XVII A.P.
DÜSSELDORF
21.5-1.6 1990
CCIR

XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990

INTERNATIONAL TELECOMMUNICATION UNION

REPORTS OF THE CCIR, 1990

(ALSO DECISIONS)

ANNEX TO VOLUME XI – PART 1

BROADCASTING SERVICE (TELEVISION)

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

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92-61-04291-0

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ANNEX TO VOLUME XI-1

BROADCASTING SERVICE (TELEVISION)

(Study Group 11)

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(In order to facilitate the retrieval of a given text, the page number of Volume XI-1 of the XVIth Plenary Assembly, Dubrovnik 1986, is indicated.)

ANNEX TO VOLUME XI-1

SECTION 11A: CHARACTERISTICS OF SYSTEMS FOR MONOCHROME AND COLOUR TELEVISION

REPORT 624-4

CHARACTERISTICS OF TELEVISION SYSTEMS

(Question 1/11)

(1974-1978-1982-1986-1990)

The following Tables, given for information purposes, contain details of a number of different television systems in use at the time of the XVIIth Plenary Assembly of the CCIR, Düsseldorf, 1990.

A list of countries and geographical areas, and the television systems used, are given in Annex I.

Specifications of the SECAM IV colour television system, which is still under consideration, are given in Annex II.

Information on the results of the comparative laboratory tests carried out on the various colour television systems in the period 1963-1966 by broadcasting authorities, administrations and industrial organizations, together with the main parameters of systems may be found in Reports 406 and 407, XIIth Plenary Assembly, New Delhi, 1970.

All television systems listed in this Report employ an aspect ratio of the picture display (width/height) of 4/3, a scanning sequence from left to right and from top to bottom and an interlace ratio of 2/1, resulting in a picture (frame) frequency of half the field frequency. All systems are capable of operating independently of the power supply frequency.

TABLE I – *Basic characteristics of video and synchronizing signals*

Item	Caracteristics		System								
			M	N [1]	B, G	H	I	D, K	K1	L	Rec. 472 [2]
1	Number of lines per picture (frame)		525	625	625	625	625	625	625	625	625
2	Field frequency, nominal value (fields/second) [3]		60 (59.94)	50	50	50	50	50	50	50	50
3	Line frequency f_H and tolerance when operated non-synchronously (Hz) [3] [4]		15 750 (15 734.264 ± 0.0003%)	15 625 ± 0.15% (± 0.00014%)	15 625 [5] ± 0.02% (± 0.0001%)	15 625 ± 0.02% (± 0.0001%)	15 625 ± 0.00002% [6]	15 625 [5] ± 0.02% (± 0.0001%)	15 625 ± 0.02% (± 0.0001%)	15 625 ± 0.02% (± 0.0001%)	15 625 ± 0.02% (± 0.0001%)
3 *(a)*	Maximum variation rate of line frequency valid for monochrome transmission (%/s) [7] [8]		0.15		0.05	0.05	0.05	0.05	0.05	0.05	
4 [10]	Nominal and peak levels of the composite video signal (%) (see Fig. 1)	blanking level (reference level)	0	0	0	0	0	0	0	0	
		peak-white-level	100	100	100	100	100	100	100	100	
		synchronizing level	−40	−40 (−43)	−43	−43	−43	−43	−43	−43	
		difference between black and blanking level	7.5 ± 2.5 [9]	7.5 ± 2.5 (0)	0	0	0	0-7	0 (colour) 0-7 (mono.)	0 (colour) 0-7 (mono.)	0^{+5}_{-0}
		peak level including chrominance signal	120		133 [11]		133	115 [12]	115 [12]	124 [12]	

TABLE 1 *(continued)*

Item	Caracteristics	System								
		M	N (1)	B, G	H	I	D, K	K1	L	Rec. 472 (2)
5	Assumed gamma of display device for which pre-correction of monochrome signal is made	2.2	2.2 (2.8)	2.8 (13)						(14)
6	Nominal video bandwidth (MHz)	4.2	4.2	5	5	5.5	6	6	6	5.0 or 5.5 or 6.0
7	Line synchronization	see Table 1-1								
8	Field synchronization	see Table 1-2								

(1) The values in brackets apply to the combination N/PAL used in Argentina.

(2) Figures are given for comparison.

(3) Figures in brackets are valid for colour transmission.

(4) In order to take full advantage of precision offset when the interfering carrier falls in the sideband of the upper video range (greater than 2 MHz) of the wanted signal a line-frequency stability of at least 2×10^{-7} is necessary.

(5) The exact value of the tolerance for line frequency when the reference of synchronism is being changed requires further study.

(6) When the reference of synchronism is being changed, this may be relaxed to 15 625 ± 0.02%.

(7) These values are not valid when the reference of synchronism is being changed.

(8) Further study is required to define maximum variation rate of line frequency valid for colour transmission. In the UK and Japan this is 0.1 Hz/s /CCIR, 1982-86b; CCIR, 1986-90/.

(9) In Japan values 0^{+10}_{-0} are used.

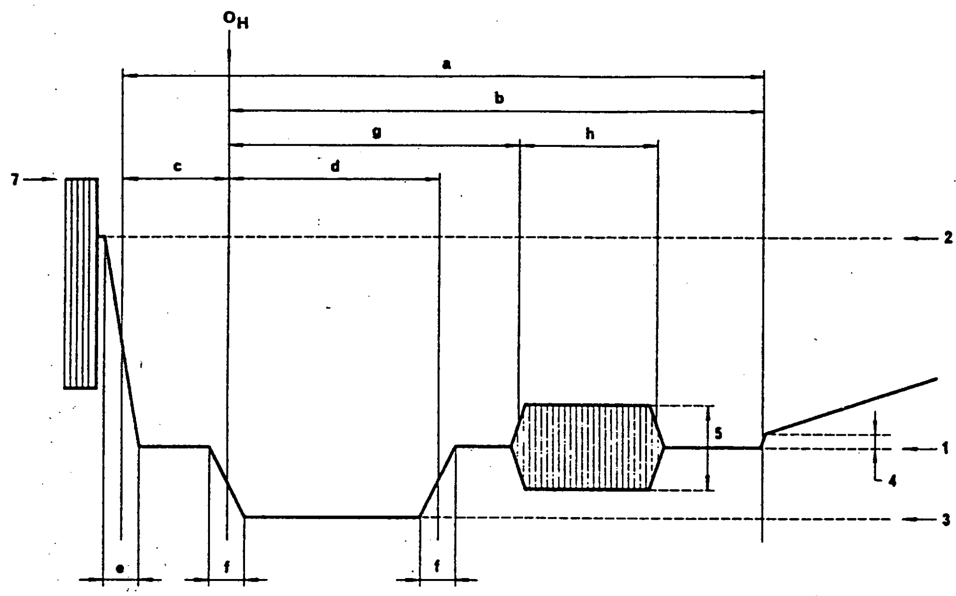
(10) It is also customary to define certain signal levels in 625-line systems, as follows:
Synchronizing level = 0
Blanking level = 30
Peak white-level = 100
For this scale, the peak level including chrominance signal for system D, K/SECAM equals 110.7. (See [CCIR, 1982-86a].) According to common studio operating practices, peak white-level = 100 corresponds to 1.0 V measured across a matched 75 ohms termination.

(11) Value applies to PAL signals.

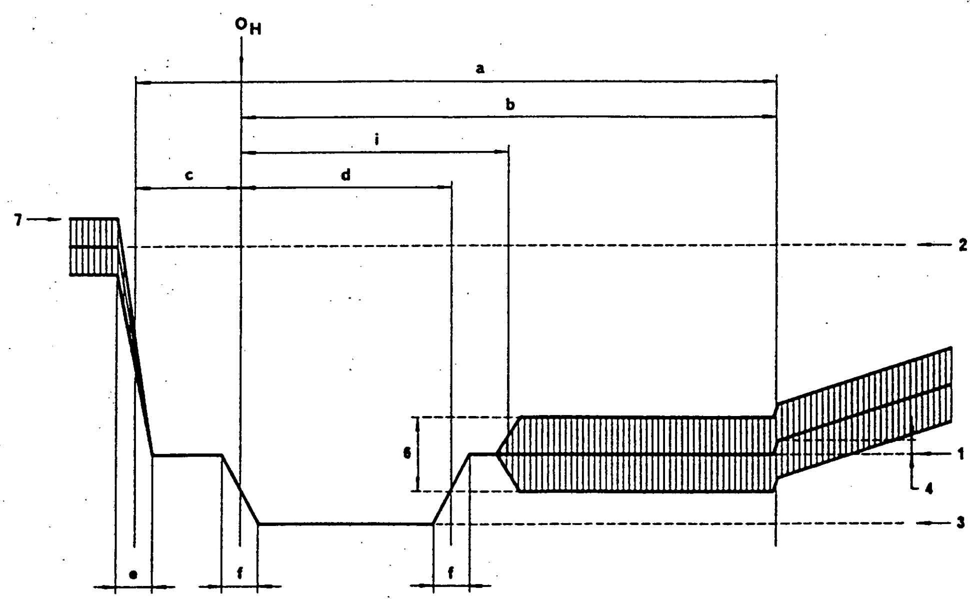
(12) Values apply to SECAM signals. For programme exchange the value is 115.

(13) Assumed value for overall gamma approximately 1.2. The gamma of the picture tube is defined as the slope of the curve giving the logarithm of the luminance reproduced as a function of the logarithm of the video signal voltage when the brightness control of the receiver is set so as to make this curve as straight as possible in a luminance range corresponding to a contrast of at least 1/40.

(14) In Recommendation 472, a gamma value for the picture signal is given as approximately 0.4.



(a) NTSC and PAL systems



(b) SECAM system

FIGURE 1 – *Levels in the composite signal and details of line-synchronizing signals*

1 blanking level
2 peak white-level
3 synchronizing level
4 difference between black and blanking levels
5 peak-to-peak value of burst
6 peak-to-peak value of colour sub-carrier
7 peak level including chrominance signal

TABLE I-1 – *Details of line synchronizing signals (see Fig. 1)*

Durations (measured between half-amplitude points on the appropriate edges) for various systems

Symbol	Characteristics	M [1]	N [2]	B, G, H, I, D, K, K1, L (see also Rec. 472)
H	Nominal line period (μs)	63.492 (63.5555)	64	64 [3]
a	Line-blanking interval (μs)	10.2 to 11.4 [8] (10.9 ± 0.2)	10.24 to 11.52 (12 ± 0.3)	12 ± 0.3 [4]
b	Interval between time datum (O_H) and back edge of line-blanking pulse (μs)	8.9 to 10.3 (9.2 to 10.3)	8.96 to 10.24 (10.5)	10.5 [5]
c	Front porch (μs)	1.27 to 2.54 (1.27 to 2.22)	1.28 to 2.56 (1.5 ± 0.3)	1.5 ± 0.3 [4] [6]
d	Synchronizing pulse (μs)	4.19 to 5.71 [8] (4.7 ± 0.1)	4.22 to 5.76 (4.7 ± 0.2)	4.7 ± 0.2
e	Build-up time (10 to 90%) of the edges of the line-blanking pulse (μs)	≤ 0.64 (≤ 0.48)	≤ 0.64 (0.3 ± 0.1)	0.3 ± 0.1
f	Build-up time (10 to 90%) of the edges of the line-synchronizing pulses (μs)	≤ 0.25	≤ 0.25 (0.2 ± 0.1)	0.2 ± 0.1 [7]

[1] Values in brackets apply to M/NTSC.

[2] The values in brackets apply to the combination N/PAL used in Argentina.

[3] In France, and the countries of the OIRT, the tolerance for the instantaneous line period value is ± 0.032 μs.

[4] In 625-line countries using Teletext System B as specified in the Annex to Recommendation 653 to reduce the possibilities of data loss, the following values are preferred [CCIR, 1982-86c and d]:

a) line blanking interval: $12^{+0.0}_{-0.3}$ μs

c) front porch: $1.5^{+0.3}_{-0.0}$ μs

[5] Average calculated value, for information. For system I the value is 10.4 [CCIR, 1982-86b].

[6] For system I, the values are 1.65 ± 0.1.

[7] For system I, the values are 0.25 ± 0.05.

[8] In Japan, the values in brackets apply to studio facilities.

FIGURE 2 – *Details of field-synchronizing waveforms*

FIGURES 2-1 – *Diagrams applicable to all systems except M*

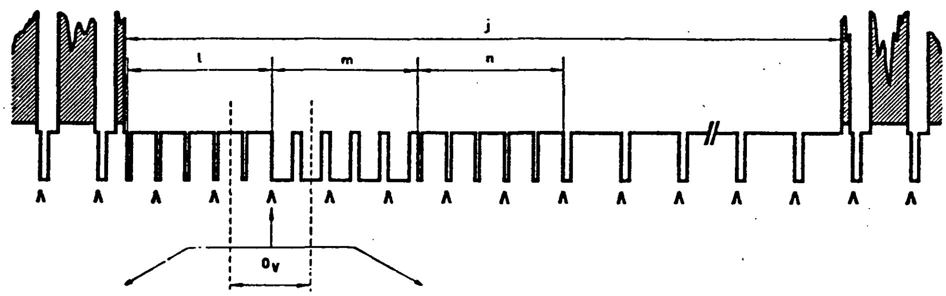


FIGURE 2-1*a* – *Signal at beginning of each first field*

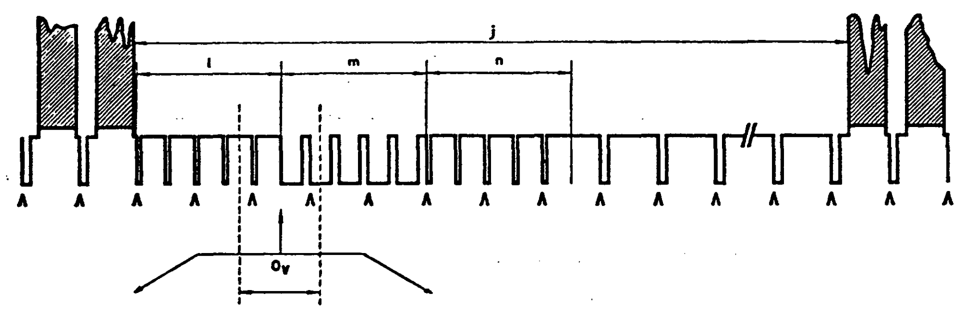
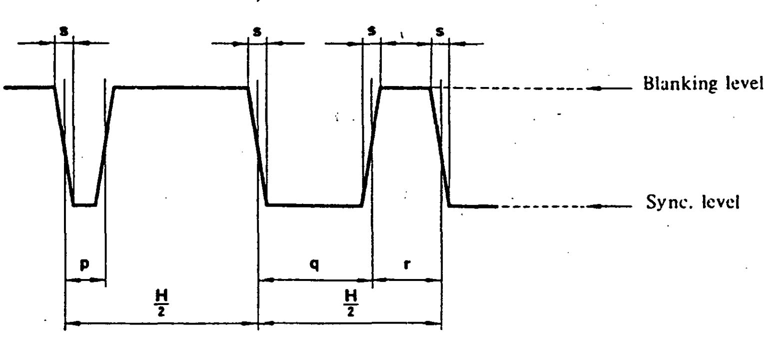


FIGURE 2-1*b* – *Signal at beginning of each second field*

Note 1. – ΛΛΛ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

Note 2. – At the beginning of each first field, the edge of the field-synchronizing pulse, O_V, coincides with the edge of a line-synchronizing pulse if *l* is an *odd* number of half-line periods as shown.

