RECOMMENDATION ITU-R BT.654*

Subjective quality of television pictures in relation to the main impairments of the analogue composite television signal

(1986)

The ITU Radiocommunication Assembly,

considering

a)   that Recommendation ITU-R BT.500 specifies the method to be used for the subjective assessment of the quality of television pictures with a view to determining the relationship between that quality and the objective value of the specific distortion;

b)   that ITU-T Recommendation J.61 describes the objective parameters of typical transmission impairment and the corresponding measurement methods and test signals;

c)   that many experimental findings have been published concerning distortion to the composite signal in 525 and 625-line colour-television systems in NTSC, PAL and SECAM coding and that, despite considerable dispersion, those results can be used for determining an impairment characteristic which is representative of an average situation;**

d)   that it would be useful to have impairment characteristics which are accepted as reference values,

recommends

–   that, with regard to the transmission characteristics applicable to the composite colour television signal, the impairment characteristics referred to in this Recommendation should be regarded as a particular way of expressing the relationship between the picture quality and the objective value of each of the distortions in question, assuming that only one of them is present at any one time;

–   that these impairment characteristics correspond to a viewing distance equal to six times the picture height;

–   that the use of these characteristics for $I \geq 2$ (represented by a dotted line in Figs. 1 to 6 of this Recommendation) requires great caution.

1   Continuous random noise

The signal-to-noise ratio is measured, unweighted, in accordance with ITU-T Recommendation J.61, Part C, § 3.2.1.

This method is applicable to all 525 and 625-line systems.

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* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2002 in accordance with Resolution ITU-R 44.

** For the application of this Recommendation to countries using systems D and K, further studies are needed.

The reference impairment characteristic concerns only the impairment due to uniform-spectrum noise (white noise). The correction factors applicable to the different situations are known.

The reference impairment characteristic is shown in Fig. 1. It conforms to the following relations:

–   impairment factor: $d = \dfrac{N_{r.m.s.}}{L}$ or $D = \left[\dfrac{L}{N_{r.m.s.}}\right]_{dB} = 20 \log \dfrac{1}{d}$ dB

–   mid opinion value ($I = 1$): $d_M = 0.0355$ or $D_M = 29$ dB
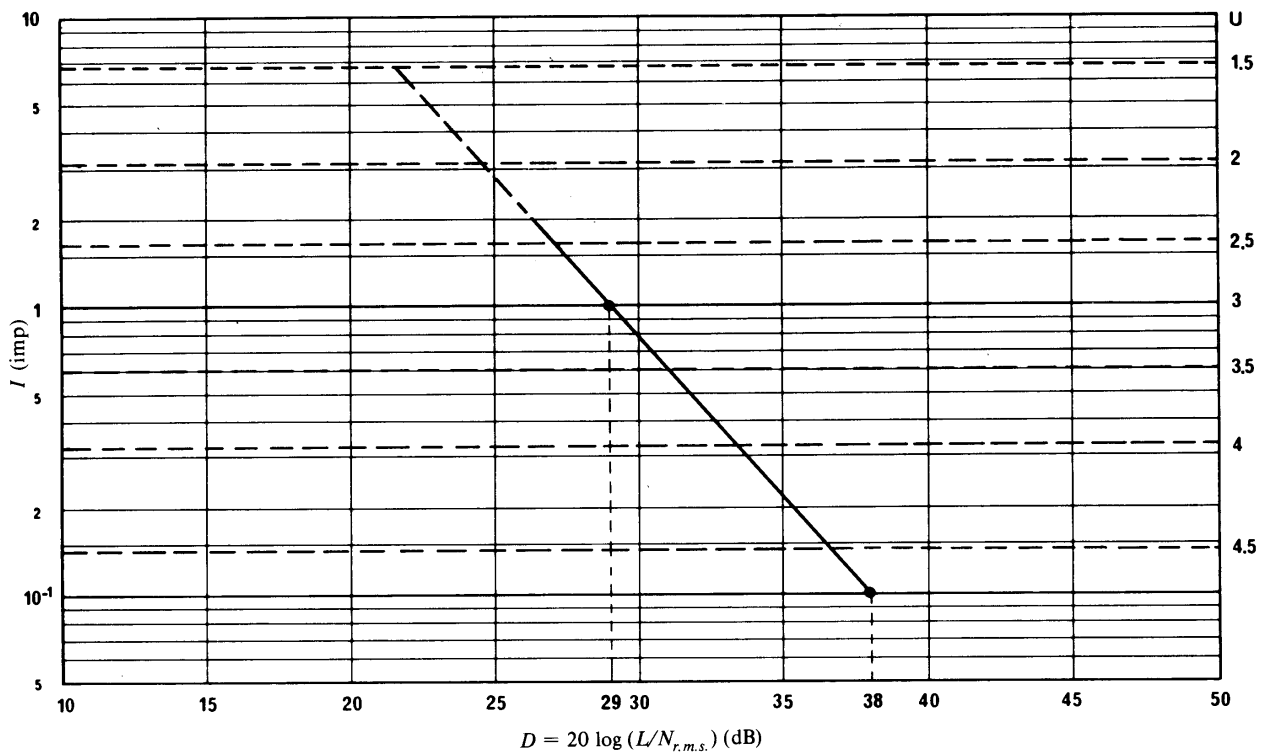
–   slope: $G = 2.22$

