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**G.951**

**DIGITAL SECTIONS AND DIGITAL LINE SYSTEMS**

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**DIGITAL LINE SYSTEMS BASED  
ON THE 1544 KBIT/S HIERARCHY  
ON SYMMETRIC PAIR CABLES**

**ITU-T Recommendation G.951**

(Extract from the *Blue Book*)

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## NOTES

1 ITU-T Recommendation G.951 was published in Fascicle III.5 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 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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## Recommendation G.951

### DIGITAL LINE SYSTEMS BASED ON THE 1544 KBIT/S HIERARCHY ON SYMMETRIC PAIR CABLES

(Malaga-Torremolinos, 1984; amended at Melbourne, 1988)

#### 1 General

This Recommendation covers digital line systems for the transmission of signals based on the 1544 kbit/s hierarchy on symmetric pair cables and includes systems operating at the following bit rates:

1544 kbit/s,  
3152 kbit/s,  
6312 kbit/s.

#### 2 Transmission medium

The system can be operated on symmetrical pair cables of various wire diameters and cable constructions including those given in Recommendations G.611, G.612, and G.613.

#### 3 Protection against interference from external sources

The digital line system can be disturbed by interference from telephone circuits carried within the same cable and by a switch when repeaters are installed in switching centres. Examples of possible ways of reducing the effect of this type of interference is the reduction of repeater section length near switching centres, segregation of pairs, the use of particular line codes, etc.

#### 4 Overall design features

##### 4.1 Availability

The availability objective of the system should be derived taking into account the availability requirement for the hypothetical reference digital section as given in draft Recommendation G.801.

##### 4.2 Reliability

MTBF values should be specified for the line system as a whole taking into account the requirements concerning availability.

##### 4.3 Repeater crosstalk-noise figures

Repeater crosstalk-noise figures are defined in Annex A, together with suggested measurement techniques. Crosstalk-noise figures quantify the performance of digital regenerators which are subject to crosstalk interference. They are functions of BER, line system line code, cable characteristics, environmental conditions, and repeater spacing loss  $A_0$  (at half the line system baud rate).

At a BER =  $10^{-x}$  and over a loss range  $A_1 \leq A_0 \leq A_2$ , crosstalk-noise figures should meet the following specifications:

a) NEXT-Noise Figure  $[R_N] \leq CA_0 + D^*$

b) FEXT-Noise Figure  $[R_F] \leq E^*$

\* It has not been possible to recommend specific values for parameters  $x$ ,  $A_1$ ,  $A_2$ ,  $C$ ,  $D$  and  $E$ .

#### 4.4 *Error Performance*

The design objective for the error ratio of the individual repeater should take into account the network performance objectives given in Recommendation G.821.

## 5 **Specific design features**

### 5.1 *Type of power feeding*

Although CCITT does not recommend the use of a specific remote power-feeding system for this symmetrical line system, in practice only the constant current d.c. feeding via the phantom circuits of the two symmetrical pairs of a system is used.

This symmetrical cable system may be subject to induced voltages and currents caused by lightning, power lines, railways, etc.

Precautions must be taken to protect the staff from any possible danger arising from the normal operating voltages and remote power-feed currents as well as from the induced voltages and currents.

Many national Administrations have issued detailed rules and regulations for the protection of persons. It is obligatory in most cases to meet these rules and regulations. In addition the CCITT Directives [1] give guidance on these problems.

Precautions are also needed for the protection of the equipment against induced voltages and currents. The equipment should therefore be designed in such a way that it passes the tests specified in Recommendation K.17 [2].

### 5.2 *Repeater spacing and cable fill*

The specific repeater spacing cannot be recommended, but general considerations concerning system planning are contained in Annex B to this Recommendation.

### 5.3 *Maintenance strategy*

#### 5.3.1 *Type of supervision and fault location*

In service monitoring or out-of-service fault location can be used.

#### 5.3.2 *Fault conditions and consequent actions*

The fault conditions and consequent actions in this section should be complementary to those recommended for digital line sections.

