

RECOMMENDATION ITU-R F.634-4*

**ERROR PERFORMANCE OBJECTIVES FOR REAL DIGITAL RADIO-RELAY LINKS
FORMING PART OF THE HIGH-GRADE PORTION OF INTERNATIONAL
DIGITAL CONNECTIONS AT A BIT RATE BELOW THE PRIMARY
RATE WITHIN AN INTEGRATED SERVICES
DIGITAL NETWORK**

(1986-1990-1991-1994-1997)

Scope

This Recommendation provides the error performance objectives for real digital radio-relay links forming part of the high-grade portion of international digital connections at a bit rate below the primary rate within an integrated services digital network. This Recommendation also provides the guidance on the factors in determining performance requirements for real digital radio-relay links forming a part of a high-grade circuit within an integrated services digital network.

It should also be noted that this Recommendation could be used only for systems designed prior to the approval of Recommendation ITU-R F.1668 in 2004.

The ITU Radiocommunication Assembly,

considering

- a) that the error performance objectives of a high-grade 2 500 km hypothetical reference digital path (HRDP) at a bit rate below the primary rate for digital radio-relay systems are given in Recommendation ITU-R F.594, which applies to $N \times 64$ kbit/s ($1 \leq N < 24$ (or < 32 , respectively)) (see Note 1);
- b) that network performance objectives for digital sections are given in ITU-T Recommendation G.921;
- c) that real paths which form part of the high-grade portion of an integrated services digital network (ISDN) sometimes differ in composition from the HRDP (see Recommendation ITU-R F.556, Fig. 1), and share radio-relay links shorter than 2 500 km with other digital links;
- d) that conformity with digital radio performance Recommendations cannot be easily established by direct measurements on real systems due to the seasonal and annual variations in propagation conditions, and that practical advice on how to apply performance Recommendations is therefore necessary;
- e) that, therefore, it is necessary to give objectives for allowable bit error ratios (BERs) as a guide in the design and planning of real radio-relay links forming part of the high-grade portion of an ISDN;
- f) that the Recommendations ITU-R F.1092 and ITU-R F.1189, based on ITU-T Recommendation G.826, give error performance objectives for constant bit rate digital paths at or above the primary rate carried by digital radio-relay systems which may form part of the international and national portions, respectively, of a 27 500 km hypothetical reference path,

recommends

- 1** that error performance should be assessed in terms of the events errored seconds (ES) and severely errored seconds (SES) and the parameters errored second ratio (ESR) and severely errored second ratio (SESR) as defined in ITU-T Recommendation G.821 (see also Recommendation ITU-R F.594);
- 2** that when establishing real digital radio-relay links with length, L (km), of between 280 km and 2 500 km providing connections at a bit rate below the primary rate and intended to form part of a high-grade circuit within an ISDN, the following error performance objectives should be respected for each direction of the $N \times 64$ kbit/s ($1 \leq N < 24$ (or < 32 , respectively)) (see Notes 1, 2, 3 and 6);
 - 2.1** that the ESR should not exceed $(L/2\,500) \times 0.0032$ in any month (see Note 5);
 - 2.2** that the SESR should not exceed $(L/2\,500) \times 0.00054$ in any month (see Note 5);

* Radiocommunication Study Group 5 made editorial amendments to this Recommendation in 2012 in accordance with Resolution ITU-R 1.

3 that Annex 1 should be used for guidance on the factors which need to be taken into account in determining performance requirements for real digital radio-relay links forming a part of a high-grade circuit within an ISDN.

NOTE 1 – N is less than 24 in the 1.544 Mbit/s based hierarchy and less than 32 in the 2.048 Mbit/s based hierarchy.

NOTE 2 – Prior to the approval of Recommendations ITU-R F.1092 (1994) and ITU-R F.1189 (1995), real digital radio-relay links forming part of the high-grade portion within an ISDN were designed by applying the error performance objectives of the earlier version of this Recommendation, i.e. ITU-R F.634-3 (published in 1994), directly at the system bit rate. As a consequence, translation rules were suggested to normalize error performance measurement results obtained at the system bit rate to the 64 kbit/s level (see Annex 2).

NOTE 3 – Performance objectives for circuits shorter than 280 km are still under study.

NOTE 4 – For the error performance objectives for circuits longer than 2 500 km see § 1.1 of Annex 1.

