EXPERIMENTAL RESULTS RELATING PICTURE QUALITY TO OBJECTIVE MAGNITUDE OF IMPAIRMENT

(Question 3/11, Study Programme 3B/11)

(1982-1986-1990)

1. Introduction

- *Study Programme 3B/11* calls for the establishment, in an appropriate form, of the relationship between the objective parameters of impaired television signals and the subjective assessment of displayed picture quality;
- *Recommendation 500* defines the methods of subjective assessment of television picture quality;
- *Recommendation 567* describes the objective parameters of typical transmission impairment and measuring methods as well as the corresponding test signals;
- Report 1205 ———— gives the basis for processing the results of subjective tests and a law of combination which best covers the cumulative effect of a number of simultaneous distortions expressed individually by a numerical value;
- *Report 313* gives a general bibliography of all documents related to the evaluation of the picture quality.

2. Classification of major types of impairments (composite colour systems (PAL, SECAM and NTSC))

This section concerns only distortions of the analogue composite signal in conformity with the measurement methods of Recommendation 567. It does not deal with the characteristics associated with component-based colour systems, both analogue and digital.

It concerns natural pictures, portraits, detailed natural scenes and does not deal with graphic and alphanumeric pictures.

2.1 *Classification*

A large number of results have been published in the technical literature (see Report 313). Comparison of the results frequently shows, for each type of impairment, a large measure of dispersion which may be attributable to considerable differences in the test conditions, particularly regarding the choice of pictures, the subjective measurement method (which includes the picture assessment scale and the relative viewing distance), the source equipment and the adjustment procedure. The receiving equipment and the setting-up procedure may also influence the results.

The dispersion also reflects the variety of the television equipment in use, and new measurements are not likely to produce major changes in an average interpretation of currently available results.

By adopting, for each type of distortion an impairment characteristic regarded as representative of an average situation, it is possible to provide a reference basis for the most common practical applications, and this may enable a correction factor to be introduced for situations defined with special precision.

Having regard to the sources of impairment commonly taken into account by researchers, it seems possible to make a classification consisting of a first group of distortions for which it is desirable to establish an impairment characteristic, and a second group for which the adoption of an impairment characteristic may be considered less important in practice or unsuitable for the statistical processing used to arrive at such a characteristic. For this group, it might suffice to give only a few figures as examples.

Recommendation 654 lists distortions and impairments of the first group and the impairment characteristics for each. The first group concerns:

1 – Short-time linear distortion
2 – Differential gain
3 – Differential phase
4 – Luminance-chrominance gain inequality
5 – Luminance-chrominance delay inequality
6 – Continuous random noise (unweighted white noise)
7 – Echo

The second group concerns:

1 – Line-time linear distortion
2 – Field-time linear distortion
3 – Long-time linear distortion
4 – Luminance signal insertion gain
5 – Synchronization signal insertion gain
6 – Steady-state delay-frequency response
7 – Luminance-on-chrominance and chrominance-on-luminance intermodulation
8 – Chrominance signal linear distortion
9 – Non-linear distortion of the luminance signal
10 – Non-linear distortion of the chrominance signal
11 – Spectral band of luminance signal
12 – Spectral band of colour difference signals
13 – Sine-wave interference
14 – Narrow-spectrum random noise
15 – Recurrent low-frequency hum
16 – Impulsive noise

2.2 *Experimental results*

Tables I, II and III present results of particular importance.

Table I gives the results of studies in the United Kingdom. These studies were carried out using the method of Recommendation 500, additional details of the tests being in accordance with § 1 of Annex IV to Report 405-5 (Dubrovnik, 1986). They apply directly to System I/PAL but small adjustments may be necessary for other systems.

Recourse should be made elsewhere [Macdiarmid and Allnatt, 1978; CCIR 1978-82a] for a list of references to detailed descriptions of the original work (see Report 313).

Table II presents results of investigations conducted in the German Democratic Republic [CCIR, 1978-82b] on System B/SECAM. The methods of Recommendation 500 were largely used here. In some types of impairment, the coefficients G and d_M are missing because in these cases the formula mentioned below does not sufficiently describe the relation.

Table III contains test results obtained in the Soviet Union [Lokshin, 1985; CCIR, 1986-1990a] for the Systems D and K/SECAM. These tests were carried out with the method described in Recommendation 500.

In all tables, values of subjective impairment* may be readily determined from the formula:

$$I_u = (d/d_M)^G \text{ imp}$$

Definitions of the objective magnitude *d* are given in the notes to the Tables.

For convenience, objective magnitudes in the units conventionally used are also listed for the mark points of 1, 1/2, 1/4 and 1/8 imp (see Annex II to Report 1205). ——— The corresponding mean scores on the quality scale of Recommendation 500 are 3.0, 3.7, 4.2 and 4.6.

* The values of *I* may be used for the addition of impairments applying one of the known summation laws (see Report 1205, Annex II, § 2).