FIGURE 1 — *Impairment characteristic for unweighted white noise*

$D = 20 \log (L/N_{r.m.s.})$ (dB)

2   Non-linear distortion

2.1   Differential gain

The differential gain is measured in accordance with ITU-T Recommendation J.61, Part C, § 3.4.1.3.

Impairment of the picture depends on the distribution of distortion on the luminance scale. The most critical variation corresponds to an increase in the amplitude of the superimposed colour sub-carrier as the luminance amplitude varies from the black level (A_0) to the white level (A_{max}), which corresponds to distortion measured in terms of value x.

Impairment depends also on the colour coding system.

The reference impairment characteristic is illustrated in Fig. 2 and corresponds to a distortion situation offering the least favourable distribution. It conforms to the following relations:

–   impairment factor: $d = x = 100 \left| \dfrac{A_{max} - A_0}{A_0} \right|$

–   mid opinion value ($I = 1$):

      NTSC and PAL systems: $d_M = 43\%$

      SECAM system: $d_M = 65\%$

–   slope (deviation of d between $I = 1$ and $I = 0.37$):

      NTSC and PAL systems: $S = 15\%$

      SECAM system: $S = 13\%$

$$d = x = 100 \left| \frac{A_{max}}{A_0} - 1 \right|$$
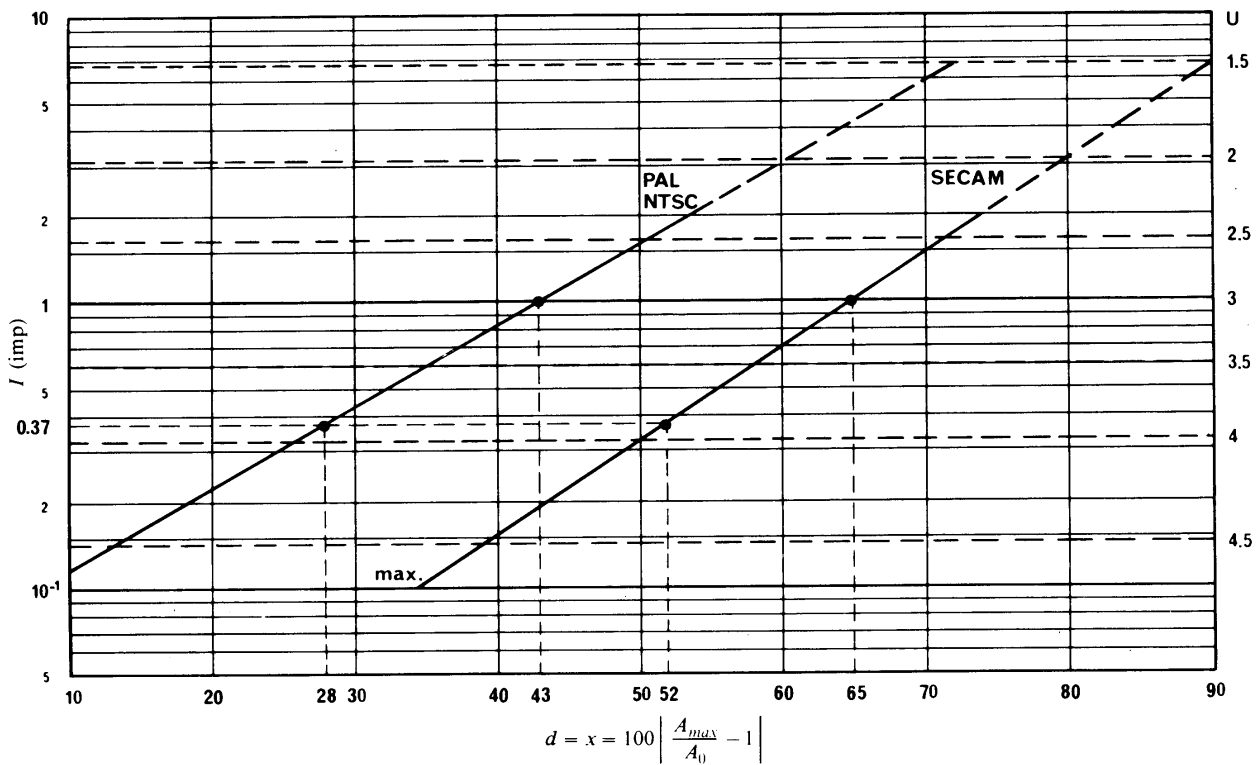
FIGURE 2 – *Impairment characteristic for differential gain*