Note 3. – At the beginning of each second field, the edge of the field-synchronizing pulse, O_V, falls midway between the edges of two line-synchronizing pulses if *l* is an *odd* number of half-line periods as shown.



(The durations are measured between the half-amplitude points on the appropriate edges)

FIGURE 2-1*c* – *Details of equalizing and synchronizing pulses*

FIGURE 2 – *Details of field-synchronizing waveforms*

FIGURES 2-2 – *Diagrams applicable to system M*

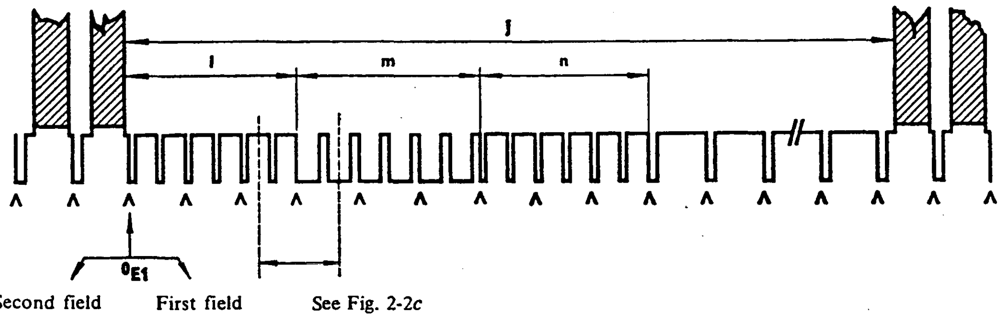


FIGURE 2-2*a* – *Signal at beginning of each first field*

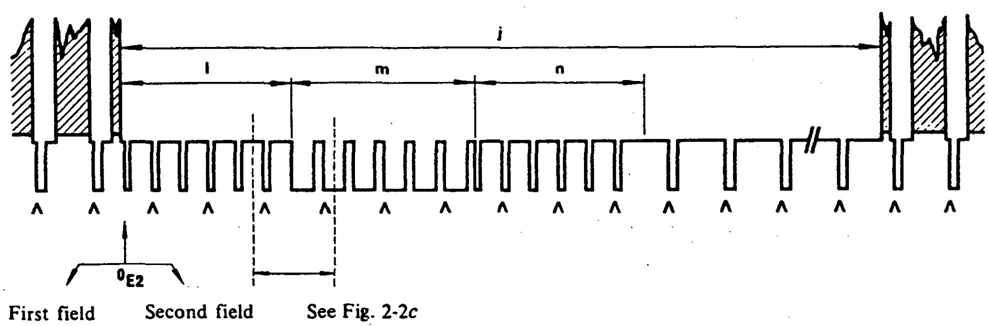


FIGURE 2-2*b* – *Signal at beginning of each second field*

Note 1. – Λ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

Note 2. – Field-one line numbers start with the first equalizing pulse in Field 1, designated O_{E1} in Fig. 2-2*a*.

Note 3. – Field-two line numbers start with the second equalizing pulse in Field 2, one-half-line period after O_{E2} in Fig. 2-3*b*.

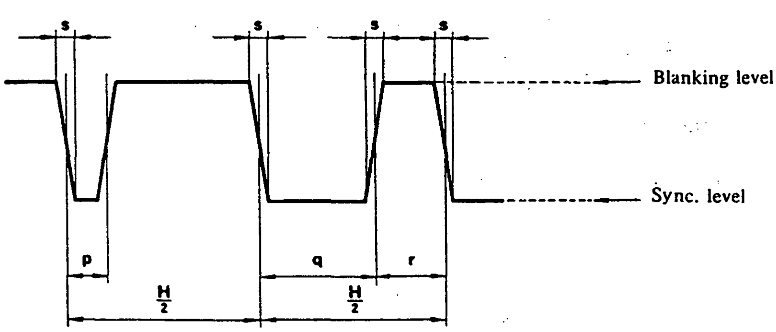


FIGURE 2-2*c* – *Details of equalizing and synchronizing pulses*

TABLE 1-2 – *Details of field synchronizing signals (see Fig. 2)*

Duration (measured between half-amplitude points on the appropriate edges) for various systems

Symbol	Characteristics	M	N (1)	B, G, H, I, D, K, K1, L (see also Rec. 472)
v	Field period (ms)	16.667 (2) (16.6833)	20	20
j	Field-blanking interval (for H and a, see Table 1-1)	(19 to 21) $H + a$ (3)	(19 to 25) $H + a$ (25 $H + a$)	25 $H + a$
j' (4)	Build-up time (10 to 90%) of the edges of field-blanking pulses (μs)	$\leqslant$ 6.35	$\leqslant$ 6.35 (0.3 ± 0.1)	0.3 ± 0.1
k (4)	Interval between front edge of field-blanking interval and front edge of first equalizing pulse (μs)	(1.5 ± 0.1)		3 ± 2 (5) (systems B/SECAM, G/SECAM, D, K, K1 and L only; no ref. in Rec. 472)
l	Duration of first sequence of equalizing pulses	3 H	3 H. (2.5 H)	2.5 H
m	Duration of sequence of synchronizing pulses	3 H	3 H (2.5 H)	2.5 H
n	Duration of second sequence of equalizing pulses	3 H	3 H (2.5 H)	2.5 H
p	Duration of equalizing pulse (μs)	(2.3 ± 0.1) (6)	2.30 to 2.56 (2.35 ± 0.1)	2.35 ± 0.1
q	Duration of field-synchronizing pulse (μs)	27.1 (nominal value)	26.52 to 28.16 (27.3)	27.3 (7) (nominal value)
r	Interval between field-synchronizing pulse (μs)	(4.7 ± 0.1)	3.84 to 5.63 (4.7 ± 0.2)	4.7 ± 0.2 (8)
s	Build-up time (10 to 90%) of synchronizing and equalizing pulses (μs)	$\leqslant$ 0.25	$\leqslant$ 0.25 (0.2 ± 0.1)	0.2 ± 0.1 (9)

(1) The values in brackets apply to the combination N/PAL used in Argentina.

(2) The value in brackets applies to the M/NTSC system.

(3) The value $0.07\,v\,{}^{+\,0.012\,v}_{-\,0}$ is used in Japan where v is the field period.

(4) Not indicated in the diagram.

(5) This value is to be specified more precisely at a later date.

(6) The following specification is also applied in Japan: an equalizing pulse has 0.45 to 0.5 times the area of a line-synchronizing pulse.

(7) For system I: 27.3 ± 0.1.

(8) For system I: 4.7 ± 0.1.

(9) For system I: 0.25 ± 0.05.

TABLE II – *Characteristics of video signal for colour television*

Item	Characteristics	Colour television system: M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL (1)
2.1	Assumed chromaticity coordinates (CIE, 1931) for primary colours of receiver	x y Red 0.67 0.33 Green 0.21 0.71 Blue 0.14 0.08		x y Red 0.64 0.33 Green 0.29 0.60 Blue 0.15 0.06 (2)			
2.2	Chromaticity coordinates for equal primary signals $E'_R = E'_G = E'_B$	Illuminant C $x = 0.310$ $y = 0.316$ (3)		Illuminant D_{65} $x = 0.313$ $y = 0.329$ (2)			
2.3	Assumed gamma value of the receiver for which the primary signals are pre-corrected (4)	2.2	2.8				
2.4	Luminance signal	$E'_Y = 0.299\ E'_R + 0.587\ E'_G + 0.114\ E'_B$ (5) E'_R, E'_G and E'_B are gamma – pre-corrected primary signals (6)					
2.5	Chrominance signals (Colour difference)	$E'_I = -0.27(E'_B - E'_Y) + 0.74(E'_R - E'_Y)$ $E'_Q = 0.41(E'_B - E'_Y) + 0.48(E'_R - E'_Y)$	$E'_U = 0.493(E'_B - E'_Y)$ $E'_V = 0.877(E'_R - E'_Y)$			$D'_R = -1.902(E'_R - E'_Y)$ $D'_B = 1.505(E'_B - E'_Y)$	
2.6	Attenuation of colour difference signals	dB MHz E'_I { < 3 at 1.3; ≥ 20 at 3.6 E'_Q { < 2 at 0.4; < 6 at 0.5; ≥ 6 at 0.6	dB MHz E'_U < 2 at 1.3 E'_V > 20 at 3.6	dB MHz E'_U < 3 at 1.3 E'_V > 20 at 4		dB MHz D'_R ≤ 3 at 1.3 D'_B ≥ 30 at 3.5 Low frequency pre-correction not taken into account (7)	dB MHz E'_U < 3 at 1.3 E'_V > 20 at 3.6

See notes at the end of Table II.

TABLE II *(continued)*

Item	Characteristics	Colour television system					
		M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL (1)
2.7	Low frequency pre-correction of colour difference signals					For sinusoidal signals: $D'_R{}^* = A_{BF}(f) D'_R$ $D'_B{}^* = A_{BF}(f) D'_B$ $A_{BF}(f) = \frac{1 + j(f/f_1)}{1 + j(f/3f_1)}$ f = signal frequency (kHz) f_1 = 85 kHz (See Fig. 6 for the amplitude response) (8)	
2.8	Time-coincidence error between luminance and chrominance signals (µs)	< 0.05 Excluding pre-correction for receiver response					
2.9	Equation of composite colour signal	$E_M = E'_Y +$ $+ E'_Q \sin(2\pi f_{sc}' + 33°) +$ $+ E'_I \cos(2\pi f_{sc}' + 33°)$ where: E'_Y, see item 2.4 E'_Q and E'_I, see item 2.5 f_{sc}, see item 2.11 (See also Fig. 4*a*)	$E_M = E'_Y + E'_U \sin 2\pi f_{sc}' \pm E'_V \cos 2\pi f_{sc}'$ where: E'_Y, see item 2.4 E'_U and E'_V, see item 2.5 f_{sc}, see item 2.11 The sign of the E'_V component is the same as that of the sub-carrier burst (changing for each line) (see item 2.16 and Fig. 4*b*)			$E_M = E'_Y + G \cos 2\pi$ $(f_{OR}' + \Delta f_{OR} \int_0^t D'_R{}^* \, dt)$ or $E_M = E'_Y + G \cos 2\pi$ $(f_{OB}' + \Delta f_{OB} \int_0^t D'_B{}^* \, dt)$ alternately from line to line where: E'_Y, see item 2.4 f_{OR} and f_{OB}, see item 2.11 Δf_{OR} and Δf_{OB}, see item 2.12 $D'_R{}^*$ and $D'_B{}^*$, see item 2.7 G, see item 2.13	
2.10	Type of chrominance sub-carrier modulation	Suppressed-carrier amplitude-modulation of two sub-carriers in quadrature				Frequency modulation	

See notes at the end of Table II.

TABLE II *(continued)*

Item	Characteristics	Colour television system					
		M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL (1)
2.11	Chrominance sub-carrier frequency *(a)* nominal value and tolerance (Hz)	3 579 545 ± 10	3 575 611.49 ± 10	4 433 618.75 ± 5	4 433 618.75 ± 1 (9) (10)	f_{OR} = 4 406 250 ± 2000 f_{OB} = 4 250 000 ± 2000 (11)	3 582 056.25 ± 5
	(b) relationship between chrominance sub-carrier frequency f_{sc} and line frequency f_H	$f_{sc} = \frac{455}{2} f_H$	$f_{sc} = \frac{909}{4} f_H$	$f_{sc} = \left(\frac{1135}{4} + \frac{1}{625}\right) f_H$		Unmodulated sub-carrier at beginning of line 282 f_H for f_{OR} 272 f_H for f_{OB} (12)	$f_{sc} = \left(\frac{917}{4} + \frac{1}{625}\right) f_H$
2.12	Bandwidth of chrominance sidebands (quadrature modulation of sub-carrier) (kHz) or Frequency deviation of chrominance sub-carrier (frequency modulation of sub-carrier) (kHz)	f_{sc} +620 −1300	f_{sc} +600 −1300	f_{sc} +570 −1300 (13)	f_{sc} +1066 −1300	Nominal deviation $D'^{*} = 1$ (14) / Maximum deviation Δf_{OR} (15): 280 ± 9 (± 14) / +350 ± 18 (± 35) −506 ± 25 (± 50) Δf_{OB} (15): 230 ± 7 (± 11.5) / +506 ± 25 (± 50) −350 ± 18 (± 35)	f_{sc} +620 −1300

See notes at the end of Table II.