TABLE I – *Experimental results for System I/PAL*

Impairment	Note (see over)	G	d_M	Mark point values (dB, except where stated)			
				1-imp	1/2-imp	1/4-imp	1/8-imp
Wideband random noise	1						
Luminance weighting	2	2.41	0.0167	36	38	41	43
Chrominance weighting	2	2.79	0.0327	30	32	34	36
Unified weighting	3	2.5	0.0123	38	41	43	45
Unweighted 5 MHz	4	2.6	0.0315	30	32	35	37
Unweighted 5.5 MHz	4	2.6	0.0330	30	32	34	37
Unweighted 6 MHz	4	2.6	0.0345	29	32	34	36
Localised random noise*	5						
3.2 kHz		1.73	0.0113	39	42	46	49
7.5 kHz		2.79	0.0271	31	33	36	38
Sine-wave noise*	6						
1 kHz		1.26	0.00546	45	50	55	60
3.2 kHz		1.26	0.0185	35	39	44	49
1 MHz		1.23	0.00765	42	47	52	57
3.2 MHz		1.19	0.0779	22	27	32	37
Undistorted crosstalk	7						
Pulse-and-bar signal		1.28	0.0155	36	41	46	50
Colour-bar signal		1.68	0.0291	31	34	38	41
Differentiated crosstalk	7						
Colour-bar signal		1.77	0.0422	27	31	34	38
Differential gain	8	2.86	0.437	44%	34%	27%	21%
Linear waveform distortion*	9						
K rating	10	2.35	0.113	11%	8.4%	6.3%	4.7%
Positive echo delay (μs):	11						
0.2		2.54	0.361	9	11	14	16
0.3		2.54	0.251	12	14	17	19
0.5		2.54	0.166	16	18	20	23
1		2.54	0.107	19	22	24	27
2		2.54	0.0814	22	24	27	29
5		2.54	0.0699	23	25	28	30
13		2.54	0.0668	24	26	28	31
Negative echo delay (μs):	11						
0.2		2.06	0.883	1	4	7	10
0.3		2.06	0.592	5	7	10	13
0.5		2.06	0.360	9	12	15	18
1		2.06	0.192	14	17	20	23
2		2.06	0.116	19	22	25	27
Gain inequality	12	2.86	0.564	56%	44%	35%	27%
Delay inequality	13	2.41	355	350 *ns*	270 *ns*	200 *ns*	150 *ns*

* Monochrome test.

Notes referring to Table I:

Note 1. – "Wideband random noise" tests were made with random noise having several spectra, each extending over all the video-frequency band. Here, *d* is the r.m.s. voltage of the noise expressed as a proportion of the nominal peak-to-peak excursion of the luminance signal (normally 0.7 V). The mark point values are expressed as signal/noise ratios, in decibels, given by −20 log *d*.

The quoted results have been combined from separate monochrome and colour tests, in which the requirement for the luminance channel in the colour tests was found to be rather less stringent than for monochrome. The more stringent result has been adopted but the ratio of the luminance and chrominance mid-opinion values has been based on the colour test. The values for *G* for the two tests were in close agreement.

Note 2. – Mark points are based on the subjective effect in the luminance channel or the chrominance channel alone, noise being measured through the appropriate weighting network (Recommendation 451, Geneva, 1974).

Note 3. – Mark points are based on the total subjective effect, noise being measured through the unified weighting network of Recommendation 567.

Note 4. – Mark points are based on the total subjective effect of flat noise extending up to 6 MHz but limited to the upper frequency designated prior to unweighted measurement. Results are not greatly affected by moderate departures of the noise spectrum from uniformity.

Note 5. – "Localized random noise" tests were each made with narrowband random noise, centered on the stated frequency, designed to simulate the noise produced by cascaded video amplifiers supplied by power units of a certain type. The definitions of *d* and the mark point values are identical with those for wideband random noise (Note 1). No weighting network is involved.

Note 6. – "Sine-wave noise" tests were each made at a frequency, close to the stated nominal frequency, at which the effect was worst. Here *d* is the peak-to-peak voltage of the noise expressed as a proportion of the nominal peak-to-peak excursion of the luminance signal (normally 0.7 V). The mark point values are expressed as signal/noise ratios, in decibels, given by −20 log *d*.

Note 7. – "Undistorted crosstalk" and "differentiated crosstalk" tests were made with the stated disturbing signals, whose line or sub-carrier frequencies were offset to give the worst effect. Differentiated crosstalk is that in which the crosstalk voltage is proportional to frequency. In both cases, *d* is taken as the peak-to-peak voltage of the "picture" portion of the crosstalk waveform, expressed as a proportion of the nominal peak-to-peak excursion of the luminance signal (normally 0.7 V), when measured with a luminance or chrominance pulse-and-bar disturbing signal as appropriate. The mark point values are expressed as signal/crosstalk ratios, in decibels, given by −20 log *d*.

Note 8. – Based on a small preliminary experiment. The result is essentially for chrominance gain at mid-grey level relative to that at black and will probably tend to over-estimate the subjective impairment when applied to a measurement of maximum error. *d* is taken as the proportional voltage error. (See § 2.1 of Recommendation 654.)

Note 9. – Based on tests with undistorted echo covering the range 0.2 to 13 μs (0.2 to 2 μs for negative echo).

Note 10. – *d* is the proportionate value of *K* as defined in Recommendation 451, Geneva, 1974. Results for positive echo were used as a transfer standard in determining the appropriate values of *G* and d_M. Mark points for *K* are expressed as percentages.

Note 11. – *d* is the magnitude of echo expressed as a proportion of that of (signal + echo), echo polarity being taken into account. The mark point values are expressed as (signal + echo)/echo ratios, in decibels, given by −20 log *d*.

Note 12. – "Gain inequality" tests were concerned with gain differences of the chrominance channel with respect to the luminance channel; *d* is taken as the proportional error of chrominance signal voltage. The mark point values are simply values of *d* expressed as percentages.