## ANNEX A

(to Recommendation G.951)

### Definition and measurement of repeaters crosstalk noise figures

#### A.1 Definition

##### a) NEXT-Noise Figure [ $R_N$ ]

$$[R_N] = [I_N] - [N_0]$$

$$I_N = \int_0^{\infty} \left| f/f_0 \right|^{3/2} |E(f)|^2 P(f) df,$$

$I_N$  = mean square near-end crosstalk (NEXT) voltage produced by a single interfering regenerator that would appear at the decision point if the NEXT loss were 0 dB at half the line system baud rate.

$N_0$  = mean square NEXT interference voltage at decision point which produces specified BER, and depends on parameters which affect the decision process and reflects impairments arising from intersymbol interference and offsets from the optimum position of the decision threshold levels and sampling instants at the regenerator decision point.

$E(f)$  = regenerator equalizer frequency transfer function.

$P(f)$  = power spectral density (single sided) of line system line code.

$f_0$  = half line system baud rate.

Quantities in square brackets are in dB, i.e.

$$[X] = 10 \log_{10} |X|.$$

##### b) FEXT-Noise Figure [ $R_F$ ]

$$[R_F] = [I_F] - [N_0]$$

$$I_F = \int_0^{\infty} \left| f/f_0 \right|^2 |E(f)|^2 |G(f)|^2 P(f) df,$$

$I_F$  = mean square far-end crosstalk (FEXT) voltage produced by a single interfering regenerator that would appear at the decision point if the FEXT loss were 0 dB at half the line system baud rate.

$N_0$  = mean square FEXT interference voltage at decision point which produces specified BER, and depends on parameters which affect the decision process and reflects impairments arising from intersymbol interference and offsets from the optimum position of the decision threshold levels and sampling instants at the regenerator decision points.

$E(f)$ ,  $P(f)$ ,  $f_0$  as in a), and

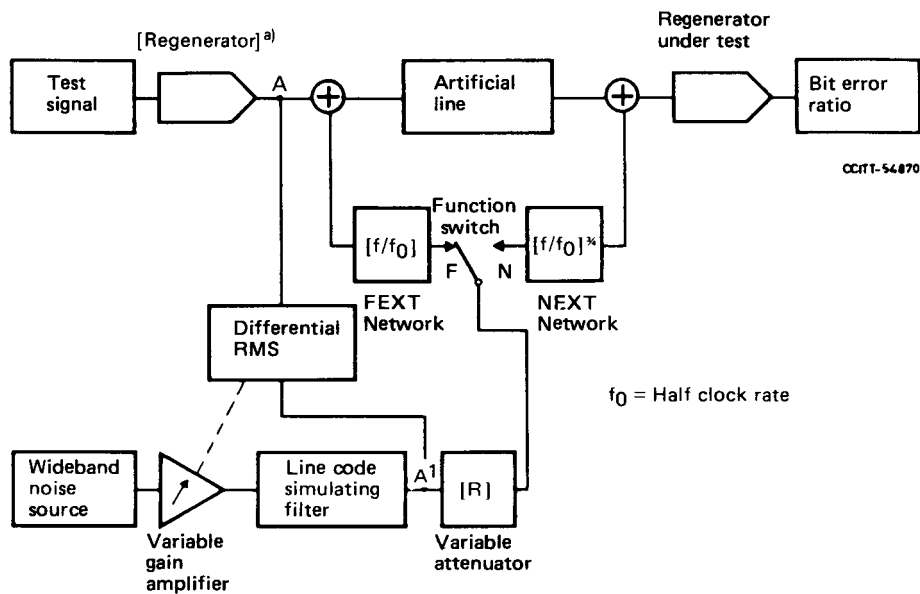
$G(f)$  = frequency transfer function of cable.

A.2 Measurement

Method a) directly relates to the definition of crosstalk-noise figure and is therefore the reference measuring method. Methods b) and c) are the possible practical alternatives. Method c) avoids the use of a selective filter.

Method a)

The NEXT-Noise Figure and FEXT-Noise Figure can be measured using the configuration shown in Figure A 1/G.951 with the Function Switch in the N and F position, respectively. The measurement consists of equating the r.m.s. voltages at A and A<sup>1</sup>, setting the artificial line to the desired loss A<sub>0</sub>, and then adjusting the variable attenuator until the desired BER = 10<sup>-x</sup> is achieved. The value of the attenuator, [R] dB, is then the NEXT-Noise Figure or FEXT-Noise Figure for the desired A<sub>0</sub> and BER.



a) The regenerator can be omitted if the test signal generator provides the appropriate pulshape.

