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DIGITAL SECTIONS AND DIGITAL LINE SYSTEMS

DIGITAL LINE SYSTEMS BASED
ON THE 1544 kbit/s HIERARCHY
ON COAXIAL PAIR CABLES

ITU-T Recommendation G.953

(Extract from the *Blue Book*)

NOTES

1   ITU-T Recommendation G.953 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.953

DIGITAL LINE SYSTEMS BASED ON THE
1544 kbit/s HIERARCHY ON COAXIAL PAIR CABLES

(Malaga-Torremolinos, 1983; 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 coaxial pair cables and includes systems conveying the following bit rates:

44 736 kbit/s
97 728 kbit/s

2   Transmission media

The systems can be operated on coaxial pairs, as defined in the Series G.620 Recommendations, in accordance with Table 1/G.953.

TABLE 1/G.953

Transmission media

System (kbit/s)	Cable Recommendation
44 736	G.623
97 728	G.623

3   Overall design features

3.1   *Availability*

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

3.2   *Reliability*

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

3.3   *Repeater noise margin*

Repeater Noise Margin is defined in Annex A together with suggested measurement techniques. The Noise Margin quantifies the performance of digital regenerators for coaxial pairs. This is a function of BER and repeater spacing loss A_0 (at half the line system baud rate).

At a BER = 10^{-7} and over the loss range of the system $A_1 \leq A_0 \leq A_2$, the Noise Margin should meet the following specification:

Noise Margin $(M) \geq B + C (A_2 - A_0)$

It has been possible to recommend specific values for parameters A_1, A_2, B and C.

Note - The degrading effect of timing jitter on Noise Margin should be measured by superimposing appropriate jitter on the test signal.

3.4 *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.

4 Specific design features

4.1 *Type of power feeding*

Although CCITT does not recommend the use of a specific remote power-feeding system for these coaxial line systems, in practice only the constant current d.c. feeding via the inner conductors of the two coaxial pairs of system is used.

These coaxial cable systems 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].

4.2 *Nominal repeater spacing*

A specific repeater spacing is not recommended but in practice the nominal values indicated in Table 2/G.953 are used by most Administrations:

TABLE 2/G.953
Nominal repeater spacings

	Nominal repeater spacing (km)
System (kbit/s)	Cable Recommendation[a] G.623
44 736	—
97 728	4.5

[a] Recommendation G.623 refers to 2.6/9.5 mm coaxial pairs.

4.3 *Maintenance strategy*

4.3.1 *Type of supervision and fault location*

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

4.3.2 *Fault conditions and consequent actions*

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

ANNEX A

(to Recommendation G.953)

Definition and measurement of repeater noise margin

A.1 *Definition*

The noise margin m_n:

$$m_n = SNR / SNR_{ER} \tag{A-1}$$

where:

$$SNR = SNR_{th} \cdot F(t, ER) \tag{A-2}$$

The product $SNR_{th} \cdot F(t, ER)$ can be considered the actual signal-to-noise ratio SNR, being the measure for the regenerator performance.

SNR_{th} is the theoretical signal-to-noise ratio determined by the system parameters such as output pulse, section loss, noise figure of the regenerator input amplifier, etc.

$F(t, ER)$ is the reduction factor due to an off-set from the optimum timing instant (including phase jitter) in conjunction with the pulse realized $S(t)$, the intersymbol interference $I(t)$ and any other disturbance which causes a corruption in the information signal (I_c).

Note - The intersymbol interference and other disturbances are fluctuating processes with bounded distributions. The "mean" reduction factor depends on *ER*, and, for a ternary signal, is given by:

$$F(t, ER) = \frac{S(t)}{S(0)} - 2\left\{ \frac{I(t)}{S(0)} - \frac{I_c}{S(0)} \right\} \tag{A-3}$$

where $S(0)$ is the realized pulse at $t = 0$ giving the maximum amplitude.