D02-sc

2.2   Differential phase

The differential phase is measured in accordance with ITU-T Recommendation J.61, Part C, § 3.4.1.3.

The picture impairment depends on the distribution of distortion on the luminance scale. The most critical variation corresponds to a negative variation in the phase difference from the black level (Φ_0) to the white level (Φ_{min}), which corresponds to a distortion measured in terms of value $-y$.

The impairment depends also on the colour coding system.

The impairment characteristic is illustrated in Fig. 3 and corresponds to a distortion situation offering the least favourable distribution. It conforms to the following relations:

– impairment factor: $\quad d = y = |\Phi_{min} - \Phi_0|$

   or $\quad D = \log d$

– mid opinion value ($I = 1$):

   NTSC system: $\quad d_M = 10°$

   PAL system: $\quad d_M = 50°$

   SECAM system: $\quad d_M = 65°$

– slope:

   all systems: $\quad G = 2.5$

NOTE – In the case of the PAL system, the fact that the impairment characteristic is a straight line has not been verified.
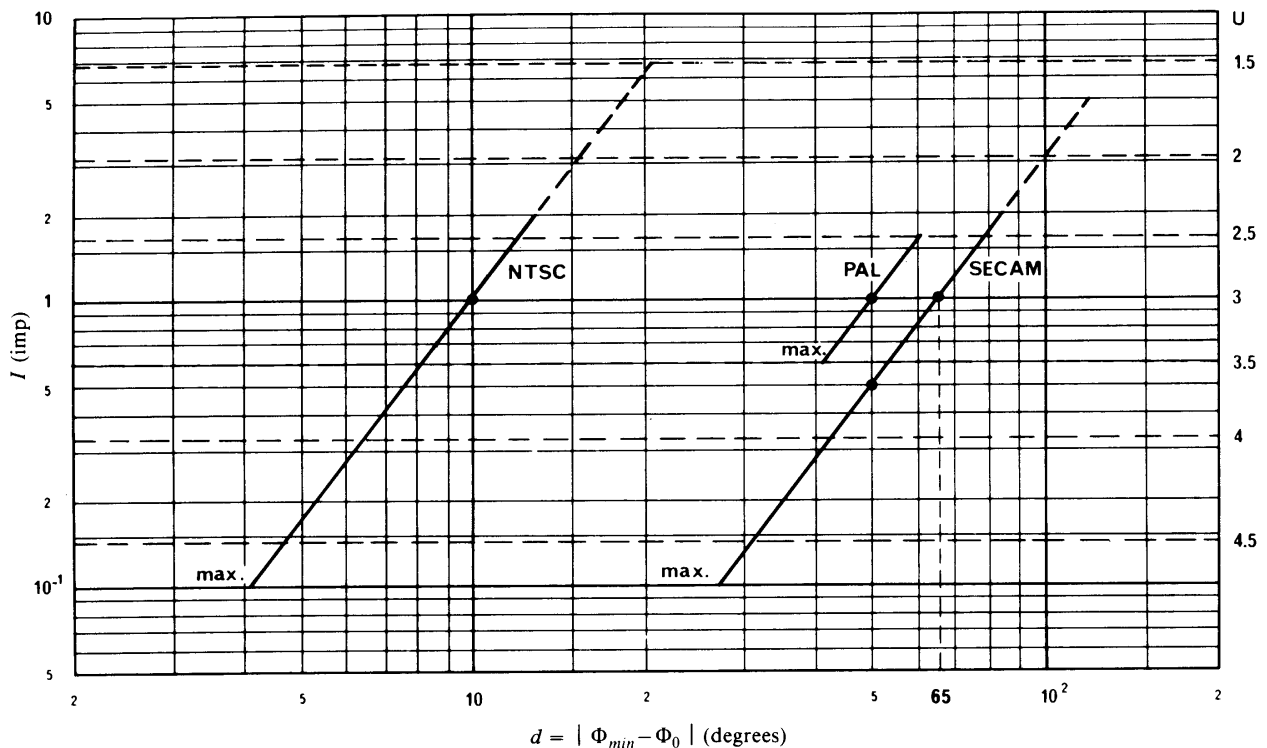