FIGURE A-1/G.951  
NEXT and FEXT-Noise Figure measurement

Method b)

The NEXT-Noise Figure [R<sub>N</sub>] can be measured using "input S/N ratio" test sets by employing the test set in a "manual mode" and performing external measurements with a selective filter (see Figure A-2/G.951). The measurement consists of:

- i) Set artificial line to 0 dB loss and using selective measure test signal power [S<sub>0</sub>] dBm.
- ii) Set artificial line to desired loss A<sub>0</sub>, adjust variable attenuator until desired BER = 10<sup>-x</sup> is obtained, switch off test signal, and using selective filter, measure noise power [P] dBm.
- iii) Then [R<sub>N</sub>] = [S<sub>0</sub>] - [P] for desired A<sub>0</sub> and BER.

Note - The degrading effect of clock jitter on NEXT-Noise Figure and FEXT-Noise Figure should be measured by superimposing appropriate jitter on the test signal.

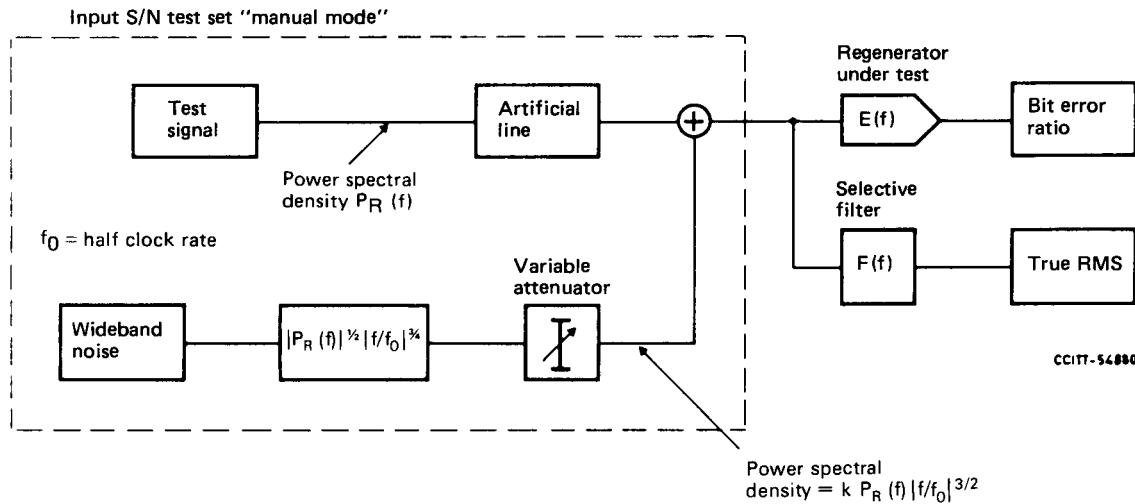


FIGURE A-2/G.951

NEXT-noise figure measurement using input S/N test set

Method c)

The NEXT-Noise Figure  $[R_N]$  can be measured using "input S/N ratio" test sets in "manual mode" with the insertion of an additional variable attenuator between the test signal and the artificial line, as shown in Figure A-3/G.951.