NOTE 5 – The term “any month”, as used in this Recommendation, is defined in Recommendation ITU-R P.581. Where measurements are used to ensure compliance with this Recommendation, then the propagation conditions also need to be assessed and related to propagation data representative of “any month” conditions.

NOTE 6 – The ESR and SESR objectives include all performance degradations other than unavailability.

NOTE 7 – The Recommendation applies only when the system is considered to be available in accordance with Recommendation ITU-R F.557 and includes periods of SESs which persist for periods of less than 10 consecutive s. Periods of SESs which persist for 10 consecutive s duration or longer are taken into account by Recommendation ITU-R F.557.

NOTE 8 – It should be noted that the requirements of this Recommendation are intended to meet the relevant performance objectives of ITU-T Recommendations G.821 and G.921 under all normally envisaged operating conditions.

ANNEX 1

Factors to be taken into account in determining performance requirements for real digital radio-relay links forming part of a high-grade circuit within an ISDN

This Annex considers factors which need to be taken into account in determining performance requirements for real digital radio-relay links forming part of a high-grade circuit within an ISDN.

1 Performance objectives for real digital radio-relay links

1.1 General consideration

For the objectives of bit error performance, a hypothetical reference digital connection at a bit rate below the primary rate has been defined in ITU-T Recommendation G.821. It is sub-divided into portions of different circuit quality, termed “high grade”, “medium grade” and “local grade”. The admissible transmission impairment is allocated to these portions in fixed percentages. The apportionments for the local grade and medium grade portions are considered as block allowances, whereas that for the high-grade portion is regarded as an allocation proportional to distance.

In conformity with ITU-T Recommendation G.821, the HRDP given in Recommendation ITU-R F.556, and the associated error performance objectives for the HRDP at a bit rate below the primary rate given in Recommendation ITU-R F.594 applying to high-grade digital radio-relay systems, form the first stage of the sub-division. To enable each administration to specify performance values for transmission systems, further sub-division into hypothetical reference digital sections (HRDS) is necessary. For digital systems of the 2 Mbit/s hierarchy, these values are given in ITU-T Recommendation G.921. Four quality classifications of HRDS have been defined and each has been assigned a fixed percentage of quality impairment. The class 1 section corresponds to the circuit classification “high grade”, but can also be used in the “medium grade” portion. Classes 2 to 4 apply to the medium-grade portion only (see Recommendation ITU-R F.696). Information on the “local grade” part, which represents only the subscriber line, is given in Recommendation ITU-R F.697.

Recommendation ITU-R F.594 gives performance objectives for the HRDP as defined in Recommendation ITU-R F.556. Real links will differ both in length and composition from the HRDP, and it is therefore desirable to provide planning objectives for the allowable BERs of such paths, particularly those which are shorter in length than the HRDP.

In general for real links there are two considerations:

- to find a method of apportioning the objectives given in Recommendation ITU-R F.594 for systems which are intended to be connected in tandem in order to form paths similar to the HRDP;
- to take into account ITU-T Recommendations G.821 and G.921 in determining objectives for digital radio-relay links used in medium- and local-grade portions of an ISDN connection.

It should be noted that in some countries real links can be longer than 2 500 km.

In these cases the objectives given in *recommends 2* may be applied to links with a real length L ($L > 2\,500$ km), but the SESR evaluated for the total link length L should not exceed the objective $0.0005 + (L/2\,500) \times 0.00004$ in any month.

Since the performance of digital radio-relay systems is dependent upon fading, it is generally agreed that the behaviour of any section of the HRDP will be statistically independent. If this is assumed, then mathematically the HRDP performance could be determined by the convolution of the probability density functions of all sections. This process is however, not a practical one, since the probability density function is not known in sufficient detail.

The example given in Fig. 1 illustrates a further important principle coming from the application of ITU-T Recommendation G.102. This Recommendation draws attention to the need for a margin between network performance objectives (NPO) and equipment design objectives (EDO) which are essentially the performance predictions for each hop (see also § 2.5.5 of ITU-T Recommendation G.102). In Fig. 1, the predicted outage for the hop (see Recommendation ITU-R F.1093) accounts for only a proportion of the objective, 10% is allocated to interference from the fixed-satellite service (FSS), whilst the remainder is used as a margin to take account of inaccuracies in the outage prediction method and for other non-deterministic effects.