FIGURE 3 – *Impairment characteristic for differential phase*

D03-sc

3   Linear distortion

3.1   Short-time waveform distortion

Short-time linear distortion is measured in accordance with ITU-T Recommendation J.61, Part C, § 3.5.1.4, by expressing the difference, as a percentage, between the peak value of the pulse B1, i.e., B_1, and the value of the luminance amplitude, i.e., L. The impairment characteristic value is:

$$d = \left| \frac{L - B_1}{L} \right| \times 100 \qquad \%$$

Impairment does not depend on the sign of $L - B_1$.

Impairment does not depend on the colour coding system.

The pulse-to-bar $2T$ ratio, i.e., $\dfrac{B_1}{L} = 1 - \dfrac{d}{100}$ can be calculated from the value d.

The impairment characteristic is illustrated in Fig. 4. It corresponds to the following conditions:

- impairment factor: $d = \left| \dfrac{L - B_1}{L} \right| \times 100$ %

  Logarithmic scale in values of d;

- mid opinion value ($I = 1$): $d_M = 40\%$
- slope: $G = 2.32$

NOTE – Short-time linear distortion is often expressed by the K factor explained in Annex IV to Part C of ITU-T Recommendation J.61.

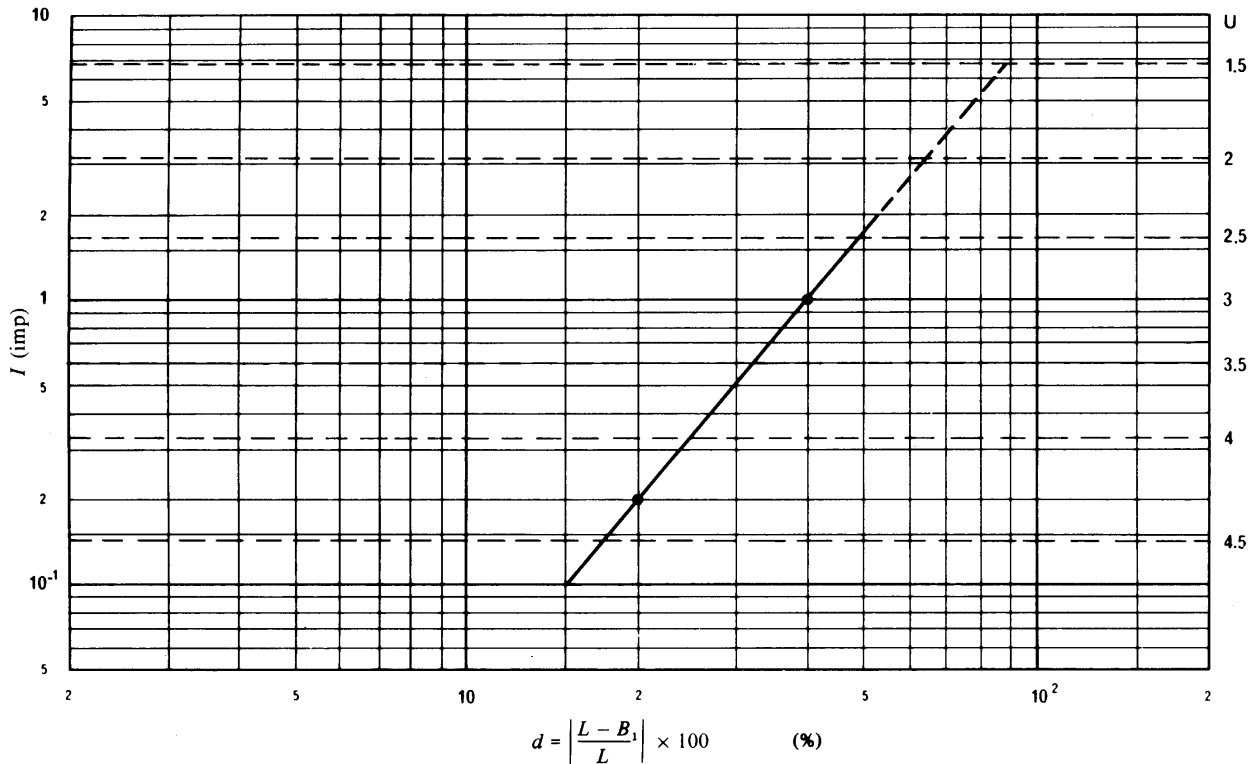This factor is such that $K = \dfrac{d}{4}$.