SNR_{ER} is the signal-to-noise ratio required for an error ratio equal to *ER*. For a ternary signal the relation between *ER* and SNR_{ER} is given by the known Gaussian distribution:

$$ER = \frac{4}{3} P[E] = \frac{4}{3\sqrt{2\pi}} \int_{SNR_{ER}}^{\infty} e^{-x^{1/2}} dx \tag{A-4}$$

A.2 *Derived definitions*

The noise marging can be measured by applying an external disturbing signal. For that purpose more practical definitions are derived.

A.2.1 SNR_{ER} (giving an error ratio ER) can be achieved by injecting sufficient white noise into the input of the regenerator:

$$SNR_{ER} = \left\{ \frac{N_T}{N_T + N_E} \right\} \cdot SNR \qquad (A\text{-}5)$$

where

   N_T = thermal noise that appears at the decision point during normal operation.

   N_E = mean power of the external noise that appears at the decision point to induce an error rate *ER*.

   Combining (A-1) and (A-5) results in the noise margin *M*:

$$M = 20 \log m_n = 10 \log \left(1 + \frac{N_E}{N_T} \right) \qquad (A\text{-}6)$$

$$N_E = N_0 \int_0^\infty |E(f)|^2 \, df \qquad (A\text{-}7)$$

$$N_T = kT \int_0^\infty |E(f)|^2 \, F(f) \, df \qquad (A\text{-}8)$$

   N_0 = power density of the external noise that is superimposed on the signal

   $E(f)$ = transfer function of the regenerator's equalizer

   k, T = Boltzmann constant and absolute temperature

   $F(f)$ = noise figure of the equalizer amplifier of the regenerator

A.2.2 By injecting a sine wave disturbing signal, a second definition for m_n can be derived.

   This disturbance causes a decreasing *F(t, ER)*, which can be defined by:

$$F_d(t, ER) = SNR_{ER} / SNR_{th}$$

Next [in accordance with (A-1) and (A-2)],

$$F(t, ER) = m_n \cdot SNR_{ER} / SNR_{th}$$

   Substraction gives:

$$F(t, ER) - F_d(t, ER) = 2 \frac{I_S}{S(0)} - (m_n - 1) SNR_{ER} / SNR_{th}$$

where $I_s / S(0)$ is the normalized disturbing signal at the decision point.

Substitution of $SNR_{th} = S(0)/2\sqrt{N_T R_0}$ and some rearrangements results in the noise margin:

$$M = 20 \log 1 \cdot \left(\frac{I_s}{SNR_{ER} \cdot \sqrt{N_T R_0}} \right) \qquad (A\text{-}9)$$

$$I_s = S_d \cdot |E(f_d)| \cdot a_c \qquad (A\text{-}10)$$

S_d = the magnitude of the disturbing signal at the input of the regenerator

f_d = the frequency of the disturbing signal

a_c = a correction factor taking into account the effect of the disturbance on the peak detector of the automatic equalizer

R_0 = the real part of the characteristic impedance of the cable.

A.3   *Measurements*

Method A is based on the definition directly related to the noise marging (A-6) and therefore, is the reference test method. Methods B and C are alternative test methods.

Method A (Figure A-1/G.953)

The values of N_E *and* N_T are measured directly at the decision point. The value of N_T is measured in the absence of both a signal and externally applied noise. Under these conditions the automatic gain control (AGC) of the equalizer must be externally controlled to a level appropriate to the corresponding cable attenuation. With the signal restored, the level of the externally applied noise is adjusted to give the desired BER. The noise level ($N_T + N_E$) is now measured with the signal removed and with the AGC set at the same value as in the measurement of N_T.
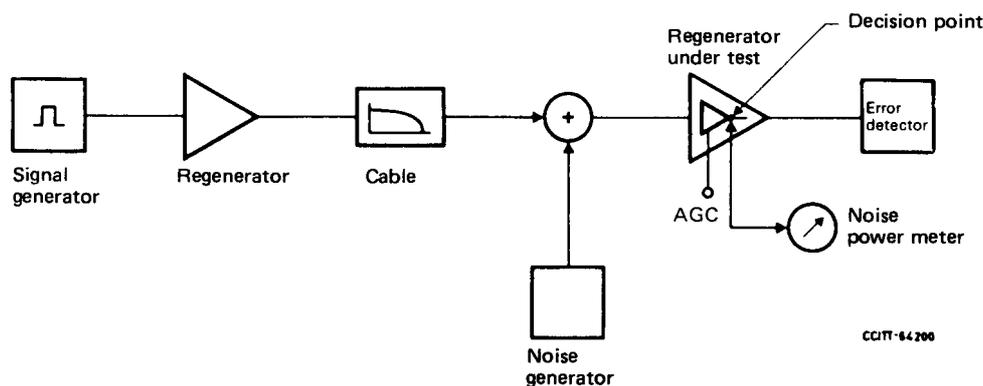