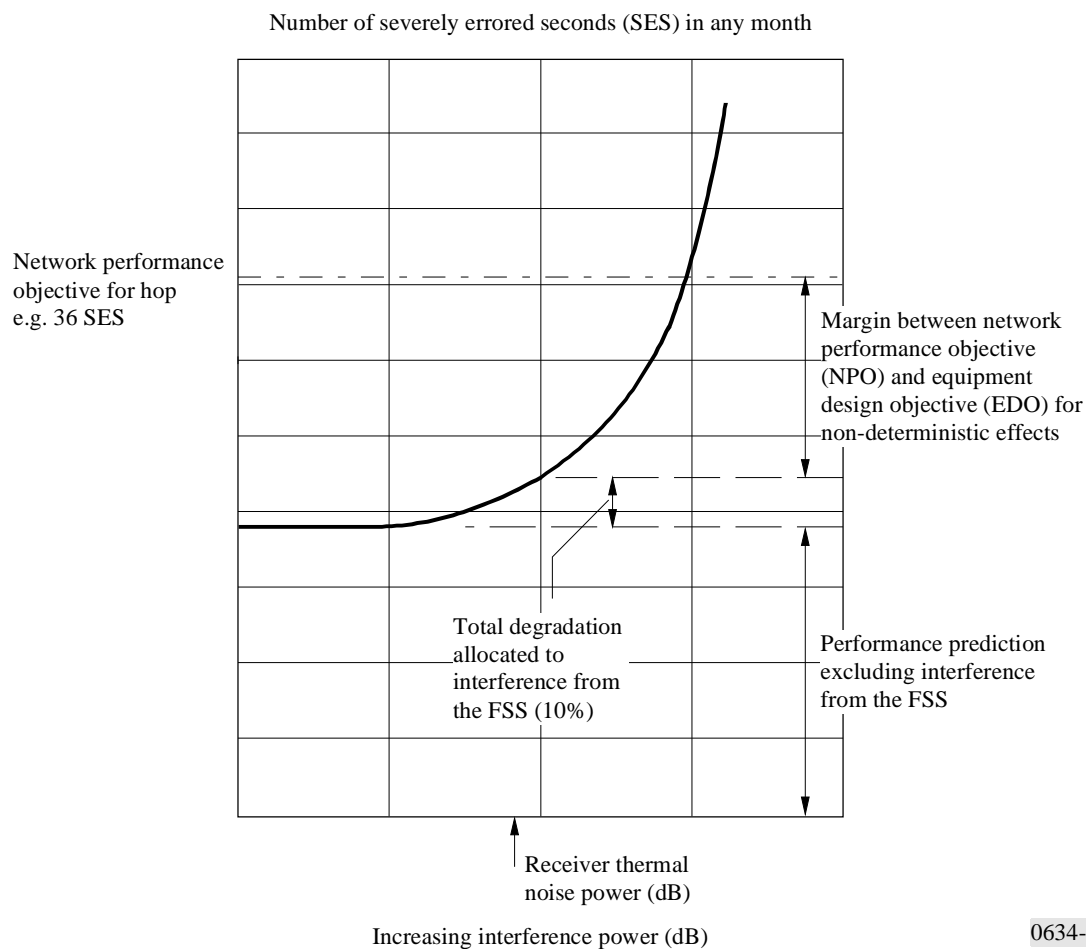
It is necessary to check that all the objectives of this Recommendation are satisfied during route design including SESR, and ESR.

Procedures for predicting performance are described in Recommendation ITU-R F.1093 and the models generally evaluate the percentage of time that a BER of 1×10^{-3} will be exceeded during a worst-month for multipath fading. Performance measurement has shown that the majority of this time is composed of event durations which are less than 10 s. For this reason, as the worst-case, the predicted multipath outage could be considered as SES rather than unavailable time (see Recommendation ITU-R F.557 for the definition of unavailable time).

1.2 Network performance objectives (NPOs) and equipment design objectives (EDOs)

ITU-T Recommendation G.801 describes the application of digital transmission models for the specification and sub-division of transmission parameters. It shows a way in which a national reference model can be used to arrive at NPOs and EDOs for real transmission paths using objectives for hypothetical reference digital connections (HRDXs), hypothetical reference digital links (HRDLs) and HRDSs. This procedure is applicable to all transmission media and thus to radio-relay systems.