TABLE II *(continued)*

Item	Characteristics	Colour television system					
		M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL [1]
2.13	Amplitude of chrominance sub-carrier	$G = \sqrt{E'^2_I + E'^2_Q}$	$G = \sqrt{E'^2_U + E'^2_V}$	[16] [17]	[16]	$G = M_0 \frac{1 + j\,16F}{1 + j\,1.26F}$ where the peak-to-peak amplitude, $2M_0$ is 23 ± 2.5% of the luminance amplitude (between blanking level and peak-white) and $F = \frac{f}{f_0} - \frac{f_0}{f}$ where f_0 = 4286 kHz and f is the instantaneous sub-carrier frequency. The deviation of frequency, f_0, from its nominal value due to misalignment of the circuits concerned should not exceed ± 20 kHz. (See Fig. 7 for the amplitude response)	
2.14	Synchronization of chrominance sub-carrier	Sub-carrier burst on blanking back porch	Sub-carrier burst on blanking back porch				
	(g) Start of sub-carrier burst (see Fig. 1*a*) (μs)	4.71 to 5.71 (5.3 nominal) at least 0.38 μs after the trailing edge of line synchronization signal	5.8 ± 0.1 after epoch O_H	5.6 ± 0.1 after epoch O_H [18]			
	(h) Duration of sub-carrier burst (see Fig. 1*a*) (μs)	2.23 to 3.11 (9 ± 1 cycles)	2.52 ± 0.28 (9 ± 1 cycles)	2.25 ± 0.23 (10 ± 1 cycles)			2.51 ± 0.28 (9 ± 1 cycles)

See notes at the end of Table II.

TABLE II *(continued)*

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Characteristics</th><th colspan="6">Colour television system</th></tr>
<tr><th>M/NTSC</th><th>M/PAL</th><th>B, D, G, H, N/PAL</th><th>I/PAL</th><th>B, D, G, H, K, K1, L/SECAM</th><th>N/PAL ([1])</th></tr>
<tr><td>2.15</td><td>Peak-to-peak value of chrominance sub-carrier burst
(see Fig. 1*a*) ([19])</td><td>4/10 of difference between blanking level and peak white-level ± 10%</td><td colspan="3">3/7 of difference between blanking level and peak white-level ± 10%
For systems D and I the tolerance is ± 3%
([16]) ([17]) ([16])</td><td></td><td></td></tr>
<tr><td>2.16</td><td>Phase of chrominance sub-carrier burst
(see Fig. 1*a*)</td><td>180° relative to $(E'_B - E'_Y)$ axis
(see Fig. 4*a*)
In the NTSC sequence of four colour fields, field 1 is identified in accordance with Note ([20])
(see also Fig. 5*c*)</td><td colspan="3">135° relative to E'_U axis with the following sign (see Fig. 4*b*)
<table>
<tr><td rowspan="4">Line</td><td colspan="8">Field Number ([21])</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td colspan="8">Burst blanking sequence (see Figs. 5*a* and 5*b*)</td></tr>
<tr><td>I</td><td>II</td><td>III</td><td>IV</td><td>I</td><td>II</td><td>III</td><td>IV</td></tr>
<tr><td>even
odd</td><td>–
+</td><td>–
+</td><td>+
–</td><td>+
–</td><td>–
+</td><td>–
+</td><td>+
–</td><td>+
–</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>2.17</td><td>Blanking of chrominance sub-carrier</td><td>Following each equalizing pulse and also during the broad synchronizing pulses in the field-blanking interval</td><td>11 lines of field-blanking interval:
260 to 270
522 to 7
259 to 269
223 to 8
(See Fig. 5*b*)</td><td colspan="2">9 lines of the field-blanking interval:
lines 311 to 319 inclusive
623 to 6 inclusive
310 to 318 inclusive
622 to 5 inclusive
(See Fig. 5*a*)</td><td>*(a)* from leading edge of line-blanking signal up to $i = 5.6 \pm 0.2$ (μs) after epoch O_H, i.e. during $c + i$ (see Fig. 1*b*) ([22])
(b) During field-blanking interval, excluding frame identification signals, or, in countries where this is possible, during the whole of the field-blanking interval (see item 2.18)</td><td></td></tr>
</table>

See notes at the end of Table II.

TABLE II *(continued)*

Item	Characteristics	Colour television system					
		M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL (1)
2.18	Synchronization of chrominance sub-carrier switching during line blanking	See item 2.16. For signals used in programme integration, the tolerance on the coincidence between the reference sub-carrier and the horizontal synchronizing pulses in nominally 0 ± 40° of the reference sub-carrier	By E'_V chrominance component of sub-carrier burst (See item 2.16)			In the SECAM system, one of two colour synchronization methods can be chosen: - line identification: by chrominance sub-carrier reference signals on the line-blanking back porch (23) - by identification signals occupying 9 lines of field-blanking period: *(a)* line 7 to 15 in 1st and 3rd field *(b)* line 320 to 328 in 2nd and 4th field (See Fig. 9) (24) *Shape of video signals corresponding to identification signals:* For lines D'_R – Trapezoid with linear variation from beginning of line on 15 ± 5 µs from 0 up to level + 1.25 and then constant at the level + 1.25 ± 0.06 (± 0.13) (See Fig. 8)	

See notes at the end of Table II.

TABLE II *(continued)*

Item	Characteristics	Colour television system					
		M/NTSC	M/PAL	B, D, G, H, N/PAL	I/PAL	B, D, G, H, K, K1, L/SECAM	N/PAL ([1])
						For lines D'_B – Trapezoid with linear variation from the beginning of the line on 18 ± 6 μs (20 ± 10 μs) from 0 down to level − 1.52 and then constant at the level − 1.52 ± 0.07 (± 0.15) (see Fig. 8) ([15]) *Peak-to-peak amplitude of identification signals:* For lines D'_B: 500 ± 50 mV For lines D'_R: 540^{+40}_{-50} mV if amplitude of luminance signal (between blanking level and peak white) equals 700 mV *Maximum deviation during transmission of identification signals (kHz):* For lines D'_R: +350 ± 18 (± 35) For lines D'_B: −350 ± 18 (± 35) ([15])	

See notes next page.

(1) These values apply to the combination N/PAL used in Argentina. Only those values are given in this column which are different from the values given in the column B, G, H, N/PAL.

(2) For SECAM systems and for existing sets, it is provisionally allowed to use the following chromaticity coordinates for the primary colours and white:

	x	y	
Red	0.67	0.33	
Green	0.21	0.71	
Blue	0.14	0.08	
White	0.310	0.316	(C-white)

(3) In Japan, the chromaticity of studio monitors is adjusted to a D-white at 9300 K.

(4) The primary signals are pre-corrected so that the optimum quality is obtained with a display having the indicated value of gamma.

(5) In certain countries using the SECAM systems and in Japan it is also permitted to obtain the luminance signal as a direct output from an independent photo-electric analyser instead of from the primary signals.

(6) For the SECAM system, it is allowable to apply a correction to reduce interference distortions between the luminance and chrominance signals by an attenuation of the luminance signal components as a function of the amplitude of the luminance components in the chrominance band.

(7) This value will be defined more precisely later.

(8) The maximum deviations from the nominal shape of the curve (see Fig. 6) should not exceed ± 0.5 dB in the frequency range from 0.1 to 0.5 MHz and ± 1.0 dB in the frequency range from 0.5 to 1.3 MHz.

(9) When the signal originates from a portable or overseas source the tolerance on the frequency may be relaxed to ± 5 Hz. Maximum rate of variation of f_{SC} : 0.1 Hz/s.

(10) This tolerance may not be maintained during such operational procedures as "genlock".

(11) A reduction of the tolerance is desirable.

(12) The initial phase of the sub-carrier undergoes in each line a variation defined by the following rule:

From frame to frame: by 0°: 180°: 0°: 180° and so on, and also from line to line in either one of the following two patterns:

0°: 0°: 180°: 0°: 0°: 180°: and so on,
or 0°: 0°: 0°: 180°: 180°: 180°: and so on.

(13) f_{sc} ± 1300 kHz is adopted in the People's Republic of China.

(14) The unity value represents the amplitude of the luminance signal between the blanking level and the peak white-level.

(15) Provisionally, the tolerances may be extended up to the values given brackets.

(16) During transmission of a monochrome programme of significant duration, in order to ensure satisfactory operation of colour-killers in receivers, all signals having the same nominal frequency as the colour sub-carrier that appears in the line-blanking interval, should be attenuated by at least 35 dB below the peak-to-peak value of the burst given in item 2.15, column 3 of Table II, and shown as item 5 in Fig. 1.

(17) The value given in Note (16) is accepted on a tentative basis.

(18) Transmitter pre-correction for receiver group delay is not included.

(19) For the use of automatic gain control circuits, it is important that the burst amplitude should maintain the correct ratio with the chrominance signal amplitude.

(20) Field 1 of the sequence of four fields in the NTSC video signal is defined by a whole line between the first equalizing pulse and the preceding horizontal synchronizing pulse and a negative-going zero-crossing of the reference sub-carrier nominally at the 50% point of the first equalizing pulse. The zero-crossing of the reference sub-carrier shall be nominally coincident with the 50% point of the leading edges of all horizontal synchronizing pulses for programme integration at the studio.

(21) Field 1 of the sequence of eight colour fields is defined as that field, where the phase $\varphi\ E'_U$ of the extrapolated E'_U component (see item 2.5 of Table II) of the video burst at the hall amplitude point of the leading edge of the line synchronizing pulse of line 1 is in the range $-90° \leqslant \varphi\ E'_U < 90°$.

(22) The value of the tolerance will be defined more precisely later.

(23) The line identification method is preferable, because it will enable agreements to be reached subsequently on the suppression of frame identification signals in international programme exchanges. In the absence of such agreements, signals meeting the SECAM standard are regarded as comprising such identification signals.

In France, a decree of 14 March 1978 specified that colour TV receivers placed on sale on or after 1 December 1979 must use the line identification method of decoding [CCIR, 1982-86c].

(24) The order in which the identification signals D_R^* and D_B^* appear on the four fields of a complete cycle given in Fig. 9 is in conformity with Recommendation 469.

TABLE III – *Characteristics of the radiated signals (monochrome and colour)*

Item		Characteristics	M	N (1)	B, G	H	I	D, K	K1	L
1	Frequency spacing (see Fig. 10)	Nominal radio-frequency channel bandwidth (MHz)	6	6	B: 7 G: 8	8	8	8	8	8
2		Sound carrier relative to vision carrier (MHz)	+4.5 (2)	+4.5	+5.5 ±0.001 (3), (4), (5), (24)	+5.5	+5.9996 ±0.0005 (25)	+6.5 ±0.001	+6.5	+6.5
3		Nearest edge of channel relative to vision carrier (MHz)	−1.25	−1.25	−1.25	−1.25	−1.25	−1.25	−1.25	−1.25
4		Nominal width of main sideband (MHz)	4.2	4.2	5	5	5.5	6	6	6
5		Nominal width of vestigial sideband (MHz)	0.75	0.75	0.75	1.25	1.25	0.75	1.25	1.25
6	Minimum attenuation of vestigial sideband (dB at MHz) (6)		20 (−1.25) 42 (−3.58)	20 (−1.25) 42 (−3.5)	20 (−1.25) 20 (−3.0) 30 (−4.43) (7)	20 (−1.75) 20 (−3.0)	20 (−3.0) 30 (−4.43)	20 (−1.25) 30 (−4.33 ±0.1) (8) (9)	20 (−2.7) 30 (−4.3) ref.: 0 (+0.8)	15 (−2.7) 30 (−4.3) ref.: 0 (+0.8)
7	Type and polarity of vision modulations		C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F neg.	C3F pos.
8	Levels in the radiated signal (% of peak carrier)	Synchronizing level	100	100	100	100	100	100	100	< 6
		Blanking level	72.5 to 77.5	72.5 to 77.5 (75 ± 2.5)	75 ± 2.5 (10)	72.5 to 77.5	76 ± 2	75 ± 2.5	75 ± 2.5	30 ± 2
		Difference between black level and blanking level	2.88 to 6.75 (26)	2.88 to 6.75	0 to 2 (nominal)	0 to 7	0 (nominal)	0 to 4.5 (11)	0 to 4.5	0 to 4.5
		Peak white-level	10 to 15	10 to 15 (10 to 12.5)	10 to 12.5 (10) (12)	10 to 12.5	20 ± 2	10 to 12.5 (13) (14)	10 to 12.5	100 (≈ 110) (15)

See notes at the end of Table III.

TABLE III *(continued)*

Item	Characteristics	M	N (1)	B, G	H	I	D, K	K1	L
9	Type of sound modulation	F3E	F3E	F3E	F3E	F3E	F3E	F3E	A3E
10	Frequency deviation (kHz)	± 25	± 25	± 50	± 50	± 50	± 50	± 50	
11	Pre-emphasis for modulation (μs)	75	75	50	50	50	50	50	
12	Ratio of effective radiated powers of vision and (primary) sound (16)	10/1 to 5/1 (17)	10/1 to 5/1	20/1 to 10/1 (3) (18) (19)(24)	5/1 to 10/1	5/1 10/1 (20)(25)	10/1 to 5/1 (21)	10/1	10/1 10/1 to 40/1(27)
13	Pre-correction for receiver group-delay characteristics at medium video frequencies (ns) (see also Fig. 3)	0	$\begin{pmatrix} 1\ \text{MHz}\ 0 \pm 100 \\ 1\ \text{MHz}\ 0 \pm 100 \\ 1\ \text{MHz}\ 0 \pm 60 \end{pmatrix}$	(22)			(23a)		
14	Pre-correction for receiver group-delay characteristics at colour sub-carrier frequency (ns) (see also Fig. 3)	−170 (nominal)	$\left(-170\,^{+60}_{-40}\right)$	−170 (nominal) (22)			(23b)		

(1) The values in brackets apply to the combination N/PAL used in Argentina.

(2) In Japan, the values +4.5 ± 0.001 are used.

(3) In the Federal Republic of Germany, Italy, the Netherlands and Switzerland a system of two sound carriers is used, the frequency of the second carrier being 242.1875 kHz above the frequency of the first sound carrier. The ratio between vision/sound e.r.p. for this second carrier is 100/1. For further information on this **system** see Report 795. For stereophonic sound transmissions a similar system is used in Australia with vision/sound power ratios being 20/1 and 100/1 for the first and second sound carriers respectively.

(4) New Zealand uses a sound carrier displaced 5.4996 ±0.0005 MHz from the vision carrier.

(5) The sound carrier for single carrier sound transmissions in Australia may be displaced 5.5 ± 0.005 MHz from the vision carrier.

(6) In some cases, low-power transmitters are operated without vestigial-sideband filter.

(7) For B/SECAM and G/SECAM: 30 dB at −4.33 MHz, within the limits of ± 0.1 MHz.

(8) In some countries, members of the OIRT, additional specifications are in use:
(a) not less than 40 dB at −4.286 MHz ± 0.5 MHz,
(b) 0 dB from −0.75 MHz to +6.0 MHz,
(c) not less than 20 dB at ± 6.375 MHz and higher;
Reference: 0 dB at +1.5 MHz.