FIGURE 4 – *Impairment characteristic for short-time linear distortion*

3.2 Chrominance-luminance inequalities

3.2.1 Gain inequality

Chrominance-luminance gain inequality is measured in accordance with ITU-T Recommendation J.61, Part C, § 3.5.3.1, the absence of distortion being expressed by equality between the luminance (E_L) and chrominance (E_C) amplitudes.

Impairment depends on the coding system and the curve is valid only for the NTSC and PAL systems. There is only an indirect effect on the SECAM system.

The impairment characteristic is illustrated in Fig. 5. It conforms to the following relations:

–   impairment factor: $d = \dfrac{E_C - E_L}{E_L}$ (logarithmic scale)

–   mid opinion value ($I = 1$): $d_M = 63\%$
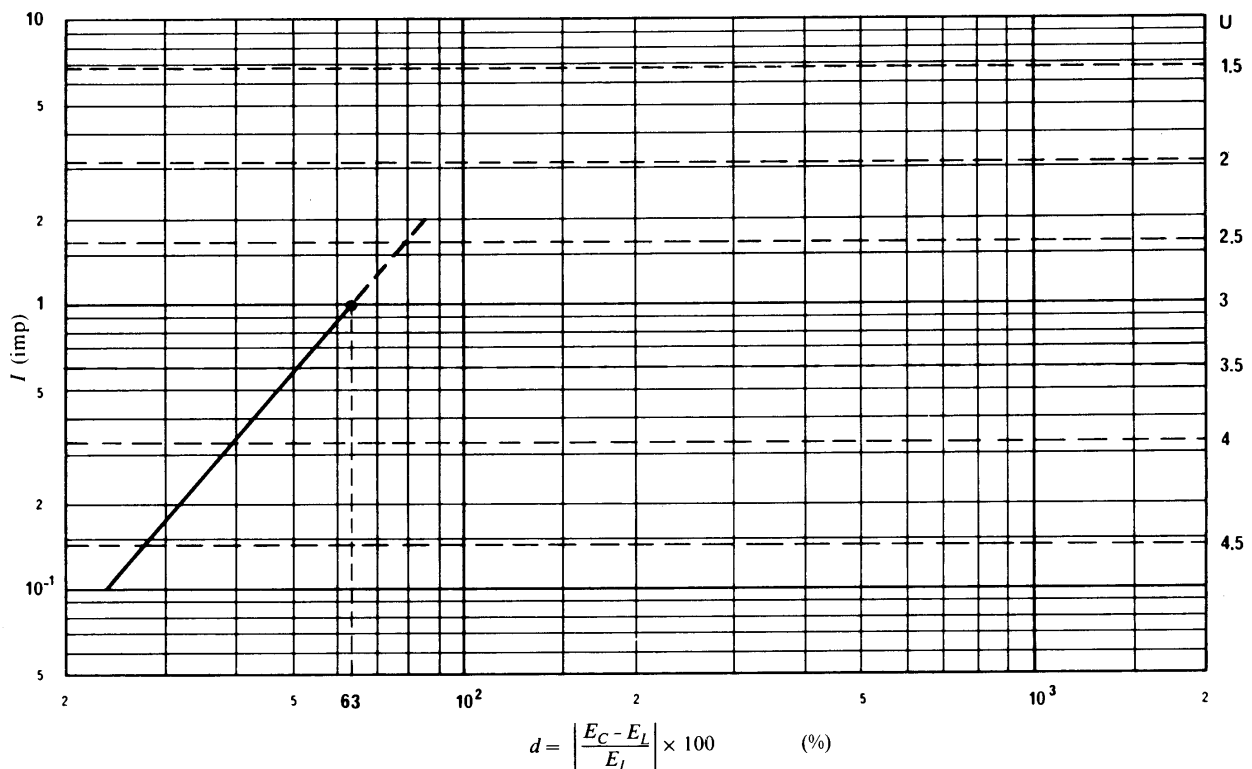
–   slope: $G = 2.33$

