail}} < 0.08$

NOTE – ($1 \leq N \leq 24$ or ≤ 31 respectively).

Appendix I

Inconsistencies between Recommendations G.821 and G.826

I.1 Introduction

In this appendix, some comparisons are made between the performance objectives and allocations in Recommendations G.821 and G.826.

I.2 Comparison of the SES definitions and objectives

a) *The criteria for declaration of an SES*

- Recommendation G.821 defines an SES condition at $N \times 64$ kbit/s in terms of a Bit Error Ratio $\geq 1 \times 10^{-3}$.
- Recommendation G.826 [3] defines an SES condition in terms of $\geq 30\%$ Errored Blocks and the detection of certain defects.

It should be noted that the two criteria do not directly equate. The relationship between the two depends on block size, bit error structure, etc.

Given the above statement on relationship of SES events, the G.821 and G.826 objectives should be aligned, such that a 64 kbit/s channel carried over a higher order path just meeting the G.826 SES objectives would meet the SES objectives specified in Recommendation G.821.

b) *Comparison of SES performance objectives and allocation principles*

Both Recommendations have a SES objective for a 27 500 km HRX/HRP of 0.002. However the apportionment strategy differs.

Recommendation G.821 apportions the initial 0.001 per Table 4, and "the remaining 0.001 is allocated on a block basis to medium and high grade classifications to accommodate the occurrence of adverse network conditions occasionally experienced on (intended to mean worst month) transmission systems". The implication is that this additional 0.001 is to accommodate radio-relay and satellite fading and should not be allocated to fibre or coaxial facilities.

Recommendation G.826 [3] allocates the total 0.002 SESR allowance to the 27 500 km HRP using the methodology specified in 6.2. No special allowance is identified for radio and the allocation for a satellite hop is much larger than the allocation in Recommendation G.821. Tables I.1a and I.1b illustrate these differences in SES allocations between Recommendations G.826 and G.821.

TABLE I.1a/G.821

Comparison of allocation of SESR objectives to international portion of the HRX/HRP (assuming no radio or satellite facilities in the connection)

Recommendation G.821	Recommendation G.826
SESR objectives for 25 000 km international path (High grade)	SESR objectives for 25 000 km international path (Assuming 4 transit countries)
$0.4 \times 0.001 = 0.0004$	$0.6 \times 0.002 = 0.0012$
The above equates to <35 SES / 24 hrs (Averaged over the month)	The above equates to <101 SES / 24 hrs (Averaged over the month)

TABLE I.1b/G.821

Comparison of SES allocation to a satellite hop

Recommendation G.821	Recommendation G.826
Initial allocation = $20\% \times 0.001 = 0.0002$ Worst month allocation = 0.0001 Total allocation = 0.0003	Allocation $35\% \times 0.002 = 0.0007$

The above tables show the differences in the performance objectives and allocations between the two Recommendations.

I.3 Comparison of Errored Second Ratio objectives

The entries in Table I.2 below show that the G.821 allocation for the international portion of a 64 kbit/s circuit is higher than the G.826 allocation for bit rates up to 15 Mbit/s.

TABLE I.2/G.821

Comparison of derived errored second ratio objectives

Recommendation G.821	Recommendation G.826
Allocation of ESR to 25 000 km international portion	Allocation of ESR to 25 000 km international portion
Bit rate 64 kbit/s $8 \times 0.004 = 0.032$	Bit rate 1.5 - 5 Mbit/s $= 4 \times 0.006 = 0.024$
	Bit rate 5 - 15 Mbit/s $= 5 \times 0.006 = 0.03$
	Bit rate 15 - 55 Mbit/s $= 7.5 \times 0.006 = 0.045$
	Bit rate 55 - 150 Mbit/s $= 16 \times 0.006 = 0.096$

On the assumption that the international portion of a 64 kbit/s connection would be carried over a higher bit rate system, it is logical to expect that the ES allocation for a 64 kbit/s channel would be equal to or smaller than (normally smaller than) the ES allocation higher rate objectives in Recommendation G.826. This inconsistency could cause considerable confusion and needs to be resolved in further work on the two Recommendations.

It might be assumed that a higher number of errored seconds is to be expected on a switched connection, however, Recommendation G.821 states "No account is taken of the error contribution from either digital switching elements or digital multiplexer equipment on the basis that it is negligible in comparison with the contribution from transmission systems." It should also be noted that in Recommendation G.826 an additional 2% of the end-to-end objectives is given to transit connections to account for additional circuit complexity.

I.4 Summary

Some inconsistencies in the ESR and SESR performance objectives and allocations between Recommendations G.821 and G.826 are identified in this appendix.

It is desirable to resolve these inconsistencies in future revisions to Recommendations G.821 and G.826.

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