(9) In the People's Republic of China, the attenuation value at the point (−4.33 ± 0.1) has not yet been determined.

(10) Australia uses the nominal modulation levels specified for system I.

(11) In the People's Republic of China, the values 0 to 5 have been adopted.

(12) Italy is considering the possibility of controlling the peak white-level after weighting the video frequency signal by a low-pass filter, so as to take account only of those spectrum components of the signal that are likely to produce inter-carrier noise in certain receivers when the nominal level is exceeded. Studies should be continued with a view to optimizing the response of the weighting filter to be used.

(13) The USSR has adopted the value 15 ± 2%.

(14) A new parameter "white level with sub-carrier" should be specified at a later date. For that parameter, the USSR has adopted the value of 7 ± 2%.

(15) The peak white-level refers to a transmission without colour sub-carrier. The figure in brackets corresponds to the peak value of the transmitted signal, taking into account the colour sub-carrier of the respective colour television system.

(16) The values to be considered are:

- the r.m.s. value of the carrier at the peak of the modulation envelope for the vision signal. For system L, only the luminance signal is to be considered. (See Note (15) above);
- the r.m.s. value of the unmodulated carrier for amplitude-modulated and frequency-modulated sound transmissions.

(17) In Japan, a ratio of 1/0.15 to 1/0.35 is used. In the United States, the sound carrier e.r.p. is not to exceed 22% of the peak authorized vision e.r.p.

(18) It may be that the Austrian Administration will continue to use a 5/1 power ratio in certain cases, when necessary.

(19) Recent studies in India [CCIR, 1982-86f] confirm the suitability of a 20/1 ratio of effective radiated powers of vision and sound. This ratio still enables the introduction of a second sound carrier.

(20) The ratio 10/1 is used in the Republic of South Africa and in the United Kingdom.

(21) In the People's Republic of China, the value 10/1 has been adopted.

(22) In the Federal Republic of Germany and the Netherlands the correction for receiver group-delay characteristics is made according to curve B in Fig. 3*a)*. Tolerances are shown in the table under Fig. 3*a)*. From [CCIR, 1966-69] it is learned that Spain uses curve A. The OIRT countries using the B/SECAM and G/SECAM systems use a nominal pre-correction of 90 ns at medium video frequencies. In Sweden, the pre-correction is 0 ± 40 ns up to 3.6 MHz. For 4.43 MHz, the correction is −170 ± 20 ns and for 5 MHz it is −350 ± 80 ns. In New Zealand the pre-correction increases linearly from 0 ± 20 ns at 0 MHz to 60 ± 50 ns at 2.25 MHz, follows curve A of Fig. 3a from 2.25 MHz to 4.43 MHz and then decreases linearly to −300 ± 75 ns at 5 MHz. In Australia, the nominal pre-correction follows curve A up to 2.5 MHz, then decreases to 0 ns at 3.5 MHz, −170 ns at 4.43 MHz and −280 ns at 5 MHz. Based on studies on receivers in India, the receiver group delay pre-equalization proposed to be adopted in India at 1 MHz, 2 MHz, 3 MHz, 4.43 MHz and 4.8 MHz are +125 ns, +150 ns, +142 ns, −75 ns and −200 ns respectively. In Denmark, the precorrection at 0, 0.25, 1.0, 2.0, 3.0, 3.8, 4.43 and 4.8 MHz are 0, +5, +53, +75, +75, 0, -170 and -400 ns.

(23a) Not yet determined. The Czechoslovak Socialist Republic proposes +90 ns (nominal value).

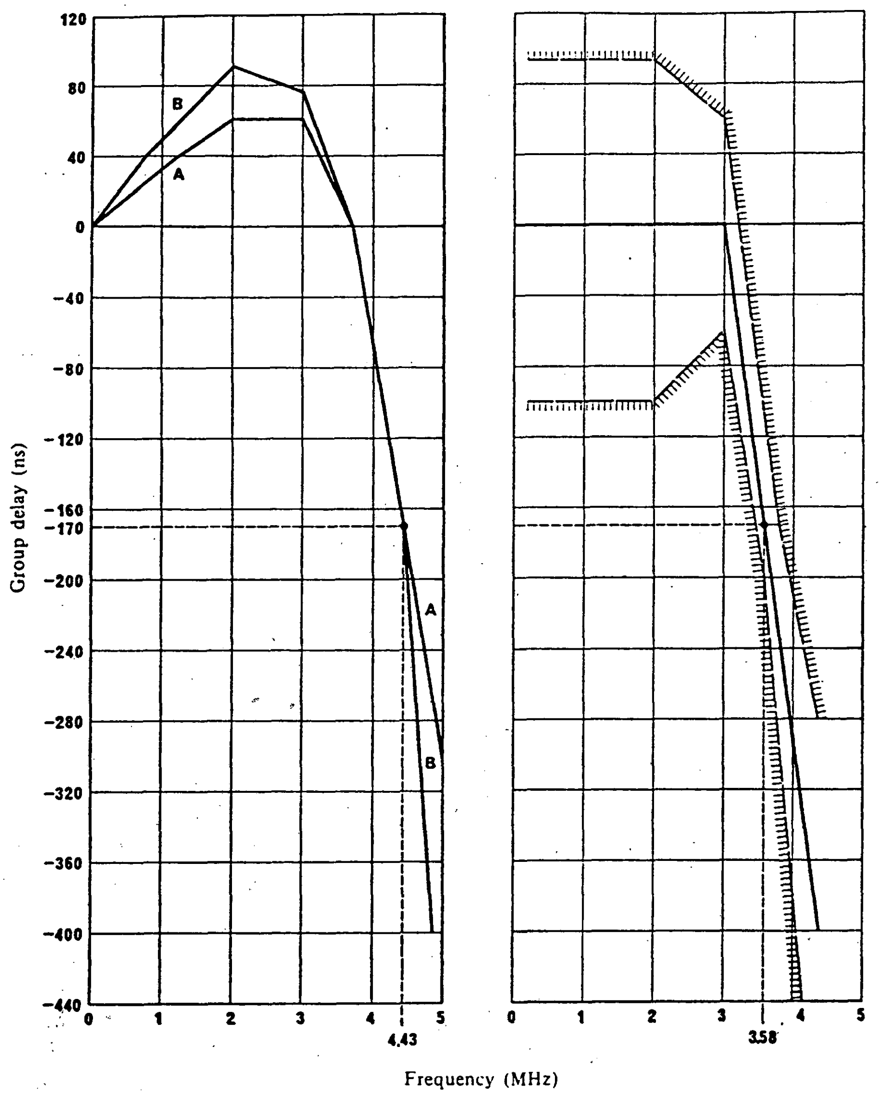
(23b) Not yet determined. The Czechoslovak Socialist Republic proposes +25 ns (nominal value).

(24) In Denmark, Finland, New Zealand, Sweden and Spain a system of two sound carriers is used. In Iceland and Norway the same system is being introduced. The second carrier is 5.85 MHz above the vision carrier and is DQPSK modulated with 728 kbit/s sound and data multiplex. The ratios between vision/sound power are 20/1 and 100/1 for the first and second carrier respectively. For further information, see Recommendation 707, Report 795 and Report 1214.

(25) In the United Kingdom, a system of two sound carriers is used. The second sound carrier is 6.552MHz above the vision carrierand is DQPSK modulated with a 728kbit/s sound and data multiplex able to carry two sound channels. The ratio between vision and sound e.r.p. for the second carrier is 100/1. Further information on this system is given in Report 795.

(26) In Japan, the values of 0 to 6.75 have been adopted.

(27) In France, experimental.



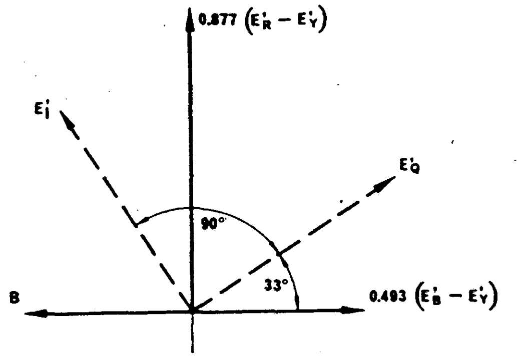
(a) B/PAL and G/PAL systems
(See Table III [22])

(b) M/PAL and M/NTSC systems

FIGURE 3 - *Curve of pre-correction for receiver group-delay characteristics*

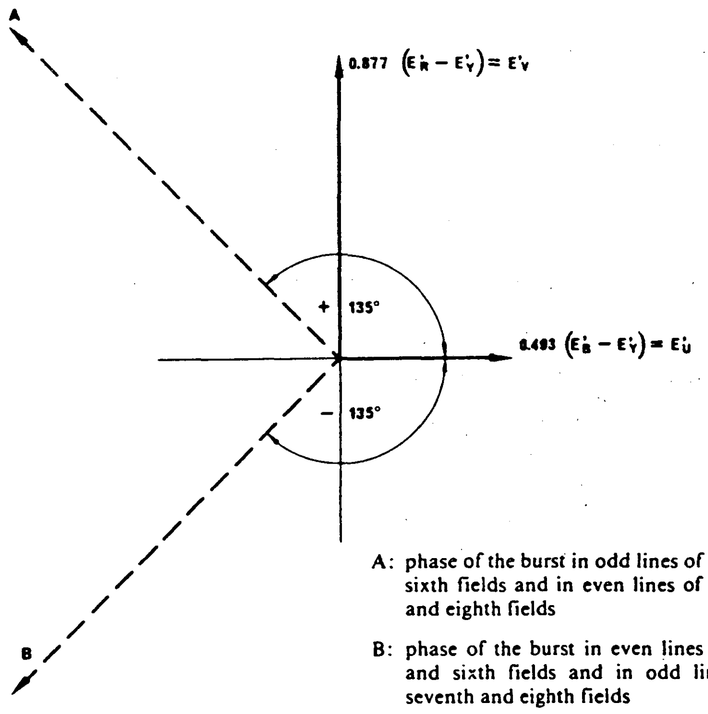
Nominal values and tolerances (ns)

Frequency (MHz)	Curve A	Curve B
0·25		$+ 5 \pm 0$
1·00	$+ 30 \pm 50$	$+ 53 \pm 40$
2·00	$+ 60 \pm 50$	$+ 90 \pm 40$
3·00	$+ 60 \pm 50$	$+ 75 \pm 40$
3·75	0 ± 50	0 ± 40
4·43	-170 ± 35	-170 ± 40
4·80	-260 ± 75	-400 ± 90



B: phase of the burst

a) NTSC system



A: phase of the burst in odd lines of the first, second, fifth and sixth fields and in even lines of the third, fourth, seventh and eighth fields

B: phase of the burst in even lines of the first, second, fifth and sixth fields and in odd lines of the third, fourth, seventh and eighth fields

b) PAL system

FIGURE 4 – *Chrominance axes and phase of the burst*

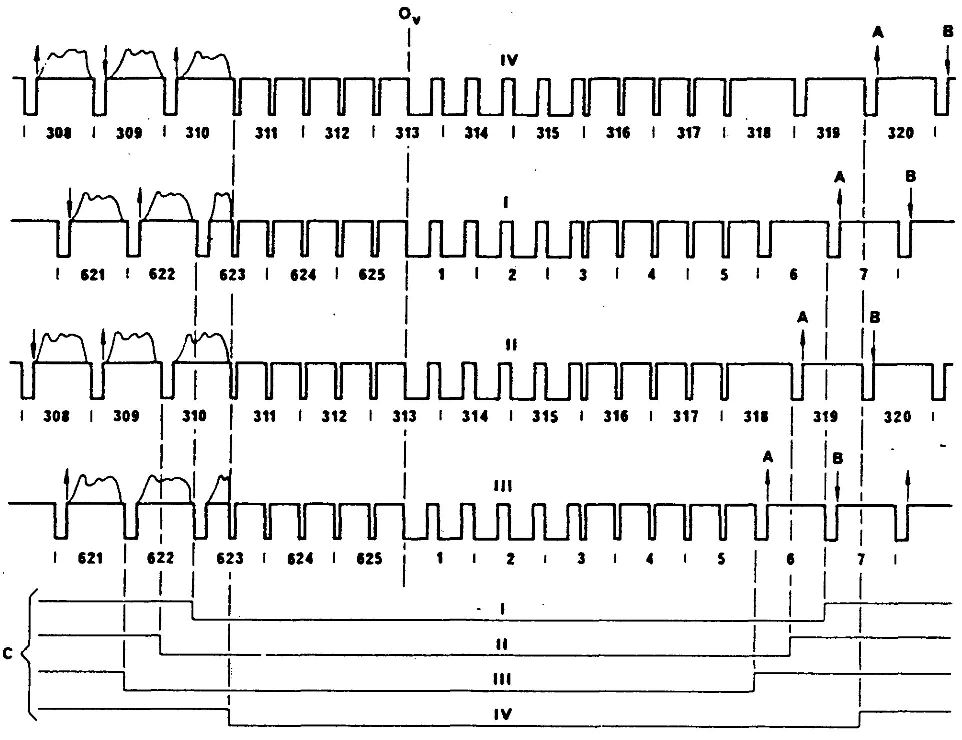


FIGURE 5a – *Burst-blanking sequence in the B, G, H and I/PAL systems*

O_V: field-synchronizing datum

I, II, III, IV: first and fifth, second and sixth, third and seventh, fourth and eighth fields (see item 2.16 of Table II)