$$d = \left| \frac{E_C - E_L}{E_L} \right| \times 100 \qquad (\%)$$

FIGURE 5 – *Impairment characteristic for chrominance-luminance gain inequalities*

D05-sc

3.2.2   Delay inequality

Delay inequality is measured in accordance with ITU-T Recommendation J.61, Part C, § 3.5.3.2, using the signal F (modulated 20T pulse for 625-line systems and 12.5T pulse for 525-line systems).

The value thus measured corresponds closely to that of the group delay of a band-limiting network in which τ_g increases with the frequency. In this case, the value of d corresponds to the value $\Delta \tau_g$ measured at colour sub-carrier frequency.

This value is appreciably different from, and higher than, that obtained by direct measurement of the time separation between a characteristic instant of a steep luminance front and the equivalent characteristic instant of the associated chrominance transition front for the same impairment and therefore the same quality level.

The impairment characteristic meets the following conditions (Fig. 6):

a)   *for the 625-line systems*

–   impairment factor: $d = \Delta\tau_g$ at 4.43 MHz

     $\Delta\tau_g$ = delay difference

     Logarithmic scale in $\Delta\tau$ expressed in ns;

–   mid opinion value ($I = 1$): $d_M = 400$ ns

–   slope: $G = 2.32$

b)   *for the 525-line systems*

–   impairment factor: $d = \Delta\tau_g$ at 3.58 MHz

     $\Delta\tau_g$ = delay difference

     Logarithmic scale in $\Delta\tau$ expressed in ns;

–   mid opinion value ($I = 1$): $d_M = 200$ ns
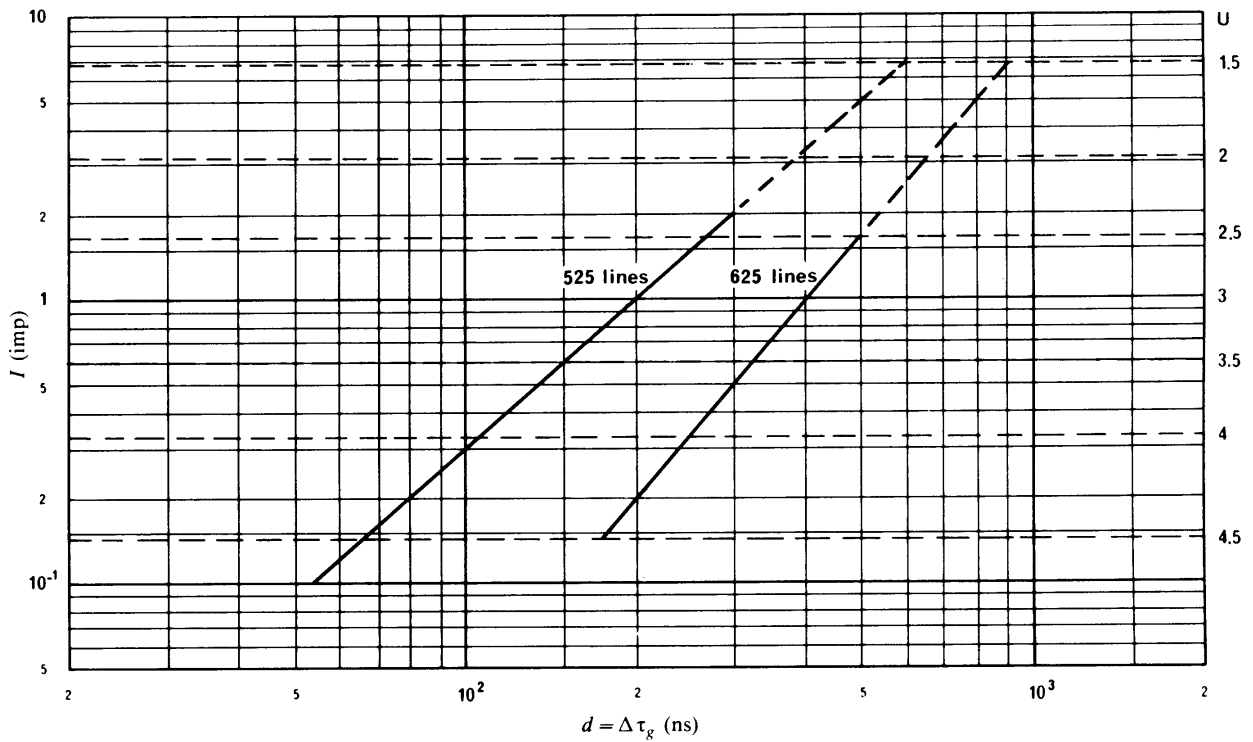
–   slope: $G = 1.76$