Note 13. – "Delay inequality" tests were concerned with delay differences of the chrominance channel with respect to the luminance channel; *d* is the relative delay, in nanoseconds, of the chrominance signal. The mark point values are expressed directly as values of *d*.

TABLE II – *Experimental results for System B/SECAM*

Impairment	Note	G	d_M	Mark point values (dB, except where stated)	
				1-imp	1/8-imp
Wideband random noise 0 to 5 MHz, luminance weighting	1	3.88	0.0118	38.5	43.2
Wideband random noise 0 to 20 kHz, luminance	1	2.96	0.00868	41.2	47.3
Hum heterodyning	2	1.08	0.0684	23.3	40.0
Crosstalk:					
- of luminance signal	3	2.02	0.0102	39.8	48.7
- of chrominance signal	3	3.27	0.240	12.4	17.9
Positive echo delay (μs):	4				
0.2		2.13	0.248	12.1	20.6
0.3		2.03	0.222	13.1	21.9
0.5		1.90	0.190	14.4	23.9
1		1.74	0.149	16.5	26.9
2		1.57	0.111	19.1	30.6
5		1.35	0.0668	23.5	36.9
Delay inequality	5	2.31	543 ns	543 ns	221 ns
Rise time	6	3.64	267 ns	267 ns	151 ns
Non-linearity	7			48%	14%
Level deviation	8			−1.7/+2.4	−0.1/+0.8

Note 1. – White noise in the frequency band mentioned was used. Here *d* represents the r.m.s. voltage of the noise expressed as a proportion of the nominal peak voltage of the luminance signal (0.7 V). The mark point values are expressed as signal/noise ratios, in decibels, given by $-20 \log d$.

Note 2. – The subjective effect of hum also depends on harmonic content, on the hum frequency, and on the type of receiver. The table gives an average value as a good approach to practical conditions. Here *d* is the ratio of the peak-to-peak value of the hum voltage to the peak level of the luminance signal (0.7 V).

Note 3. – The interfering signals were respectively an electronic monochrome picture and colour bar signal.

Note 4. – *d* means the ratio of echo to signal.

Note 5. – Here *d* expresses directly the delay time between the luminance and the chrominance channel.

The experiments showed no great differences in the subjective assessment of positive or negative deviations of the same magnitude.

Note 6. – The 10 to 90% rise time of an ideal step, after passing through the transmission channel in question was measured as *d*.

Note 7. – The non-linearity of the amplitude characteristic can be evaluated by amplitude measurement of a small audio signal, *A*, superimposed on a saw-tooth signal.

The value obtained,

$$d = \frac{A_{max} - A_{min}}{A_{max}} \times 100\%$$

is not sufficient to indicate the subjective effect on the picture quality because the shape of the amplitude characteristic is also of importance. The mark point given is valid only for gently curved characteristics.

Note 8. – In the SECAM system the deviations of level result in changes of colour saturation. Here *d* means the difference between peak-to-peak amplitude of the luminance signal and its nominal value (0.7 V), divided by this nominal value.

TABLE III

Test data for the systems D and K/SECAM

Impairment	Note	G	d_M	Mark point values (dB, except where stated) 1	1/2	1/4	1/8
1	2	3	4	5	6	7	8
Wideband random noise							
Weighting by unified circuit:							
Frequency band 5 MHz	1	2	0.0141	37	40	43	46
Frequency band 6 MHz	1	2	0.0133	37.5	40.5	43.5	46.5
Positive echo, delayed by (μs)	2						
0.2		2.6	0.245	12	14	17	19
0.3		2.4	0.191	14	17	20	22
0.5		2.17	0.140	17	20	23	25
1		1.9	0.0912	21	24	27	30
2		1.76	0.0650	24	27	31	34
5		1.67	0.0631	24	28	31	35
Negative echo, delayed by (μs)	2						
0.2		2.51	0.251	12	14	17	19
0.3		2.35	0.210	14	16	19	21
0.5		2.25	0.160	16	19	21	24
1		2.18	0.103	20	22	25	28
2		2.10	0.0716	23	26	29	32
5		2.05	0.0631	24	27	30	33
Time divergence of luminance and chrominance signals	3	2.32	400 ns	400 ns	300 ns	220 ns	160 ns
Non-linearity	4	2	53%	53%	37%	26%	19%

Notes to Table III

1. The tests were carried out for noise having various spectra in the frequency band indicated. Weighting was carried out with the unified CCIR circuit with time constant 0.245 μs. d - r.m.s. noise voltage to nominal luminance signal amplitude ratio (generally 0.7 V). The mark point values are defined as the signal-to-noise ratio (in decibels), i.e., - 20 log d.

2. d designates the echo-to-signal ratio. The mark points give the signal-to-echo ratio (in decibels), i.e., - 20 log d.

3. d directly expresses the time divergence between the luminance and colour difference signals.

4. The data relates to luminance signal distortions. The values are given by the formula:

$$d = \frac{A_{max} - A_{min}}{A_{max}} 100\%$$

where A - RF signal amplitude superimposed on the luminance test signal.

3. New studies on impairments

3.1 The results which appear in the preceding sections concern only the distortions sustained by the analogue composite signal, measured in accordance with the methods of Recommendation 567 and applicable to TV pictures corresponding to natural scenes.