A: phase of burst: nominal value +135°

B: phase of burst: nominal value −135°

C: burst-blanking intervals

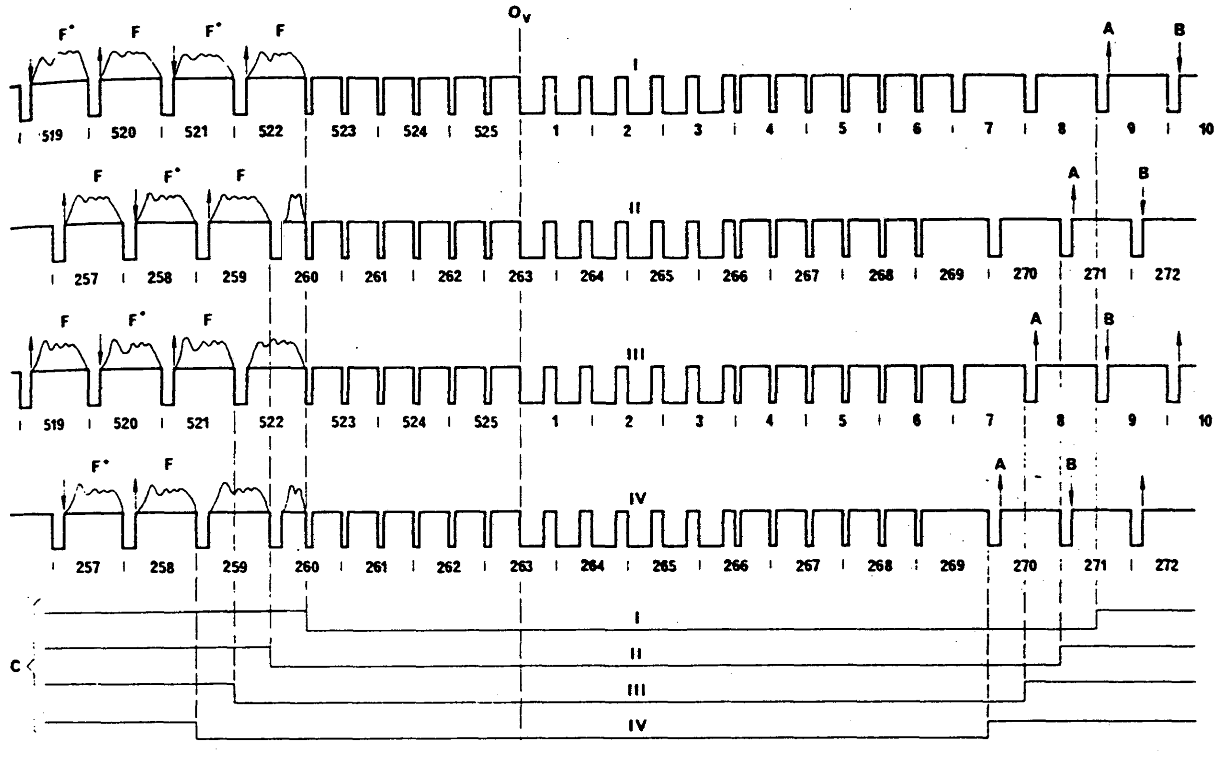


FIGURE 5b – *Burst-blanking sequence in M/PAL system*

O_V:	field-synchronizing datum
I, II, III, IV:	first and fifth, second and sixth, third and seventh, fourth and eighth fields (see item 2.16 of Table II)
A:	phase of burst: nominal value + 135°
B:	phase of burst: nominal value – 135°
C:	burst-blanking intervals

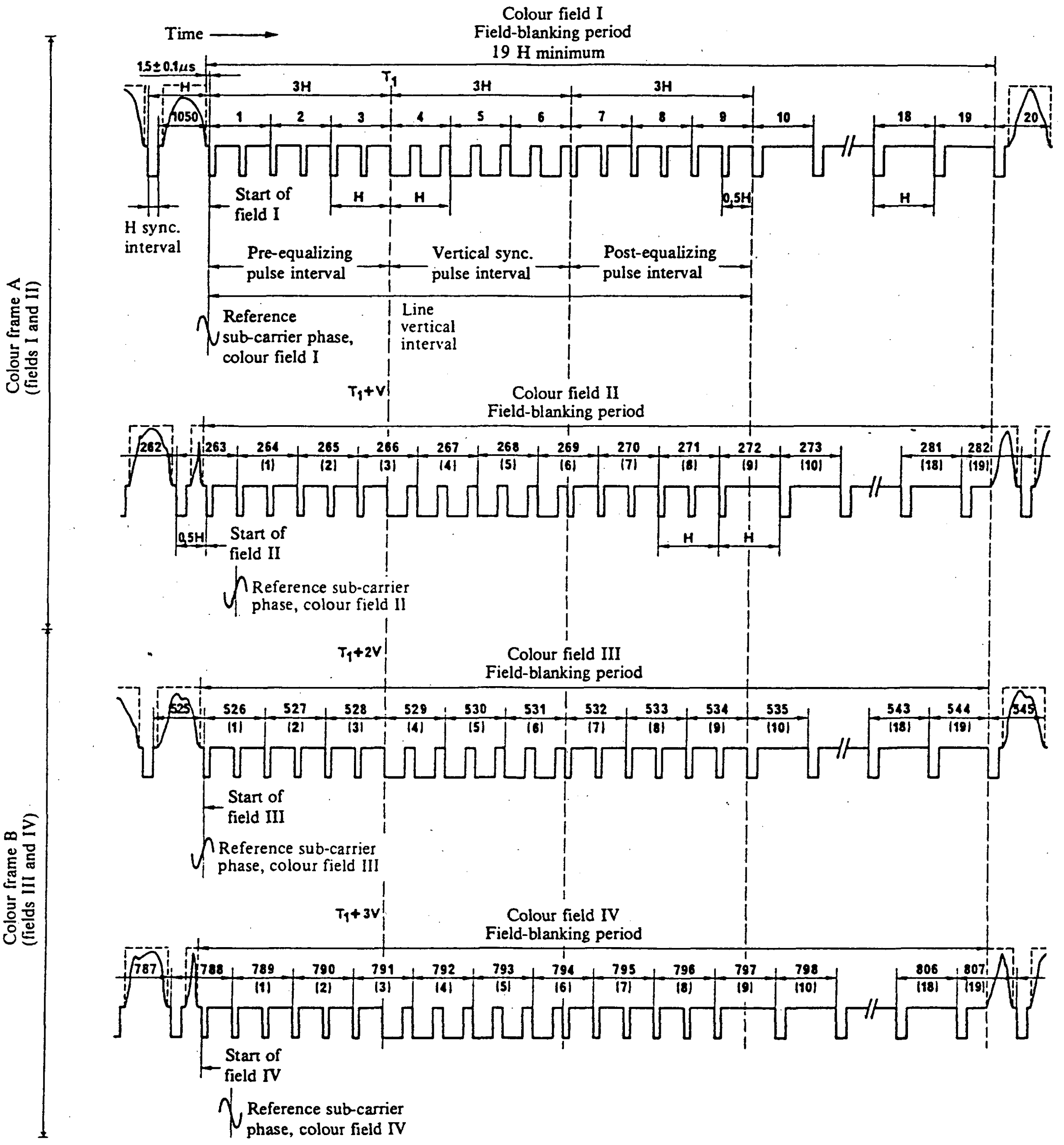


FIGURE 5c – *Burst-blanking sequence in M/NTSC System*

Note. – The numbering of specific lines is in accordance with new engineering practice. Line numbers in parentheses ( ) represent an alternative method of line numbering used in some systems in some countries.

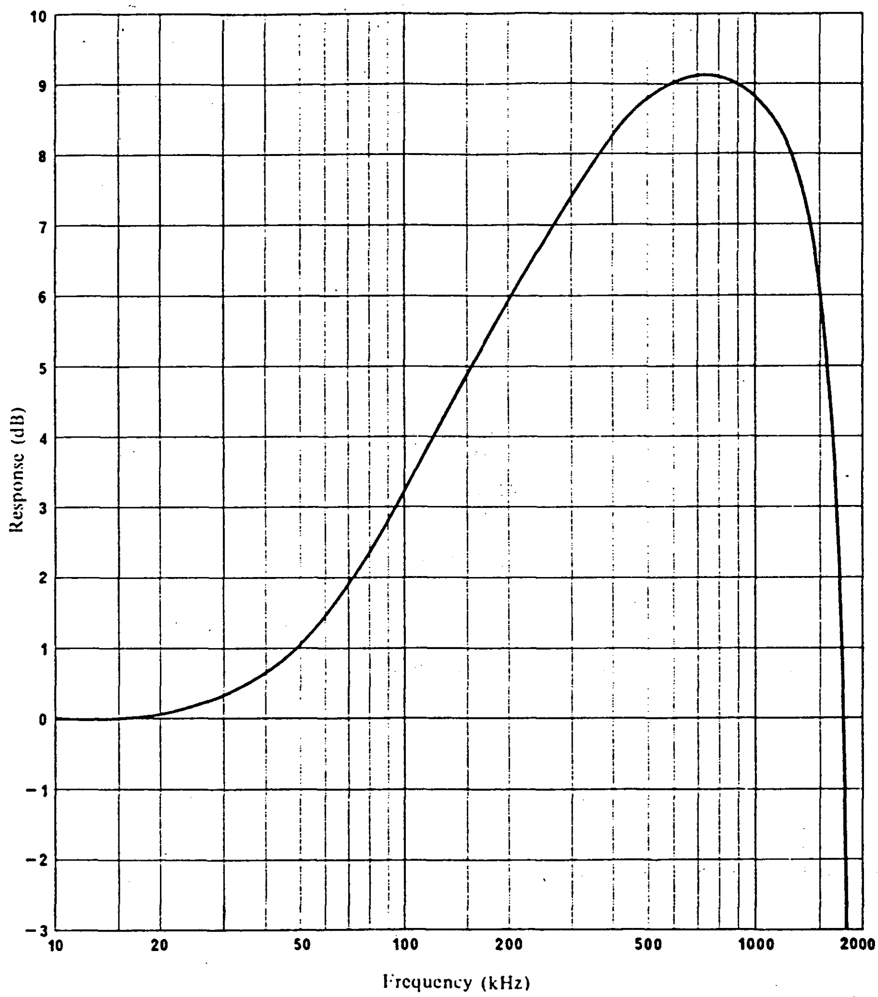


FIGURE 6 – *Nominal response of transfer function resulting from the video-frequency precorrection circuit $A_{BF}(f)$ and the low-pass filter (See Table II, item 2.7)*

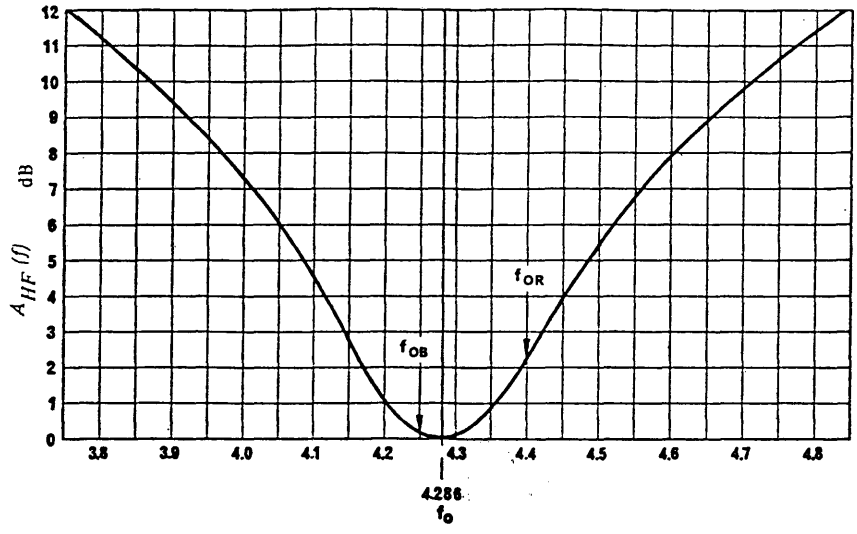


FIGURE 7 – *Attenuation curve of frequency correction $A_{HF}(f)$*

Deviations from the nominal curve outside point f_0 must not exceed ± 0.5 dB

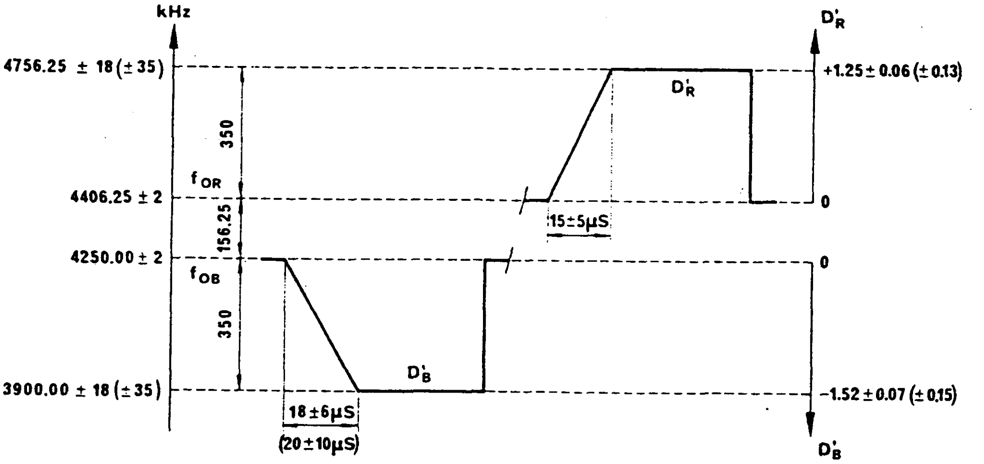


FIGURE 8 – *Shape of video signals corresponding to the chrominance synchronization signals*

The value 1 represents the amplitude of the luminance signal between the blanking level and the white level. Provisionally, the tolerances may be extended up to the values given in brackets.