FIGURE 6 – *Impairment characteristic for chrominance-luminance delay inequality*

D06-sc

4   Echo

Consideration is given to the effect of superimposing a direct signal and a reflected signal producing a permanent "ghost" picture.

Impairment depends on:

–   the polarity of the echo, and it is noted that maximum impairment occurs with a positive echo;

–   the time separation between the direct signal and the echo signal;

–   the distortion of the echo signal.

The impairment characteristic illustrated in Fig. 7 corresponds to the case of an undistorted positive echo 1 μs behind the direct signal (E = echo amplitude, S = signal amplitude).

When the echo delay time is less than 1 μs, the following results apply to monochrome television or to the luminance signal in colour television. In the case of colour signals, additional effects occur which, in the PAL and NTSC systems, can be interpreted by using the gain inequality characteristic.

This characteristic meets the following conditions:

–   impairment factor: $d = \dfrac{E}{S}$ or $D = 20 \log \dfrac{S}{E}$ dB

–   mid opinion value ($I = 1$): $d_M = 0.126$ or $D_M = 18$ dB

–   slope: $G_M = 2.33$

For time separations other than 1 μs, the value D_1 should be corrected as shown in Fig. 8.

Thus the value D_x for $\Delta t = X$ is corrected to $D_1 = D_x - \Delta D$ to obtain the corresponding impairment value in Fig. 7.

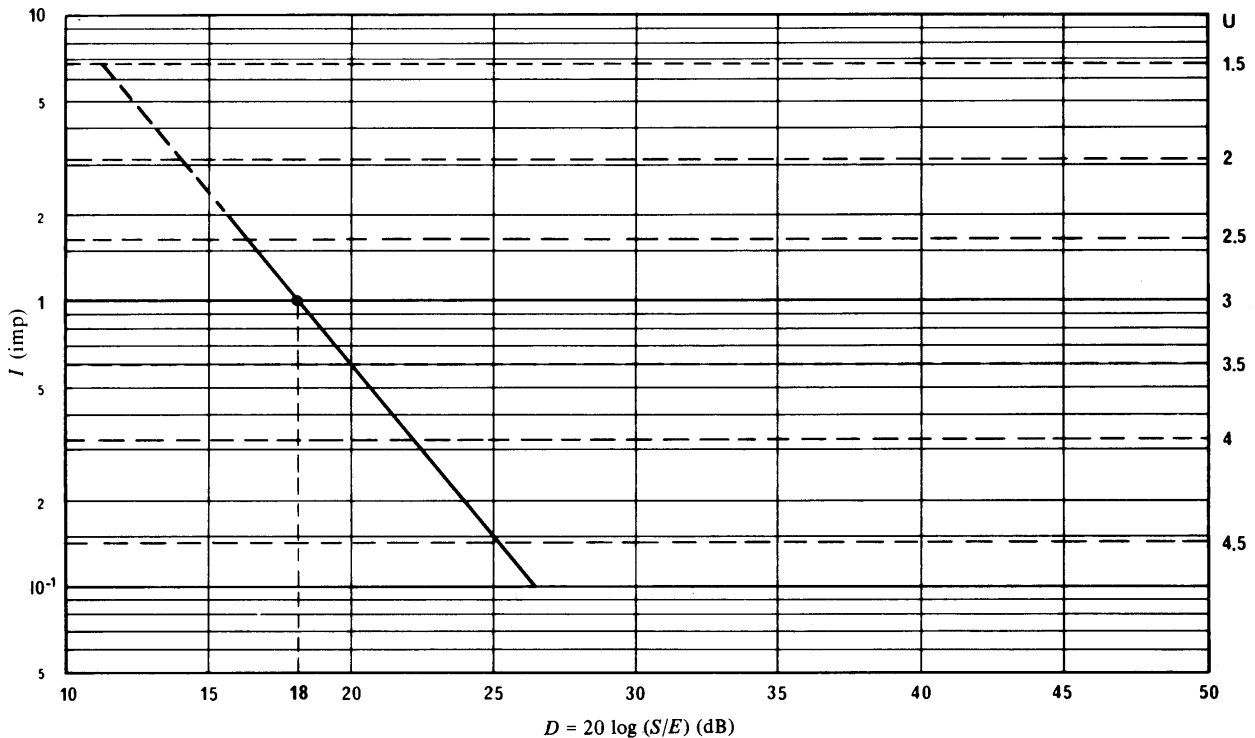The slope of the characteristic is not substantially altered.