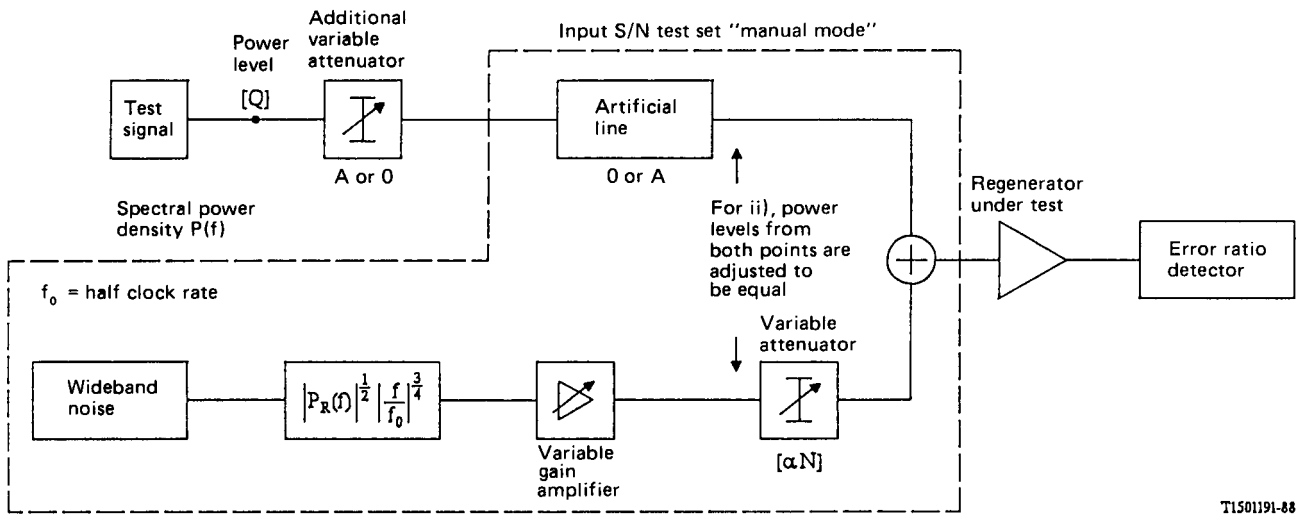
The measurement procedure is as follows:

- i) set the artificial line to 0 dB loss and the additional variable attenuator to A dB loss;
- ii) regulate the variable gain amplifier until the power level of the variable attenuator input is equal to  $[Q1] - A$  dB, the power level of the artificial line output;
- iii) set the artificial line to A dB loss and the additional variable attenuator to 0 dB loss;
- iv) adjust the variable attenuator until the desired BER =  $10^{-x}$  is reached. The attenuation value of the attenuator is  $[\alpha N]$  dB;
- v) calculate  $[R_N] = [\alpha N] + A - [W_N]$

$$\text{where } [W_N] = 10 \log_{10} \left[ \int_0^{\infty} P_R(f) df / \int_0^{\infty} \left| \frac{f}{f_0} \right|^{3/2} P_R(f) df \right]$$

in which  $P_R(f)$  = spectral power density (single sided) of line code.

It would be better to obtain  $W_N$  by measurement. Of course, the value of  $W_N$  can also be calculated according to  $P_R(f)$  of AMI or HDB<sub>3</sub> in a certain frequency range, for example,  $W_N = -3.59$  dB in the range from 0 to 10 240 kHz.



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FIGURE A-3/G.951

**NEXT-noise figure measurement using input S/N test set**

ANNEX B

(to Recommendation G.951)

**Guidance notes for the satisfactory achievement of the error performance objectives**

B.1 To comply with the Network Performance Objectives (NPO) it is necessary to take into account many interrelated factors. Figure B-1/G.951 illustrates diagrammatically the interrelationship between all the factors that impact on this matter. The basis upon which digital line system installation planning guidelines are formulated is dependent on the circumstances of each Administration. For example, some Administrations may have cables with favourable characteristics, whilst at the same time the network may experience serious levels of unquantifiable interference (network effects). An Administration must, therefore, make a judgement as to the significance of each effect in their network and formulate cable utilization guidelines which satisfy the digital line section error performance requirements.