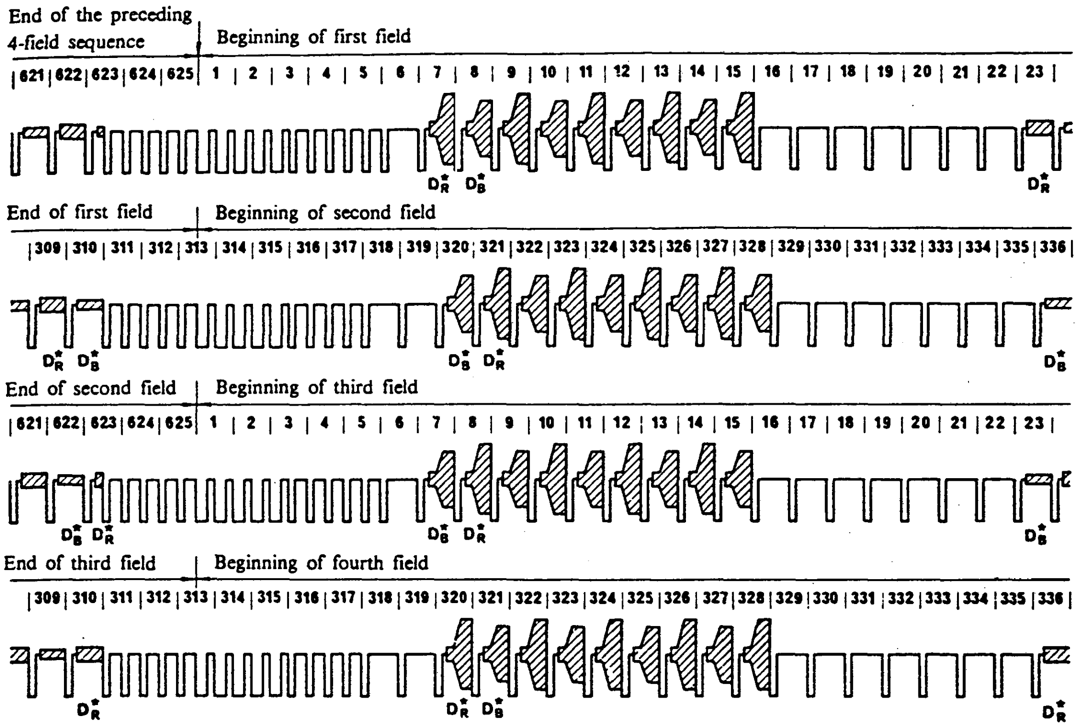


FIGURE 9 – *Sequence of D_R^* or D_B^* signal over four consecutive fields*

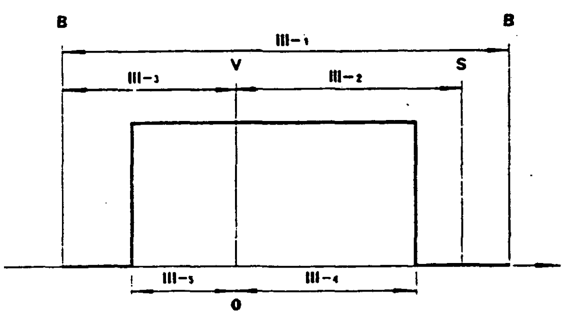


FIGURE 10 – *Significance of items 1 to 5 in Table III*

B : Channel limit
V : Vision carrier
S : Sound carrier

REFERENCES

CCIR Documents

[1966-69]: XI/170 (Spain).

[1978-82]: 11/251 (EBU).

[1982-86]: **a.** 11/286 (USSR); **b.** 11/273 (United Kingdom); **c.** 11/365 (Australia); **d.** 11/376 (Germany (Federal Republic of)); **e.** 11/297 (France); **f.** 11/397 (India).

/1986-90/: 11/64 (Japan).

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VAN DAEL, J. W. [December, 1978] Disturbances occurring at edits on PAL 625-line video tapes. *EBU Rev. Tech.*, 172, 265-281.

CCIR Documents

[1966-69]: XI/136 (United Kingdom); XI/194 (Netherlands).

[1970-74]: 11/1 (EBU); 11/63 (USA); 11/276 (Germany (Federal Republic of)).

[1974-78]: 11/54 (OIRT); 11/440 (OIRT).

ANNEX I

SYSTEMS USED IN VARIOUS COUNTRIES/GEOGRAPHICAL AREAS

Explanation of signs used in the table:

* : planned (whether the standard is indicated or not);

– : not yet planned, or no information received;

/ : the abbreviation following the stroke indicates the colour transmission system in use (NTSC, PAL or SECAM).

(Figures in brackets refer to the notes following the table.)

Country/Geographical area	System used in bands: I/III VHF broadcasting (Band 8)		IV/V UHF broadcasting (Band 9)	
Afganistan (Democratic Republic of)	D/SECAM		–	
Algeria (Algerian Democratic and Popular Republic)	B/PAL	(8)	G/PAL	(8)
Germany (Federal Republic of)	B/PAL	(12)	G/PAL	(12)
Angola (People's Republic of)	I/PAL	(8)	I/PAL*	(8)
Netherlands Antilles	M		–	
Saudi Arabia (Kingdom of)	B/SECAM,PAL	(8)	G/SECAM	(8)
Argentine Republic	N/PAL		N/PAL	
Australia	B/PAL	(11)	B/PAL	(11)
Austria	B/PAL		G/PAL	(1)
Bahrain (State of)	B/PAL		G/PAL	
Bangladesh (People's Republic of)	B/PAL		–	
Belgium	B/PAL		H/PAL	
Benin (People's Republic of)	K1/SECAM	(8)	K1/SECAM	(8)
Bermuda	M/NTSC		–	
Burma (Socialist Republic of the Union of)	M/NTSC		–	
Bolivia (Republic of)	M/NTSC		M/NTSC	
Botswana	I/PAL	(8)	I/PAL*	(8)
Brazil (Federative Republic of)	M/PAL		M/PAL	
Brunei Darussalam	B/PAL		–	
Bulgaria (People's Republic of)	D/SECAM		K/SECAM	
Burkina Faso	K1/SECAM	(8)	K1*/SECAM	(8)
Burundi (Republic of)	K1/SECAM*	(8)	K1/SECAM*	(8)
Cameroon (Republic of)	B/PAL		G*/PAL	
Canada	M/NTSC		M/NTSC	
Cape Verde (Republic of)	K1/SECAM*	(8)	K1/SECAM*	(8)
Central African Republic	K1/SECAM*	(8)	K1/SECAM*	(8)
Chile	M/NTSC		M/NTSC	
China (People's Republic of)	D/PAL		D/PAL	
Cyprus (Republic of)	B/SECAM		G/SECAM	
Colombia (Republic of)	M/NTSC		M*	
Comores (Islamic Federal Republic of)	K1/SECAM*	(8)	K1/SECAM*	(8)
Congo (People's Republic of the)	K1/SECAM*	(8)	K1/SECAM*	(8)
Korea (Republic of)	M/NTSC		M/NTSC	
Costa Rica	M/NTSC		M/NTSC	
Côte d'Ivoire (Republic of)	K1/SECAM	(8)	K1/SECAM*	(8)
Cuba	M/NTSC		M/NTSC	
Denmark (Including Greenland and Faeroe Islands)	B/PAL	(13)	G/PAL	(13)
Djibouti (Republic of)	B/SECAM	(8)	–	(8)
Egypt (Arab Republic of)	B/SECAM	(8)	G/SECAM	(8)
El Salvador (Republic of)	M/NTSC			
United Arab Emirates	B/PAL		G/PAL	
Spain	B/PAL	(13)	G/PAL	(13)
United States of America	M/NTSC		M/NTSC	
Ethiopia	B,G/PAL	(8)	G/PAL*	(8)
Finland	B/PAL	(13)	G/PAL	(13)
France	L/SECAM	(7)(14)	L/SECAM	(7)(14)
Gabonese Republic	K1/SECAM	(8)	K1/SECAM*	(8)
Gambia (Republic of the)	I/PAL	(8)	I/PAL*	(8)
Ghana	B/PAL	(8)	B/PAL*	(8)
Gibraltar	B/PAL		G/PAL	
Greece	B/SECAM		G/SECAM	
Guinea (Republic of)	K1/SECAM,PAL*	(8)	K1/PAL*	(8)
Guinea-Bissau (Republic of)	I/PAL*	(8)	I/PAL*	(8)
Equatorial Guinea (Republic of)	B/PAL	(8)	G/PAL*	(8)
Hong Kong	–		I/PAL	
Hungarian People's Republic	D/SECAM		K/SECAM	
India (Republic of)	B/PAL		–	
Indonesia (Republic of)	B/PAL		–	
Iran (Islamic Republic of)	B/SECAM		G/SECAM	
Iraq (Republic of)	B,G/SECAM	(8)	G/SECAM*	(8)
Ireland	I/PAL	(3)	I/PAL	(3)
Iceland	B/PAL	(13)	G*	(13)
Israel (State of)	B/PAL		G/PAL	(5)
Italy	B/PAL	(12)	G/PAL	(12)
Jamaica	N		–	
Japan	M/NTSC		M/NTSC	
Jordan (Hashemite Kingdom of)	B		G*	

Country/Geographical area	System used in bands: I/III VHF broadcasting (Band 8)		IV/V UHF broadcasting (Band 9)	
Kenya (Republic of)	B/PAL	(8)	B,G/PAL*	(8)
Kuwait (State of)	B/PAL	(8)	G/PAL*	(8)
Lesotho (Kingdom of)	I*/PAL	(8)	I*/PAL	(8)
Liberia (Republic of)	B/PAL	(8)	G/PAL*	(8)
Libya (Socialist People's Libyan Arab Jamahiriya)	B,G/PAL	(8)	B,G/PAL*	(8)
Luxembourg	B/PAL		G/PAL, L/SECAM	
Madagascar (Democratic Republic of)	K1/SECAM	(8)	K/SECAM*	(8)
Malaysia	B/PAL		G/PAL	
Malawi	I/PAL	(8)	I/PAL*	(8)
Maldives	B/PAL		–	
Mali (Republic of)	B/SECAM	(8)	G/SECAM*	(8)
Malta (Republic of)	B/PAL		–	
Morocco (Kingdom of)	B,G/SECAM	(8)	G/SECAM	(8)
Mauritius	B,G/SECAM	(8)	B,G/SECAM*	(8)
Mauritania (Islamic Republic of)	B/SECAM	(8)	B/SECAM*	(8)
Mexico	M/NTSC		M/NTSC	
Monaco	L/SECAM		G/PAL, G/SECAM	
Mongolian People's Republic	D/SECAM		–	
Montserrat	M/NTSC		–	
Mozambique (People's Republic of)	G/PAL*	(8)	G/PAL	(8)
Namibia	I/PAL	(8)	I/PAL	(8)
Niger (Republic of the)	K1/SECAM	(8)	K1/SECAM	(8)
Nigeria (Federal Republic of)	B/PAL	(8)	I/PAL*	(8)
Norway	B/PAL	(13)	G/PAL	(13)
New Zealand	B/PAL	(13)(10)	G/PAL	(13)(10)
Oman (Sultanate of)	B/PAL		G/PAL	
Uganda (Republic of)	B/PAL	(8)	-	(8)
Pakistan (Islamic Republic of)	B/PAL		G/PAL	
Panama (Republic of)	M/NTSC		M*/NTSC	
Papua New Guinea	B/PAL		G/PAL	
Netherlands (Kingdom of the)	B/PAL	(12)	G/PAL	(12)
Peru	M/NTSC		M/NTSC	
Poland (People's Republic of)	D/SECAM		K/SECAM	
Portugal	B/PAL		G/PAL	
Qatar (State of)	B/PAL		G/PAL	
Syrian Arab Republic	B/PAL		G/PAL	
German Democratic Republic	B/SECAM		G/SECAM	
Democratic People's Republic of Korea	D/PAL		K/PAL	
Roumania (Socialist Republic of)	D/PAL		K/PAL	
United Kingdom of Great Britain and Northern Ireland	–	(4)	I/PAL	(13)
Rwanda (Republic of)	K1/SECAM*	(8)	K1/SECAM*	(8)
St. Christopher and Nevis	M/NTSC		–	
Sao Tome and Principe (Dem. Rep. of)	B/PAL	(8)	-	(8)
Senegal (Republic of the)	K1/SECAM	(8)	K1/SECAM*	(8)
Seychelles	B/PAL	(8)	-	(8)
Sierra Leone	B/PAL	(8)	G/PAL*	(8)
Singapore (Republic of)	B/PAL		G*/PAL	(9)
Somali Democratic Republic	B/PAL	(8)	G/PAL*	(8)
Sudan (Republic of the)	B/PAL	(8)	G/PAL*	(8)
Sri Lanka (Democratic Socialist Republic of)	B		–	
South Africa (Republic of)	I/PAL		I/PAL	
Sweden	B/PAL	(13)	G/PAL	(13)
Switzerland (Confederation of)	B/PAL		G/PAL	(6)
Surinam (Republic of)	M/NTSC		–	
Tanzania (United Republic of)	I/PAL	(8)	I/PAL	(8)
Chad (Republic of the)	K1/SECAM*	(8)	K1/SECAM*	(8)
Czechoslovak Socialist Republic	D/SECAM		K/SECAM	
Thailand	B/PAL		G/PAL*	
Togolese Republic	K1/SECAM	(8)	K1/SECAM*	(8)
Tunisia	B/SECAM, PAL	(2)	G/SECAM, PAL	(2)
Turkey	B/PAL		G/PAL	
Union of Soviet Socialist Republics	D/SECAM		K/SECAM	
Uruguay (Oriental Republic of)	N/PAL		–	
Venezuela (Republic of)	M		–	
British Virgin Islands	M/NTSC		–	
Viet Nam (Socialist Republic of)	D/SECAM		K/SECAM	
Yemen Arab Republic	B/PAL	(8)	G/PAL*	(8)
Yemen (People's Democratic Rep. of)	B/PAL	(8)	-	(8)
Yugoslavia (Socialist Federal Republic of)	B/PAL		G/PAL	
Zaire (Republic of)	K1/SECAM	(8)	K1/SECAM*	(8)
Zambia (Republic of)	G/PAL*	(8)	G/PAL*	(8)
Zimbabwe (Republic of)	G/PAL*	(8)	G/PAL*	(8)

Note 1. – Austria reserves the right to the possible use of additional frequency-modulated sound carriers, in the band between 5.75 and 6.75 MHz, in relation to the picture carrier.

Note 2. – In Tunisia SECAM is used for broadcasting the national programmes; PAL is used for rebroadcasting other programmes.

Note 3. – System I will be used at all stations though with a vision to sound ratio of up to 10/1. In addition Ireland reserves the right to the possible use of an additional sound carrier in the band between 5.5 MHz and 6.75 MHz in relation to the vision carrier.

Note 4. – The United Kingdom has ceased to use Bands I and III for television broadcasting.

Note 5. – No final decision has been taken about the width of the residual sideband, but for planning purposes this country is willing to accept the assumption of a residual sideband 1.25 MHz wide.

Note 6. – The Swiss Administration is planning to use additional frequency-modulated sound carriers, in the frequency interval between the spacings of 5.5 and 6.5 MHz in relation to the picture carrier, at levels lower than or equal to the normal level of the sound carrier, for additional sound-tracks or for sound broadcasting.

Note 7. – In the French Overseas departments and territories, the system K1 is used instead of L/SECAM which is used in the metropolitan area.

Note 8. - This information has been taken from the preliminary requirements file as submitted by the administrations concerned to the ITU in preparation of the African Television Planning Conference AFBC(2). In a number of cases transmitters using different systems as those indicated in the requirements file may continue to operate for a transitional period.

