

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 (μ s):	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 (μ s):	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 1:

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 μ s (0.2 to 2 μ s 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 .