The new developments in television systems, such as component analogue systems (MAC), digital television, systems of graphic or alphanumeric picture transmission, lead to new methods of measurement and new results, certain aspects of which are already mentioned in Report 1205 and Report 956.

3.2 *Bandwidth of the luminance component*

Regarding the activity and interest newly shown for colour systems based on components, both analogue and digital, the interest for the characteristic linking subjective quality to the bandwidth of the components is useful and opportune.

Throughout the studies, which led to the adoption of digital studio standards (Recommendation 601), numerous experiments have been made concerning the bandwidth of component signals.

The effective bandwidth of the channel conveying the luminance component of a television signal between picture source and picture display determines the amount of blurring of the displayed picture. In composite colour systems (PAL, SECAM and NTSC), the presence of a colour sub-carrier and the means of decoding the composite signal modify the effective luminance bandwidth in a manner dependent on the details of the decoder design. However, in monochrome systems and the emerging colour systems using separate component transmission, the bandwidth of the luminance channel is known and its effect on picture quality can therefore be determined.

Bandwidth is defined here (assuming a low-pass channel) as the frequency at which the insertion loss of the channel is 3 dB greater than the average loss at low frequencies.

The impairment produced by a given reduction of bandwidth depends significantly on:

- the viewing distance; the impairment is greater at closer viewing distances
- the type of picture displayed; graphics and alphanumerics are most sensitive while pictures with low-contrast details, such as portraits, are least sensitive.

The impairment characteristics illustrated in Fig. 1 give results for two viewing distances (4 and 6 times picture height) and two classes of picture (graphics and natural scenes with large amounts of detail).

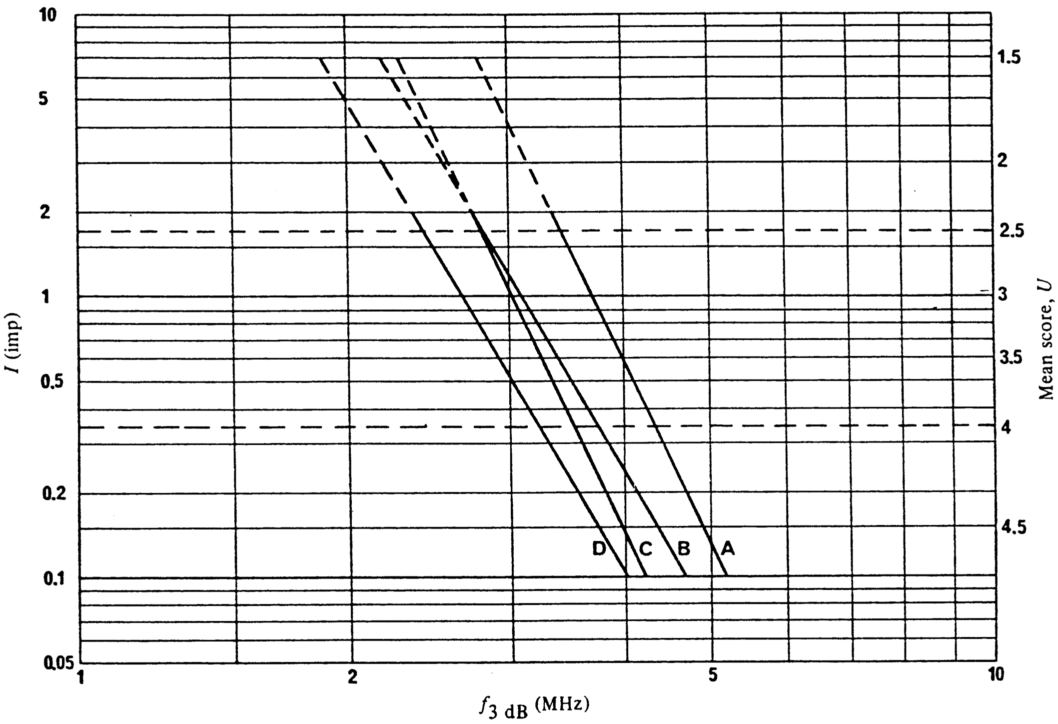


FIGURE 1 – *Impairment characteristics for bandwidth restriction of the luminance signal*

A: graphics and alphanumerics – viewing distance = 4 H
B: graphics and alphanumerics – viewing distance = 6 H
C: detailed natural scenes – viewing distance = 4 H
D: detailed natural scenes – viewing distance = 6 H
U: mean score, 5-grade scale

The results apply to 625-line systems:

– impairment factor: $d = f_{3\ dB}$

$f_{3\ dB}$: 3 dB bandwidth (MHz)

– mid-opinion values (I = 1):

viewing distance:	4H	6H
graphics	d_M = 3.70	d_M = 3.09
scenes	d_M = 3.02	d_M = 2.67