Note 9. – Singapore reserves the right to use additional frequency-modulation sound channels in the band between 5.5 and 6.5 MHz in relation to the picture carrier, for additional sound channels for sound broadcasting.

Note 10. – In New Zealand ——— the modulation levels are identical to those of System I.

Note 11. – Australia uses nominal modulation levels as specified for System I. For stereophonic sound transmission, an additional f.m. carrier is used similar to the system used in the Federal Republic of Germany .

Note 12. - The Federal Republic of Germany, Italy and the Netherlands use an additional f.m. carrier for stereophonic or two-channel sound transmission.

Note 13. - Denmark, Spain, Finland, Iceland, Norway, New Zealand, United Kingdom and Sweden have approved the use of an additional digital carrier for stereophonic or multichannel sound transmission.

Note 14. - In France, the use of an additional digital carrier for stereophonic or multichannel sound transmission is being investigated.

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[1986-90] : 11/41 (United Kingdom); 11/44 (Sweden); 11/64 (Japan); 11/79 (France); 11/80 (France); 11/142 (Netherlands).

ANNEX II

CHIEF TECHNICAL CHARACTERISTICS OF THE SECAM IV COLOUR TELEVISION SYSTEM

1. Signals transmitted

SECAM IV is compatible with standard black-and-white 625-line television systems, except system N. The luminance signal is obtained from gamma-corrected primary signals E'_R, E'_G, E'_B, and corresponds to the equation:

$$E'_Y = 0.30\ E'_R + 0.59\ E'_G + 0.11\ E'_B$$

The colour information is transmitted by two colour-difference signals:

$$D'_R = \frac{1}{1.14}(E'_R - E'_Y)$$

$$D'_B = \frac{1}{2.03}(E'_B - E'_Y)$$

Before modulation, the frequency band of the colour-difference signals occupies more than 1.5 MHz.

2. Transmission procedure

The colour-difference signals are transmitted by modulation of a sub-carrier. They are differentiated from one line to the next as follows:

Signal transmitted during one of the lines

$$E_{S1} = \left\{\sqrt{D'^2_B + D'^2_R} + E_p\right\} \cos\left[\omega_0 t + \varphi(t)\right]$$

Signal transmitted during the following line

$$E_{S2} = \left\{\sqrt{D'^2_R + D'^2_B} + E_p\right\} \cos(\omega_0 t + \varphi_0)$$

where:

E_p is a d.c. voltage equal to 10% of the maximum signal,

$$\varphi(t) = \text{arc tan}\ (D'_B / D'_R)$$

3. Frequency of the colour sub-carrier

The frequency of the colour sub-carrier is equal to: f_0 = 4.43361875 MHz. It is related to the line sweep frequency, f_H = 15 625 Hz, by the following equation:

$$f_0 = (284 - 1/4)\ f_H + 25\ \text{Hz}.$$

4. Colour synchronization signal

The receiver switch is synchronized by synchronization signals transmitted with the composite video signal. They represent six wave trains of the colour sub-carrier, each train lasting about 40 µs. They are transmitted during the field returns in the 6th-11th lines of the first field and in the 319th-324th lines of the second field. During the even lines, the sub-carrier phase in the train is $\varphi = 90°$, and during all the odd lines $\varphi = 180°$. The amplitude of each wave train is equal to 30% of the composite signal E'_Y measured between the white and black levels.

5. Reception procedure

The colour-difference signals D'_R and D'_B are obtained by multiplication of the transmitted signals $E_{(2n+1)}$ and E_{2n}, each signal being delayed in turn by the duration of one line. The level of the signal E_{2n} must be 10 to 20 times higher than that of the signal $E_{(2n+1)}$.

To obtain the correct polarity for the signals E'_{B-Y} and E'_{R-Y} at each line, a switch working to the line periodicity is used.

REPORT 1077-1

ENHANCED 4:3 ASPECT RATIO TELEVISION SYSTEMS

(Question 42/11)

(1986-1990)

1. Introduction

Since the development of electronic television, the art has experienced a continuous evolutionary development which has produced a stream of improvements in the quality of pictures displayed to the viewer. A quantum step in quality occurred with the introduction of colour. New digital technology now offers storage, filtering and processing capabilities that will permit separate scanning standards for the picture source, emission and in the display, thereby providing increased quality through conventional television systems. New distribution media having wider bandwidth, such as broadcasting satellites, will permit new services with increased definition and wider aspect ratios.

2. Definition of terms

The term *enhanced television* designates a number of different improvements applicable to 525/60 and 625/50 television systems, providing an aspect ratio of 4 : 3 or wider, either with unchanged or with new emission standards.

The term enhanced television is used here to include all television systems (from source to display) not covered by Report 624 (Conventional television systems) and Report 801 (High definition television). It is noted that the signal format may change at different parts of the signal chain.

Enhanced television systems may be classified according to the following parameters:

Aspect ratio - either normal aspect ratio (4:3) or wider aspect ratio (for example, 16:9). Enhancements not involving a wider aspect ratio are described in this report. Wider aspect ratio systems are described in Report 1220.

Signal format - either composite (based on NTSC, PAL or SECAM) or component (for example, MAC systems).

It should be noted that there exists no clear definition of some of the terms widely used in the description of enhanced television systems. For example:

Compatibility: Various degrees of compatibility are possible. These range from full compatibility with existing systems, through systems that share the same scanning formats, to systems that have no direct compatibility with existing systems. The compatibility can also apply only to parts of the systems, for example, receiver compatibility.

Resolution: Enhanced television systems do not necessarily imply the provision of increased resolution; in some circumstances the resolution may be reduced as a result of other enhancements, such as provision of a wider aspect ratio.

3. Areas of possible 4:3 enhancements

Enhancements to conventional television systems are expected to be introduced in the areas listed below, all of which will contribute, in a varying degree, to improving the overall quality of the received television picture:

- alias effects generated by the scanning process;
- luminance/colour difference cross-effects;
- signal processing capability;
- generation of moiré and non-linear signal distortion in video tape recorders;
- immunity to transmission impairments;
- receiver decoding and display techniques.

4. Enhancement ———of various signal formats

4.1 *Composite formats*

The composite signal formats NTSC, PAL and SECAM suffer from noticeable signal impairment due to cross colour and cross luminance. Significant quality improvements can be achieved by the use of multi-dimension separation filters based on line stores or frame stores. Complementary pre-filtering of the video before colour encoding can further improve picture quality.

Methods for achieving some of these improvements are discussed in the references [Khleborodov, 1971; Wendland, 1979; Clarke, 1981; Jackson and Tan, 1981; Tonge, 1981; Schönfelder, 1983].

The British Broadcasting Corporation demonstrated the use of picture stores for PAL decoding to a joint EBU/SMPTE Meeting in London in April 1980 [Clarke, 1981] and the effects of motion-adaptive luminance/chrominance separation methods at the International Broadcast Convention (IBC) in 1982 [Clarke, 1982].

The picture quality possible from the use of field stores in the receiver to process conventional PAL signals was demonstrated by Philips N.V. at the International Television Symposium at Montreux in 1983.

When appropriate filtering is applied ahead of the display, further improvements in the effective vertical resolution can be achieved by filtering at the source. The so-called Kell effect, that results from the excess Nyquist margin in the vertical sampling (scanning) of the image that must be allowed at the camera to avoid aliasing, reduces the effective vertical resolution of a television system.

Studies in the Federal Republic of Germany have shown that oversampling (double line-rate scanning) at the camera, followed by vertical filtering and aperture corrections, followed by subsampling (selecting alternate lines) for transmission, can increase the Kell factor to a number approaching unity, thus increasing the effective vertical resolution of a television system by a factor of 30-40%. When this technique is combined with display filtering (§ 6), much larger increases in vertical resolution should be possible [Wendland, 1979].

The theoretical aspects of source and display filtering are presented in [Tonge, 1981].

Work has been reported in numerous publications in the United States, Japan and in other countries on investigations to devise enhancements to the composite NTSC system. Some of these ideas are applicable to PAL and work on them is proceeding in research institutes in Europe.

In Japan an NTSC-compatible enhanced television system, known as EDTV-1, described in [CCIR, 1986-90a] has been operational since the end of August 1989. The new system includes hardware for five key techniques: Higher resolution signal sources, pre-compensation of detail in highly saturated colour pictures, adaptive emphasis of high frequency components in the luminance signal, insertion of a ghost-cancelling reference (GCR) signal for ghost reduction in television receivers as shown in Report 478, and receivers with 525 line progressive display and three dimensional Y/C separation filters. Subjective tests using 18 still pictures showed an improvement of about 1.5 grades on the CCIR 7-point comparison scale. Ghost interference, evaluated as grade 2.5 on a 5-point impairment scale, was improved to better than grade 4 at most of the locations tested.

4.2 ——— *Component formats*

Further improvements in picture quality can be obtained by the use of signals in analogue component form due to the absence of luminance/chrominance cross-talk, the possible expansion of colour difference bandwidth and the elimination of artifacts caused by the high-frequency and high-amplitude sub-carrier present in composite systems.

The digital television experiments that preceded the adoption of Recommendation 601 clearly showed the advantages of handling video signals in component rather than composite form.

The use of analogue components may be viewed as either an evolutionary step towards the all-digital studio based on Recommendation 601 or as a system which in itself provides an adequate level of performance except in certain specialized areas. In both cases a high level of compatibility should exist between the digital component signals, the analogue component forms used in many portable equipments, the analogue component forms used in the studio and for satellite broadcasting, and the relevant composite signals.

When the main concern is to maintain compatibility with existing equipments and infra-structures, the work reported in [CCIR, 1982-86a, b] indicates that subject to further study a MAC 3-1-0 time compression and time-division multiplex coding is feasible with slight modifications to existing equipment, and that a MAC 4-2-0 coding is feasible with more major modifications. Experiments have shown that the pictures obtained with a MAC 3-1-0 coding are clearly superior to those obtained with SECAM coding. Existing analogue recording, distribution and switching equipment was used in the studio, and mixing options were proposed. Re-utilization of existing equipment would permit a flexible transition to digital operation.

The use of video, in component form, has many advantages for the studio compared to composite video, when critical operations such as colour matte and picture manipulation are considered. The CCIR has already defined a signal format (see Recommendation 601) and suggested an interface arrangement (see Recommendation 656) for a digital component signal and there is now a need to define equivalent signal forms and interfaces for the analogue component signal, thus allowing the benefits of components to be realized at an early date. The technology for analogue component equipment is a small extension from current designs and leads to a logical progression towards the digital component studio [Baldwin, 1983]. In Study Programme 42A/11, the essential issues are outlined. In the United States of America, SMPTE has already set up a Working Group on Analogue Component Video charged with arriving at a draft standard for studio application at an early date. There is general agreement among those active in the field, that a signal form employing time-compression and time-division multiplexing is the most attractive one.

In the case of the recorder, the benefits have already been demonstrated in both 525-line and 625-line countries, through modifications to existing recorders which show improved quality with no increase in tape consumption.

[CCIR, 1982-86c] describes the hardware implications and problem areas when recording multiplexed analogue signals derived from a family of digital standards as described in [CCIR, 1982-86b] on conventional 25.4 mm video tape recorders. It concludes that only MAC signals of the form 4-2-0 or 3-1-0 lend themselves to an economical modification of existing recorders.

4.2.1 —— *Studio* applications

A wealth of information regarding the quality obtainable in 525-line and 625-line television systems by the use of components and the resulting improvements in production processing [SMPTEJ, 1981; EBU, 1981; Nishizawa *et al.*, 1981; CCIR, 1978-82a, b, c, d] has been generated; it seems that an analogue component system would offer a quality considerably above that of composite (NTSC, PAL, SECAM) systems but that technology and economic considerations impose a limit somewhat below that of the digital component 4 : 2 : 2 system, particularly if the constraints of current equipment and of recording standards are considered. It appears that colour signal bandwidths of 2 to 2.2 MHz are feasible with a modest improvement in luminance performance. There could be significant improvements in colour noise and the elimination of cross-effects and vertical artifacts (PAL and SECAM). Intermodulation effects such as differential gain and phase would also be eliminated if a time-multiplexed component format were to be employed.

Time-multiplexed analogue components can be routed through conventional coaxial cables, amplifiers and cross-point matrices, provided the signal bandwidth is not excessive and cross-talk behaviour in the frequency range above 5 MHz can be controlled. Most current equipment for picture origination can provide component outputs suitable for generating time-multiplexed analogue signals.

For the mixer, the use of analogue components will improve colour matte and eliminate the decode/re-encode functions found in many special effects systems. The result will be better quality and somewhat less complexity.

4.2.1.1 Parallel analogue component interface

Report 803 contains, in its Annex II, the standard parallel component video interface for non-composite ENG signals, intended for use in existing ENG equipment and used for most recent equipment of this type.

For reasons of compatibility with this equipment, the quality and field of application of which is increasing, it is desirable that the definition of a analogue component parallel interface designed for the various uses contemplated in the report should be based on this interface.

4.2.1.2 Serial analogue component interface

The EBU has defined [CCIR, 1986-90b] a format for a serial analogue component interface to facilitate the introduction of digital component production equipment into existing television studio areas. This format, known as S-MAC, is designed to achieve the maximum transparency with respect to 4:2:2 digital signals (Recommendations 601 and 656) and enables the signals to pass, in analogue form, through existing switching systems, designed for use with composite signals.

In the United Kingdom, an implementation of the S-MAC system has been developed [Dalton and Malcher, 1988] to carry analogue component signals between separate areas in a production centre.

4.2.1.3 *Digital component formats*

Experience has shown that digital component equipment can provide unsurpassed capability in terms of high and constant quality together with processing flexibility.

Recommendation 601 describes a family of coding standards for studio operation. Reports 629 and 962 provide additional information on the associated filtering and on digital television in general.

Recommendation 656 specifies interfaces for the equipment using the main digital studio level of Recommendation 601 and, also gives further information on the operation of such interfaces.

Recommendation 657 specifies the format for the interchange of programmes recorded digitally on magnetic tape.

Studies in the United States of America have concluded that digital component signals in accordance with Recommendation 601 are the preferred format for in-plant distribution of enhanced television signals, even if derived from component analogue or high line-rate sources [CCIR, 1982-86d].