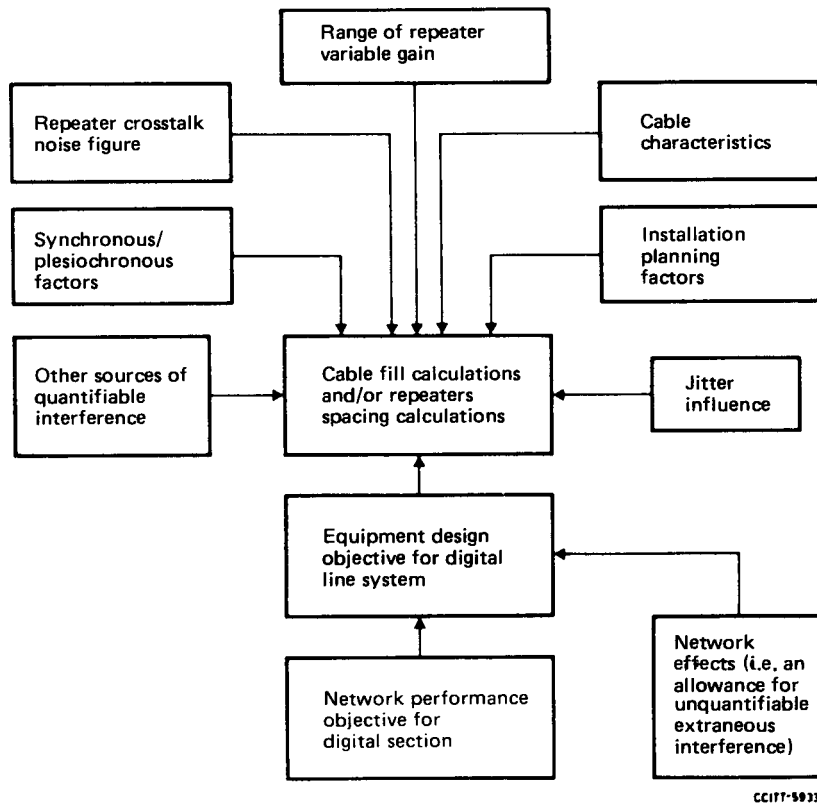


FIGURE B-1/G.951

Factors impacting on the error performance of a digital line system on symmetrical pairs

The following notes highlight a number of important considerations concerning the formulation of system installation planning guidelines.

*Note 1* - In the process of establishing cable utilization guidelines the crosstalk noise figure is the only parameter describing the intrinsic quality of the regenerator under crosstalk interference conditions. This parameter, which is based on the *average* power spectral density of the total crosstalk interference, provides a useful approximation to the system's immunity to crosstalk from plesiochronous data streams, and is the correct measure for synchronous data streams provided the phases of the disturbing systems are randomized. It is also based on an assumption of random data on the disturbing systems and therefore cannot be applied to the case of repetitive data patterns. However the use of scramblers effectively makes almost all data patterns appear to be random [3].

*Note 2* - In an operational environment, regenerators may be subject to other sources of interference which are difficult to quantify and which may induce errors. In some instances specific interference mechanisms have been quantified and appropriate limits and testing procedures are reflected in national specifications. These aspects are currently under study within CCITT and as operational experience is gained it might be possible to introduce further tests that accommodate these other interference mechanisms.

*Note 3* - Maximum cable utilization should be based on complying with the network performance objective. To satisfy this objective Administrations may adopt one of the following approaches:

- i) In circumstances where Administrations are able to judge the significance of the "network effects" cable fill calculations should be based on an objective determined by discounting "network effects" from the network performance objective.
- ii) In circumstances where Administrations are not able to judge the significance of the network effects, cable fill calculations should be based on the equipment design objective.

*Note 4* - The use of a reduced line symbol rate code provides a more favourable crosstalk environment, and this feature will impact on cable fill calculations.

*Note 5* - When changing from a plesiochronous to a synchronous network operation, some cable crosstalk couplings and relative phasings of the system clocks lead to increases in system margins whilst others lead to reduced system margins by up to a maximum of 3 dB for practical systems. It is believed that there are more cases with increased margin than reduced margin and that there is therefore no need to introduce any extra margin when changing from plesiochronous to synchronous operations [3].

Scramblers may be used to ensure that the interference from several identical repetitive sequences does not exceed the levels occurring with random data.

## References

- [1] CCITT Manual *Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines*, ITU, Geneva, 1988.
- [2] CCITT Recommendation *Tests on power-fed repeaters using solid state devices in order to check the arrangements for protection from external interference*, Vol. IX, Rec. K.17.
- [3] SMITH, B. M. and POTTER, P. G. [June 1986] - Design Criteria for Crosstalk Interference between Digital Signals in Multipair Cable, *IEEE Trans. Commun.*, Vol. COM-34, No. 6.