FIGURE 7 – *Impairment characteristic for an undistorted positive echo having a delay of 1 μs*
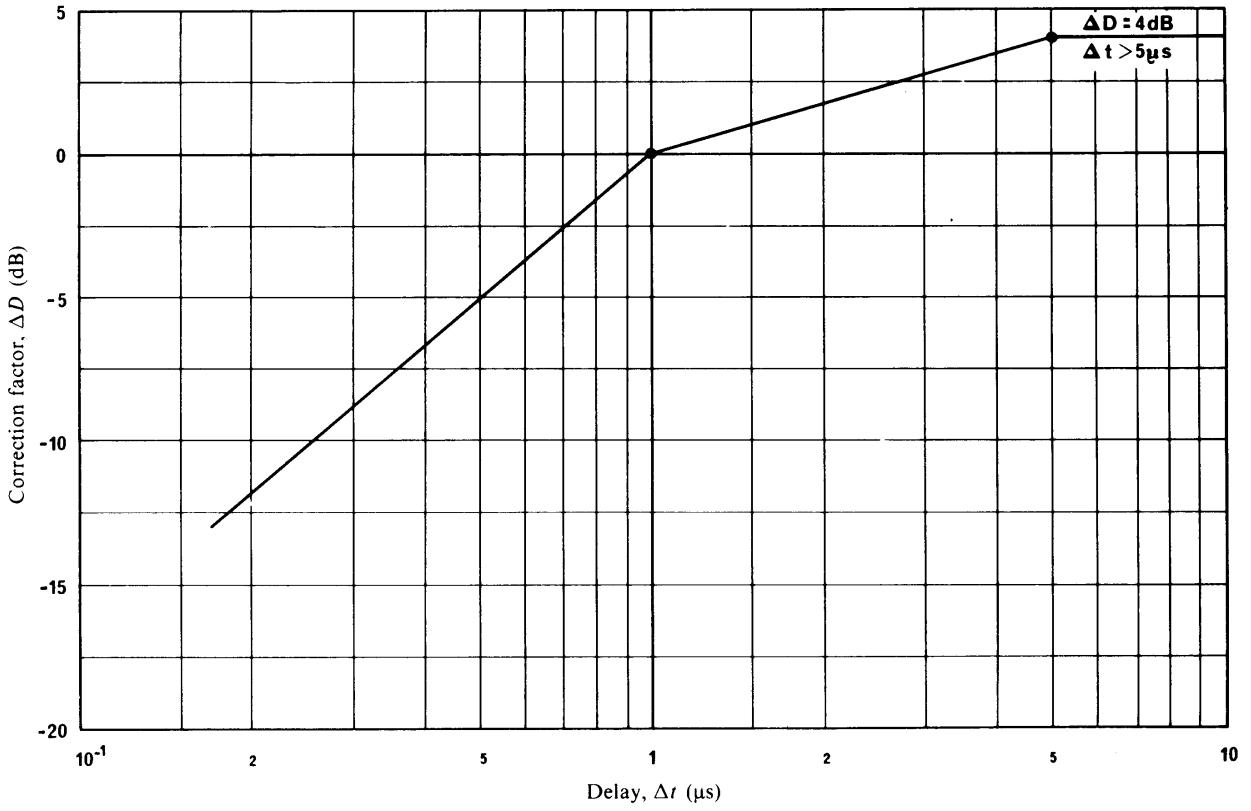
FIGURE 8 – *Correction factor to be applied to the abscissa values of D in Fig. 7*
to obtain the signal/echo ratio for other values of delay

D08-sc