– slope

viewing distance:	4H	6H
	G = 6.80	G = 5.60

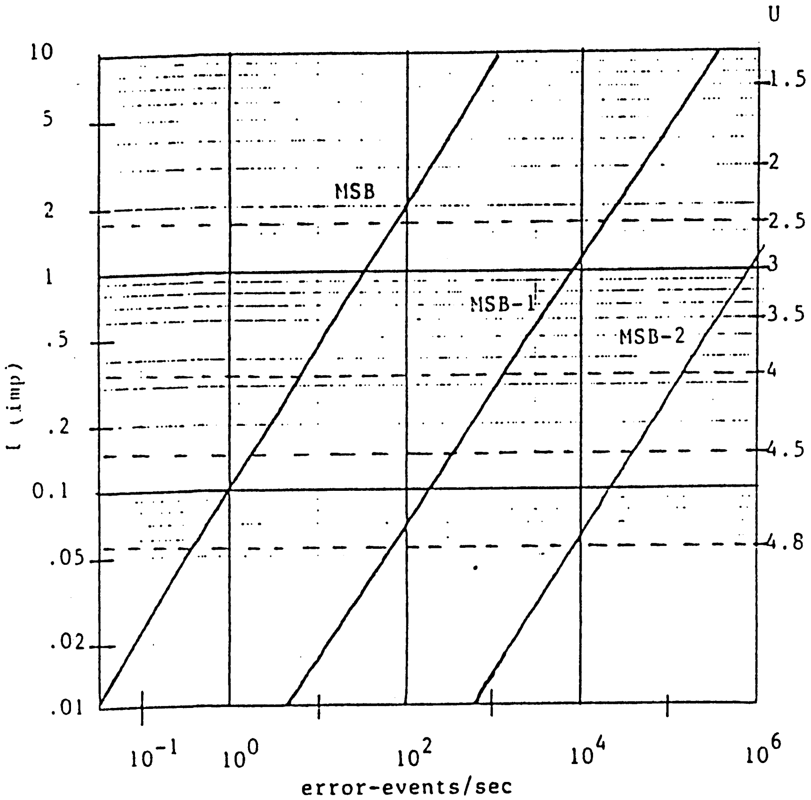
3.3 The subjective effects of random bit errors in YUV digital component video signals

A recent evaluation has been made in the United Kingdom for 625/50 4:2:2 signals, and the results are given in Figs. 2 and 3. The unit "error-events-per-second" is used as a measure of error rate and curves are given for most, second most, and third most significant bits. The impairment scale was used with a test duration of 20 seconds in the assessments. 20 expert observers at both 4H and 6H were used. The test pictures were "Boats" and "Blackboard with toys". Basic quality and downstream processed quality (colour matte) were assessed. A logistic model was fitted to the data.

The measure of error rate which has been used (error-events-per-second) is simply related to the bit-error ratio. The Y component and U/V component bit streams each have a data rate of 108 Mbit/s. Thus, N error-events-per-second corresponds to a bit-error ratio of about $8N/10^8$. For the U and V components in Fig. 3, the bit-error ratio is $N/(54 \times 10^6)$.

The results show that for a given number of error-events-per-second the most significant bit of the luminance signal is the most sensitive to the errors, the sensitivity decreasing rapidly for bits of lesser significance. The use of chroma-key in downstream processing increases the sensitivity to errors in the U and particularly the V components. Moreover, in this case the sensitivity does not decrease so rapidly with bit significance as in the U/V bit stream of Fig. 2.

It is hoped that other administrations, particularly those using 525/60 4:2:2 signals will be encouraged to make similar studies so that in future such material can be included in an enlarged Recommendation 654.



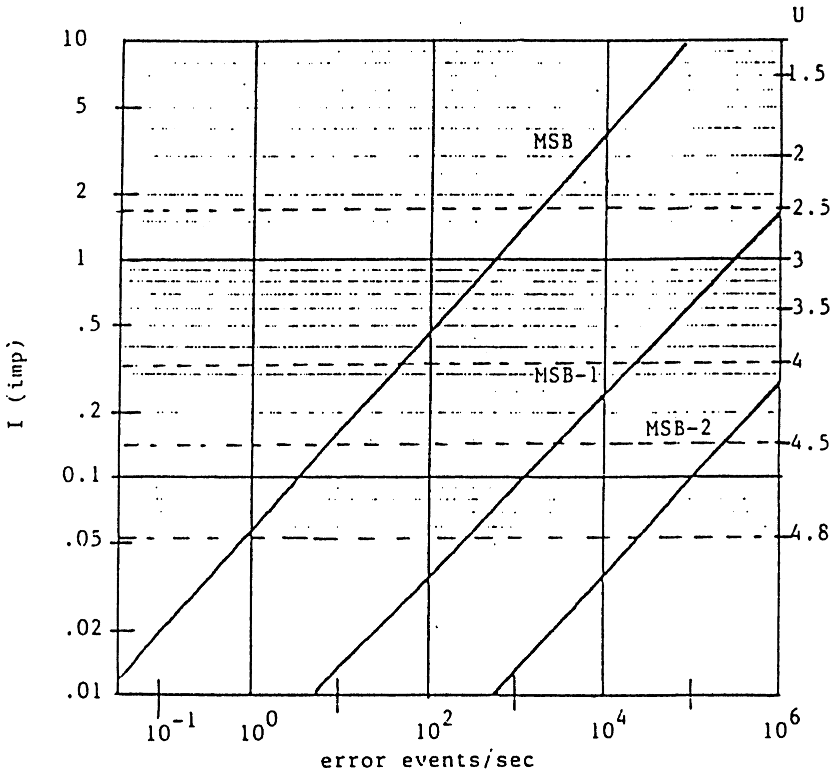


FIGURE 2 - Impairment characteristics for random single-bit errors in bits of various significance

(a) Errors in luminance (Y) component signal

		d_M	G
Y component	MSB	3.60 x 10	0.64
	MSB-1	8.45×10^3	0.61
	MSB-2	8.28×10^5	0.64

(b) Errors in colour-difference (U/V) component signals

		d_M	G
U/V component	MSB	5.83×10^2	0.45
	MSB-1	3.07×10^5	0.42
	MSB-2	2.04×10^7	0.43