FIGURE 1
Performance degradations due to the FSS



With the aid of HRDS, each administration can establish its own reference model tailored to the prevailing national network conditions. It has to be ensured, however, that this model meets the objectives of ITU-T Recommendation G.821. To obtain a representative network model, the individual network parts should be composed of digital sections such that as many as possible of the real links are taken into consideration. A block allowance can then be determined for each model network part, from the chosen arrangement of digital sections and their associated allocation percentages. This block allowance represents a NPO for the network parts concerned and has to be met by real transmission paths. In terms of design, any radio-relay systems employed in these parts must be capable of fulfilling the applicable NPO. In this method, the radio-relay systems to be used (e.g. frequency band, bit rate, etc.) and the maximum possible number of hops are defined for each part of the network. Equipment design objectives could then be specified by taking into account environmental effects, equipment ageing, etc. If, in practice, real links are installed which do not exhaust the values given for a particular part of the network model – e.g. have less hops – it is proposed that the link should still be allocated the full block allowance. The idea is to reduce the constraints at the time of the initial concept of the system. For example, the use of space diversity, use of adaptive time domain equalizers could be reduced, smaller sized antennas and lower power transmitters could be used and appropriate performance allowances for oversized hop lengths could be provided.

1.3 Intermittent failure mechanisms

A system can experience an intermittent malfunction before total failure occurs. It is important, in maintaining good service, to detect such a condition as early as possible and take corrective action.

2 Error performance objectives for periods shorter than one month

The criteria given in ITU-T Recommendation G.821 (and hence Recommendation ITU-R F.594 and this Recommendation) are normally too long for use as maintenance limits or for circuit provisioning tests. Measurements over much shorter periods (e.g. one day) may be necessary in order to determine whether a circuit is fit for service or should receive maintenance attention.

Radio systems differ from line systems in that the significant performance degradations (i.e. those due to fading) tend to be concentrated into a few days whereas for line systems they tend to be randomly distributed throughout the month. For this reason the mathematical models being examined by the ITU-T to describe the distribution of performance degradations within a month may not be suitable for radio systems. This subject requires active study.

Field measurements have shown that radio systems cannot respect daily performance objectives which are linearly sub-divided with distance and time from the 2 500 km HRDP. The measurements show that a 24-h performance objective of 20% of the one month objective can be met for SES and ES criteria. Further measurements are required to confirm the validity of these limits. However, the ITU-T Recommendation G.821 parameters are not ideally suited for monitoring radio system performance over short periods, particularly where fading causes bursty error distributions. Any performance assessment derived from a single 24-h measurement period will contain a significant degree of uncertainty. It is therefore proposed that any limits used for periods shorter than one month should only be used in conjunction with other supporting performance related data; for example:

- other system parameters (e.g. automatic gain control (AGC) levels and trends);
- local meteorological data;
- performance of other radio links in the area;
- historical performance of radio system.

3 Interference from the FSS

Many of the frequency bands used by radio-relay systems are now shared with the FSS. Interference from the FSS generally may take two forms:

- from earth stations in the bands used for up links;
- from satellites in the bands used for down links

to digital radio systems. The limits for the degradations to a 2 500 km HRDP quoted in Recommendation ITU-R SF.615 are given in Table 1.

TABLE 1
Recommended limits for performance and availability degradations due to
interference from sharing with the FSS

Criterion	Objective for 2 500 km HRDP (Recommendations ITU-R F.594 and ITU-R F.557)	Allowance for band sharing
1) SESR	0.00054 in any month	0.000054 in any month
2) ESR	0.0032 in any month	0.00032 in any month
3) Unavailability	0.3% of a period probably greater than one year	0.03% of a period probably greater than one year

Some allowance needs to be made for these degradations when setting real route design objectives for systems operating in the shared bands. It is therefore necessary to consider how to apportion the degradations in Table 1 to shorter links.

Sharing models have previously assumed that only one or two stations within a 2 500 km HRDP will be significantly affected by this kind of interference. This would imply that the majority of the degradations listed in Table 1 could be allocated to one or two hops and that sharing criteria (e.g. power flux-density limits, equivalent isotropic radiated power limits) can be derived on this basis.