FIGURE A-1/G.953

Measurement of noise margin (Method A)

Method B (Figure A-2/G.953)

This method realizes a measurement without the need to access the decision point. The applied noise at the input, to cause a given BER, is measured directly. The corresponding value at the decision point and also the thermal noise (N_T) are evaluated by means of the transfer function and the noise figure of the amplifier equalizer.

Note - Both the transfer and the noise figure of the amplifier equalizer need to be calculated and measured on a sample of repeaters before this method can be applied to a particular repeater design.

Method C (Figure A-2/G.953)

This method is similar to the previous method (B) except that in this case the applied disturbance is a sine wave signal. This applied signal at the input, to cause a given error ratio, is likewise measured directly.

The corresponding disturbance at the decision point (I_s) as well as the thermal noise voltage ($\sqrt{N_T R_0}$) are evaluated by means of the transfer function, the noise figure of the equalizer and the correction factor a_c, which have to be determined.

Note - It follows from (A-8) and (A-9):

$$M = 20 \log (1 + S_d \cdot X / SNR_{ER})$$

$$\text{where } X = |E(f_d)| \cdot a_c / \sqrt{N_T R_0}$$

being an unknown factor, which has to be determined on the basis of measurements on a sample of prototype regenerators before this method can be applied to a particular regenerator design.

For this purpose, the noise margin of the prototype regenerator needs to be measured in accordance with the reference test method (A).

Note 2 - This method allows the presence of an LBO-network at the regenerator input. In contrast to method B it is not necessary to insert a complementary filter in the injection path.

Note 3 - To obtain the most accurate measurement the disturbing frequency should be around the Nyquist frequency.
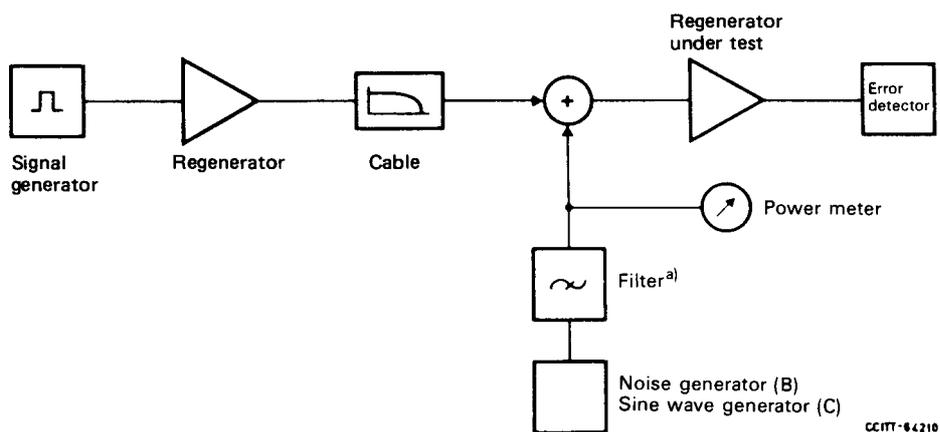
a) Can be deleted in Method C.

FIGURE A-2/G.953

Measurement of noise margin (Methods B and C)

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.