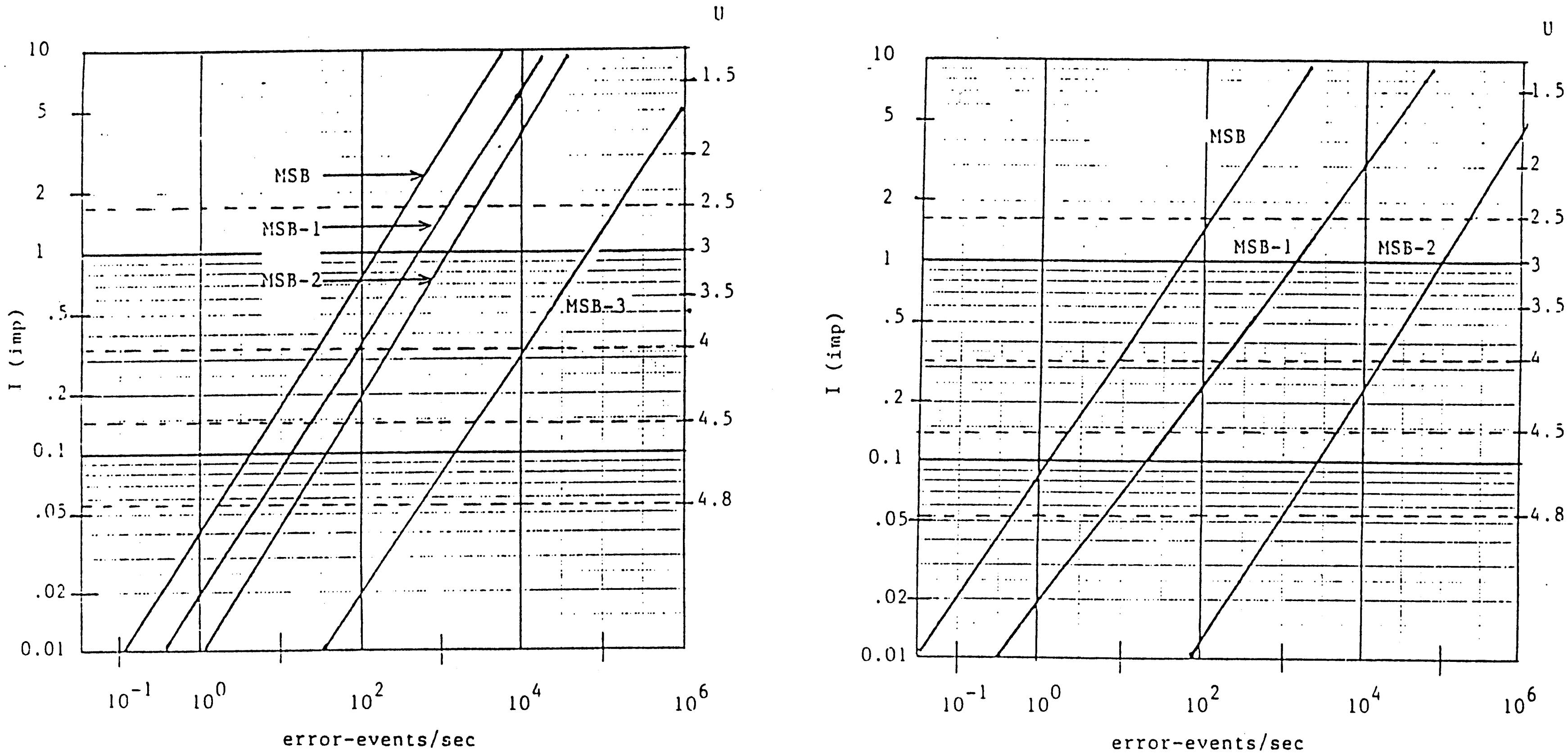


FIGURE 3 - Impairment characteristics for random single-bit errors after chroma-key processing

(a) errors in bits of various significance in U component

		d_M	G
U component	MSB	1.67×10^2	0.63
	MSB-1	5.50×10^2	0.63
	MSB-2	1.31×10^3	0.65
	MSB-3	6.44×10^4	0.60

(b) errors in bits of various significance in V component

		d_M	G
V component	MSB	6.66×10	0.60
	MSB-1	1.37×10^3	0.55
	MSB-2	9.78×10^4	0.64

3.4 Continuous random noise

Investigations of possible impairments characteristics [Lokshin, 1985; CCIR, 1986-1990b] suggest that the level of noise with typical spectral distribution might be standardized using a single impairment characteristic that may be applicable to all television broadcasting systems. This characteristic defines the ratio of the picture signal level to the weighted value of the noise voltage, the weighing being carried out using the CCIR unified network in a 5 MHz band.

The suggested impairment characteristic is shown in Figure 4. It can be described by means of the following equations:

- value of the distortion

$$d = \frac{N_{r.m.s.}}{L} \quad \text{or } D = 20 \text{ lg} \left[\frac{L}{N_{r.m.s.}} \right] \quad \text{(dB)}$$

- mid-score value (I = 1 imp):

$d_M = 0.0141$ or $D_M = 37$ dB

- slope: G = 2.

The signal/(weighted)noise ratio is measured in accordance with section C.3.2.1 of Recommendation 567.