However, this may in future be an unrealistic assumption since the number of earth stations is generally increasing (especially for systems operating above 10 GHz) and these now are often sited close to major cities. In consequence, the number of radio-relay receivers affected will also generally increase. This could lead to subsequent performance degradations which were not taken into account in the initial route design.

The most prudent basis for apportioning these FSS degradations within the HRDP would be on a hop-by-hop basis. Thus the 10% degradation would be included in the performance budget at the route design stage as illustrated in Fig. 1 for the case of SES.

ANNEX 2

Translation rules suggested for the normalization of error performance measurement results obtained at the system bit rate at or above the primary rate to the 64 kbit/s level

(applicable only to digital radio-relay links designed prior to the approval of Recommendations ITU-R F.1092 (1994) and ITU-R F.1189 (1995))

This Annex can be used for digital radio-relay links within the high-grade portion of an ISDN that were designed prior to the approval of Recommendations ITU-R F.1092 (1994) and ITU-R F.1189 (1995). In this case the relationship between objectives at 64 kbit/s and corresponding parameters at the system bit rate should be taken into account.

1 SESR objectives

Various theoretical and experimental studies have indicated that the direct translation of SESR is accurate within a few per cent, or:

$$SESR_{64} = SESR_{system\ bit\ rate}$$

The SESR normalized to 64 kbit/s can be assessed from measurements made at the system bit rate as follows:

$$SESR_{64} = Y + Z$$

where:

Y: SESR at the system bit rate

Z: non-SESR at the system bit rate containing one or more loss of frame alignment at the system bit rate.

The factor Z represents an allowance for error bursts which are extended or cause loss of frame alignment during the demultiplexing process between the system bit rate and 64 kbit/s.

It should be noted that Z could be dependent on transmission equipment design and will not necessarily include all non-SES at the measurement bit rate which ultimately cause SES at the 64 kbit/s level. Certain error bursts which can pass transparently through demultiplexers at the hierarchical level of the source of the error burst without causing a loss of frame alignment at that level, can cause losses of frame alignment in demultiplexers at lower hierarchical levels. These events cannot, therefore, be accurately assessed as SES in the measurement at the source of the event.

In the case of digital radio-relay systems the factor Z is thought to lie between 0.01 and 0.05 of the measured performance Y.

2 Relationship between ESR objective at 64 kbit/s and corresponding parameters at the system bit rate

The following relationship is used.

The ESR at 64 kbit/s is given by:

$$\frac{1}{J} \sum_{i=1}^J (n/N)_i$$

where:

n : number of errors in the i^{th} s at the system bit rate

N : system bit rate divided by 64 kbit/s

J : integer number of 1 s periods (excluding unavailable time) within the total measurement period.

The ratio $(n/N)_i$ for the i^{th} s is:

$$n/N \quad \text{if} \quad 0 < n < N$$

or

$$1 \quad \text{if} \quad n > N.$$

This relationship is conservative, since it assumes that the errors occurring at system bit rate are uniformly distributed among the 64 kbit/s channels.

In practice, due to the non-uniform distribution of errors the actual result at 64 kbit/s is better than the value calculated with the expression given above.

Field measurements indicate agreement with a less severe translation which assumes a Poisson distribution of the errors occurring at line bit rate in the 64 kbit/s channels.

A practical way of using the above formulae is to compute the probability of an ES at 64 kbit/s, $(n/N)_i$, for each second i and summing these probabilities over all the seconds J in the measurement period (e.g. one month). The result will be an estimate of the total number of ES at 64 kbit/s. Division by J gives the ESR in the measurement period. The accuracy of this process depends on the translation that takes place, every second, using the above formula. Measurements have demonstrated that this process gives answers that are within about $\pm 25\%$ of the true number of ES obtained by actually demultiplexing the signal to 64 kbit/s. It is necessary that the monitoring circuit perform the above described operations in real-time, namely the counting of bit errors in 1 s intervals at the system bit rate, truncating the numbers at $n = N$, and then accumulating and scaling them. There is strong experimental evidence that compatible ESR objectives at higher rates are difficult to establish because they are heavily dependent on the particular kind of radio equipment and path. It is therefore recommended that the ESR objective only be applied at 64 kbit/s.

Use may be made of a selective demultiplexing method which extracts from the high bit rate signal a secondary error signal by sampling at 64 kbit/s which permits an estimation of system performance at the 64 kbit/s rate to be made.