Further study of the proposed impairment characteristic is suggested.

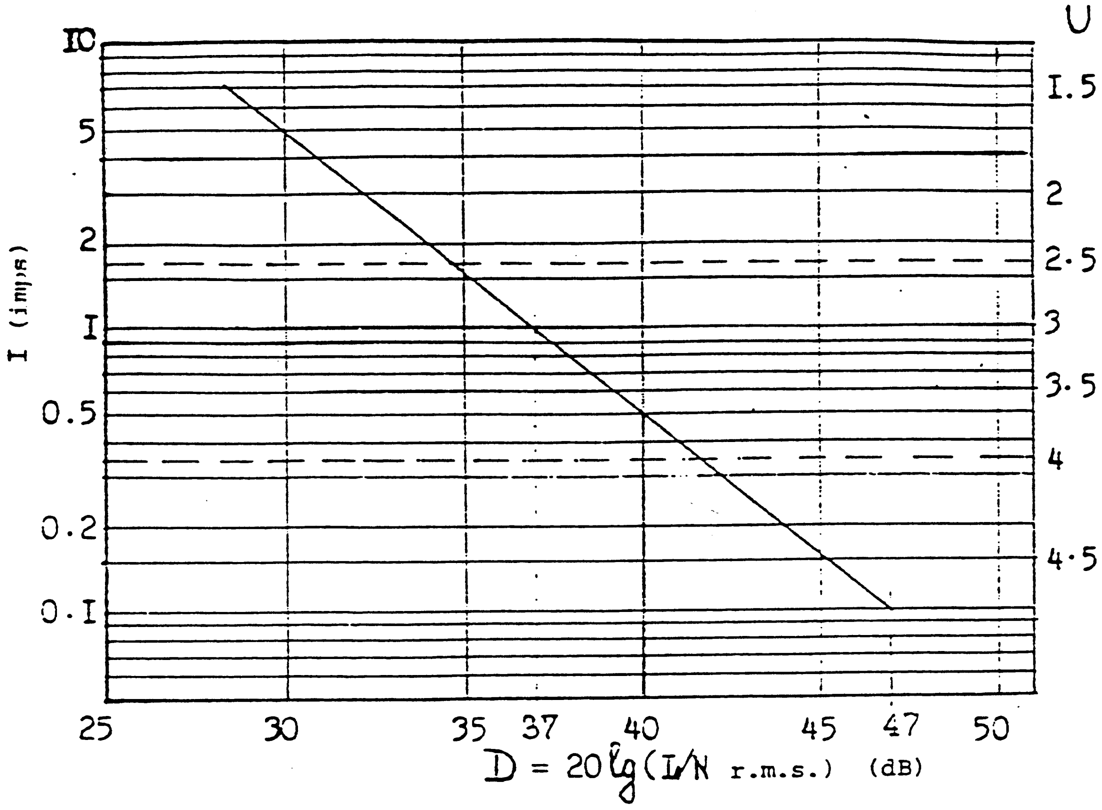


FIGURE 4

Impairment characteristic for (weighted) noise

3.5 Effects of sine-wave noise on picture quality

Subjective assessment tests have been carried out in the People's Republic of China [CCIR, 1986-90c] concerning the effects of sine-wave noise on picture quality. The experiments were conducted in two frequency bands, 50 Hz - 10 kHz, and 10 kHz - 6 MHz. The results of the tests are given in the tables of the document.

3.6 Echo signal

Studies of possible impairment characteristics [CCIR, 1986-1990d] have suggested that the level of the non-distorted (positive and negative) echo signal might be standardized using a unified impairment characteristic which may apply for all television broadcasting systems.

The suggested impairment characteristic for the non-distorted echo-signal is described by the following expressions:

- value of distortion: $d = E/S$ or $D = 20 \log (S/E)$, dB
- value for mean evaluation ($I = 1$ imp):
  $d_M (\Delta t) = 0.04/|\Delta t| + 0.05$, or
  $D_M (\Delta t) = -20 \log (0.04/|\Delta t| + 0.05)$, dB;
- slope: $G(\Delta t) = 0.15/|\Delta t| + 1.85$;
- value of D for different values of I and Δt (μs):
  $D = D_M (\Delta t) - (20 \log I)/G(\Delta t)$, dB.

Figure 5 gives the values of D for characteristic picture impairment levels.

Further study of the proposed impairment characteristic is suggested.

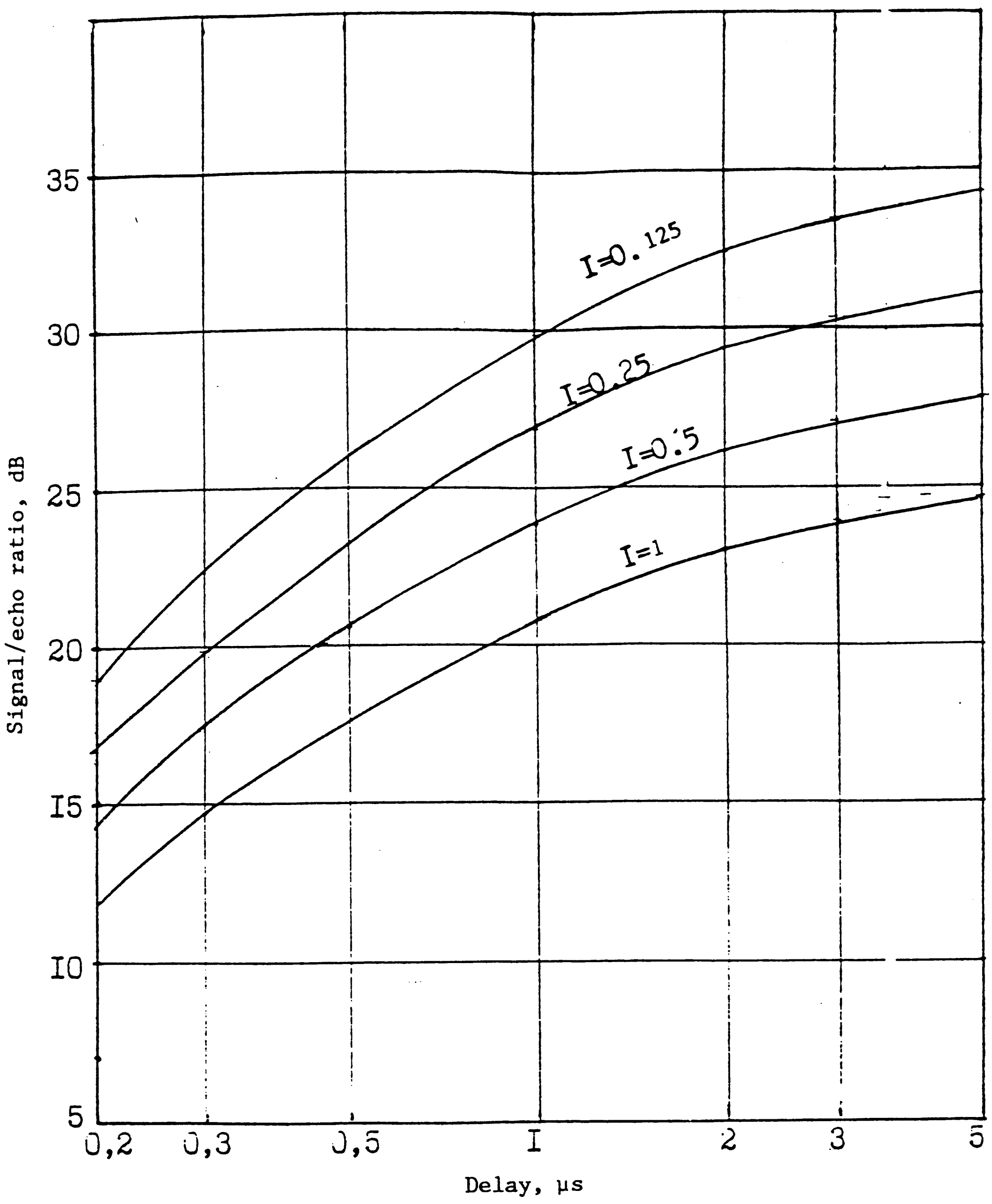


FIGURE 5
Impairment characteristic for echo signals

REFERENCES

LOKSHIN, M.G. [1985] - Unifitsirovannaya vzveshivayushchaya tsep dlya izmereniya shumov v sisteme SEKAM (A unified weighting network for measuring noise in the SECAM system), Tekhnika kino i televideniya, No. 10, 31-35.

MACDIARMID, I. F. and ALLNATT, J. W. [1978] Performance requirements for the transmission of the PAL coded signal. *Proc. IEE*, Vol. 125, 571-580.

CCIR Documents

[1978-82]: a. 11/38 (United Kingdom); b. 11/331 (German Democratic Republic).

[1986-90]: a. 11/451 (USSR); b. 11/453 (USSR); c. 11/145 (People's Republic of China); d. 11/452 (USSR).

REPORT 1082-1

STUDIES TOWARD THE UNIFICATION OF PICTURE ASSESSMENT METHODOLOGY

(Question 3/11 and Study Programme 3A/11)

(1986-1990)

1. INTRODUCTION

Recommendation 500———— has been prepared, and is regularly reviewed, to provide instructions on what seem the best available methods for the assessment of picture quality in a controlled laboratory environment. The methods need to be reviewed at intervals, to reflect the evolution of studies in new systems, and to reflect the evolution of methodology itself.

Although the methods outlined in Sections 2 and 3 of Rec 500 ————have been carefully considered and designed with the knowledge available, they are not free of shortcomings. If new alternative methods are designed and proven to be free of them, they must be candidates to supercede the existing methods.

The main drawbacks of the methods currently given in Sections 2 and 3 are as follows:

- The conceptual differences between the meanings of the quality scale descriptors is not necessarily uniform. It is known to vary between linguistic groups, cultural groups, and between individuals, to a non-negligeable extent. Processing of results is currently based on the approximation that the conceptual difference is uniform; so, interpreting results to indicate a consistent measure of absolute quality or impairment is also an approximation. In fact, results could even misrepresent the magnitudes of differences by as much as ±50%.

- For reasons which may include the differences in meanings associated with descriptors mentioned above, the correlation of results between laboratories is not considered sufficiently good for alternative systems with small impairments or high-quality, to be reliably evaluated in different laboratories, and the absolute results compared. Rank order is consistent, however.

- The stability of the methods in Sections 2 and 3 of Rec. 500 derives in part from the systematic use of a high-quality reference. There are circumstances where a high-quality reference is not available; and, in these cases, the methods cannot be used.

- Double stimulus methods take more than twice as much time as single stimulus methods and thus are accordingly more expensive to conduct.