4.2.2 *Circuit transmission*

The transmission of the analogue component signals between studio centres or between an 0B site and its associated control studio, for example, will certainly be required. Due to the lack of a colour sub-carrier in such signals, it appears that some relaxation of frequency response and of linearity requirements can be tolerated.

In the case of studio signals, having a bandwidth of 9 to 11 MHz, new or updated equipment might be required. A number of alternatives are possible and should be the subject of joint studies with the CMTT. It should be noted, however, that these video signals will have close compatibility with the 4 : 2 : 2 digital standard and hence any digital transmission systems (and associated bit-rate reduction) installed for such digital video signals will be suitable also for analogue component signals converted into the 4 : 2 : 2 digital form. In the case of analogue transmission facilities, the best arrangement is not yet clear. (See Question 24/CMTT.)

In Italy, an investigation has been carried out by RAI [CCIR, 1982-86e] with the purpose of assessing the possibility of transmitting television signals, having a baseband bandwidth greater than conventional systems in the network of contribution links with a channel spacing according to Recommendation 382. The preliminary results show the possibility of exploiting the network with signals having a bandwidth of up to 10 MHz. A foreseen application consists of the use of time-compressed and multiplexed analogue components for the contributions from one studio centre to another; the actual bandwidth of the luminance and of the two simultaneous colour-difference components is close to that of Recommendation 601.

In the case of lower quality signals (§4.2.4), a transmission channel bandwidth of perhaps 5 or 6 MHz will suffice, making it possible to use existing facilities, established for composite signals, as long as the specified waveform maintains adequate clamping.

The study related in [CCIR, 1986-90c], carried out in France on the transmission of electronic news gathering signals over transmission media in service, as well as the objective and subjective simulation trials conducted have shown that the most suitable signals for this purpose are MAC 3-1-0 and MAC 4-2-0 type signals. A preference emerges for the MAC 4-2-0 signal, which would be capable of exploiting any improvement in the quality of the original signals and will benefit from the industrial spin-off from the MAC systems developed for direct satellite broadcasting.

Furthermore, for reasons of compatibility with existing transmission networks, particularly from the point of view of the alignment and network surveillance systems, it is preferable to retain the same or extremely similar line and field blanking signals as those applied for composite signals.

[CCIR, 1986-90d] reports on simulated and full-scale tests made with a MAC 4:2:0 encoded signal, known as T-MAC, showing its value for transmitting enhanced quality television signals over existing networks (see also CCIR Report 1096).

[Dalton and Malcher, 1988] describe the development of a MAC 4:1:1 system for ENG applications using existing narrow-band 5 MHz links.

[CCIR, 1982-86f] gives an overview of objective measurement methods for analogue component transmission systems and notes that the methods of measurement in Recommendation 567 supplemented by the response to a *T* sine-squared pulse may be suitable, provided that the *T* and *2T* pulse widths are appropriately chosen for the channel bandwidths. The correlation between these objective parameters and subjective quality, however, remains to be confirmed.

A test signal for routine measurements of the *T*-pulse response which may be useful for analogue component systems is described in [CCIR, 1982-86g].

4.2.3 Emission

4.2.3.1 Satellite broadcasting in analogue component

The emission aspects of analogue component signals in the broadcasting-satellite service are discussed in Report 1074.

The use of time-multiplexed analogue components was initially proposed in the United Kingdom [Lucas and Windram, 1981] for new broadcasting-satellite services in that country.

The substantial improvements achievable from the transmission of time-multiplexed analogue components combined with postfiltering at the display were demonstrated widely in 1982 by the Independent Broadcasting Authority.

4.2.3.2 Terrestrial broadcasting in analogue component

Studies made in France and described in [CCIR, 1986-90e], have demonstrated that the D2-MAC/packet standard is compatible with vestigial sideband AM transmission in an 8 MHz channel. MAC picture band reduction to 6 MHz still provides 4.5 quality (at an observation distance of 6H).

A system achieving a substantial improvement of MAC/packet signal reception in the presence of echoes is described in [CCIR, 1986-90f]. This system uses adaptive equalization and Viterbi decoding of the data burst.

4.2.4 *Lower quality applications*

When portability concerns are paramount, or the use of a narrower bandwidth recorder or emission channel is important, then a signal based on line-sequential transmission of colour difference signals may be adequate, in spite of the resolution loss and vertical colour aliasing introduced [CCIR, 1982-86h]. Work in [CCIR, 1982-86a; Schachlbauer, 1983] indicates that a quality level considerably better than that of composite signals can be obtained in this way using equivalent channels.

Luminance bandwidths of about 4 MHz and colour difference signal bandwidths of about 2 MHz are achievable in a 6 MHz channel bandwidth. Commercial equipment employing two recording channels is available with similar performance.

Report 803, Annex 1, describes an interface for equipment interconnection of an electronic news-gathering system. The more general application of this interface is discussed in § 4.2.1.1. This system illustrates the evolutionary tendency in production systems and provides considerably improved ENG quality.

Experiments related in [CCIR, 1986-90g] have shown that electronic pictures are very sensitive to coding methods involving low-pass filtering and subsampling of the 4:2:2 digital representation of these pictures. Consequently bit rate reduction methods using systematic low pass filtering and subsampling should be avoided when transmitting these pictures.

5. Display enhancement

The availability of low-cost field stores in domestic receivers permits separation of the display scanning parameters from those of the emission standard. Cross-colour and cross-luminance in composite systems can be significantly reduced by luminance/chrominance separation filters using frame stores. An increase in the field frequency can eliminate large area flicker. An increase in the number of lines and the use of sequential scanning can significantly reduce the interline flicker and the line crawl that occur in conventional television systems.

Methods for achieving some of these improvements are discussed in [Wendland, 1979, 1982; Jackson and Tan, 1981; Lucas and Windram, 1981; Sandbank and Moffat, 1983; Schönfelder, 1983].

In Japan, a scan-conversion system using a motion-adaptive spatio-temporal interpolation filter with receiver frame memory has been developed [Nishizawa and Tanaka, 1982; CCIR, 1982-86i] to reduce interlaced line-scanning impairments. It improves picture quality for both still and moving pictures.

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APPENDIX I

The major links in the television chain (production, distribution, display) may be specified using different but related standards. Table I identifies in its "boxes" the basic elements of present and possible future television systems. The boxes of the same line correspond to standards of different quality levels. Conversion between production standards is envisaged according to operational requirements. Television services use different paths going from production to display; paths in the vertical direction represent the most straight forward way of implementing one service, nevertheless, oblique paths are usable if required. As an example, a signal produced in analogue components (box 2) may feed a composite signal distribution network (box 5) and decoded for display in a conventional form (box 9). On the other side the same production signal may feed a multiplexed-analogue-components signal distribution network (box 6) and could in turn feed either a conventional *RGB* display (box 10) or an improved display using scanning up-conversion (box 11).

TABLE I – *A tentative classification of TV standards: arrows indicate the main paths of interest*

Field of application of baseband standards	Systems based on conventional scanning structures (625/50 or 525/60 2 : 1 interlaced, 4:3 aspect ratio)		Wider aspect ratio systems	
Production of television programmes	PAL/SECAM/NTSC (Rep. 624) 1	Analogue Y, $R-Y$, $B-Y$ components (Rep. 1077) Digital Y, C_R, C_B, components (Rec. 601) 2	625/50 and 525/60 related wider aspect ratio television (Report 1220)	HDTV production (Rep. 801) 4
Distribution of television programmes (transmission and emission)	PAL/SECAM/NTSC (Rep. 624) 5	Time-compressed and multiplexed analogue Y, $R-Y$, $B-Y$ components (MAC) (Reps. 1073, 1074, 1077) 6	Wider aspect ratio television distribution (Report 1220) 7	HDTV distribution 8
Display of broadcast programmes	R, G, B components (decoded from composite) 9	R, G, B components (derived from Y, $R-Y$, $B-Y$) 10	Up-converted R, G, B components 11 (Report 1220)	HDTV R, G, B components 12

REPORT 1220

WIDER ASPECT RATIO TELEVISION SYSTEMS*

(Question 42/11, Study Programme 42B/11)

(1990)

1. Introduction

Television pictures wider than the conventional 4:3 aspect ratio have been available for many years through the medium of cinematographic film. However, the development of high definition television with an aspect ratio of 16:9 has increased the availability of wide aspect ratio source material and has led to the development of wide aspect ratio television displays. There is therefore considerable current interest in ways of using wide aspect ratio formats for 4:3 enhanced and conventional television systems, in addition to those of high definition described in Report 801. It is noted that many of the enhancements described in the context of 4:3 aspect ratio systems in Report 1077 can also be applied to the wider aspect ratio systems described here.

The problems of protection ratio and radio-frequency receiver characteristics will be studied in IWP 11/5 (see Decision 42).

The new wide screen formats may be used in several ways. For example, the total screen may be used to combine one main 4:3 picture and several smaller sub-pictures. These sub-pictures might provide a variety of other services, such as teletext, transmitted pages of text, transmitted stills, etc.

Decision 91 and Report 1224 describe the work to be done and the main results already reached on the matter of harmonization with other international standardizing bodies for industrial/consumer usage applications.

2. Wide aspect ratio systems

Several wide aspect ratio systems have been described and demonstrated.

In Japan, the time compressed integration (TCI) multiplexing system has been developed [CCIR, 1982-86a] for use in HDTV broadcasting by satellite, but the concept is also applicable to wide aspect ratio systems [Rhodes, 1982].

In the Netherlands and the United Kingdom, the concept of time-multiplexed analogue components has been extended and applied to the vertical or horizontal dimension so that wider aspect ratios are more readily obtained [Long, 1983; Windram *et al.*, 1983; CCIR, 1982-86b].

* The Director, CCIR is requested to bring this Report to the attention of the IEC.

At the International Television Symposium at Montreux in 1983, Philips N.V. demonstrated the feasibility of a 5 : 3 aspect ratio in a system with line-multiplexed (vertical) luminance and colour-difference components.

In the United Kingdom, the IBA has developed a system based on the 625-line C-MAC/packet coding scheme for the single-channel transmission of wide aspect ratio television, and also for BSS in the 12 GHz band [Windram *et al.*, 1983]. This system is called enhanced C-MAC.

In [CCIR, 1982-86c] it is claimed that it is possible that the enhanced C-MAC system transmission system for a higher line-rate HDTV production standard based on a 50 Hz field rate. (For example, the enhanced C-MAC transmission format could interface readily with a 625-line non-interlaced source.) It is also claimed that an enhanced transmission system could then equally be seen as an HDTV-transmission system using vertical sub-sampling.

It has been suggested that, within the existing WARC-1977 planning constraints, the compressed video bandwidth for C, D and D2-MAC could be increased from about 9 MHz to about 12 MHz (CCIR Report 1074, section 3.6.1). This increase could be used to provide 33% more resolution for a conventional 4:3 aspect ratio MAC signal. Alternatively it could provide for an increase in aspect ratio from 4:3 to 16:9 whilst retaining the same resolution as for conventional MAC transmissions. The latter is a form of wide aspect ratio MAC which has been suggested as a step along an evolutionary path leading from conventional MAC through to high definition MAC (HD-MAC). The use of a non-linear pre-and de-emphasis characteristic with this system enables the signal-to-noise degradation caused by the additional bandwidth needed by this arrangement to be fully compensated in the region near FM threshold [Windram and Drury, 1988].

In Japan, the study of a second generation NTSC-compatible enhanced television system, known as EDTV-2, began in August 1989. The target features of the EDTV-2 system [Kawauchi, 1989] are wider aspect ratio, increased horizontal and vertical picture resolution and higher fidelity PCM sound.

In the Federal Republic of Germany an enhanced PAL-compatible system, featuring 16:9 aspect ratio on new wide-screen receivers is being investigated [Ziemer and Matzel, 1989a,b]. On conventional 4:3 displays compatibility is achieved by presenting the 16:9 material in a "letterbox" configuration. The system further employs means to provide an increased horizontal luminance resolution with reduced cross-effects (Q-PAL [Silverberg, 1989] or I-PAL M [Holoch et al., 1985]), in order to cope with the requirements of increased detail reproduction in wide-screen pictures.

[Tichit and Tonge, 1989] describe joint experiments in France and the United Kingdom of a system using progressive scanning at source and display, with synthesized interlaced scanning for studio processes and transmission. A 16:9 aspect ratio system has been implemented using existing studio component equipment. It can be delivered to the home using MAC signals and provides a displayed image of substantially enhanced resolution.

Sources delivering progressive scanned signals with bandwidths in excess of 15 MHz have been used, sub-sampled with a field quincunx pattern in order to reach a data rate of 216 Mbit/s, recordable on unmodified D1 video tape recorders. It is noted that signals resulting from tapes recorded using this technique cannot be directly intermixed with conventional 4:3 recordings.

Up-conversion from the received signal to progressive display is provided by motion adaptive signal interpolation. Alternatively, MAC transmission enables compatible reception of wide aspect ratio signals on 4:3 MAC receivers.

3. Multiple picture display applications

New wide aspect ratio television sets for domestic use were demonstrated during the IFA 89 exhibition [CCIR, 1986-90]. The equipment uses a 16:9 aspect ratio high definition screen to display a range of either high definition signals directly or conventionally scanned 16:9 signals by up-conversion. The display operates with a horizontal scanning frequency of 31.25 kHz. Format control is possible so that, for example, a 4:3 aspect ratio signal can be displayed so as to fill the picture height. The remaining part of the display can then be used for other purposes, such as the display of one animated compressed picture and two still pictures. In this way, the wide screen format can be used to give multiple picture-in-picture displays in a domestic receiver (see Report 1225).

The requirements of additional reception circuitry for the simultaneous display of multiple programme channels as sub-pictures in a wide aspect ratio display are to be studied by IWP 11/5. The general principles concerning such applications, which include teletext and teletext-like presentations are already embodied in the terms of reference of JIWP 10-11/5. JIWP 10-11/6 will be examining the quality assessment of wide aspect ratio systems including the issue of sub-pictures or picture windows which are inset or adjacent to the main picture (see Rec. 500, Rec. 710 and Report 1216).

In Japan, [Ogino et al., 1989 and Achiha et al., 1983] a multi-scan high definition 16:9 projection display has been developed to display HDTV, conventional television and other signals, such as the output of personal computers. A range of vertical scanning frequencies from 40 Hz to 120 Hz is provided. Horizontal scanning frequencies from 15 kHz to 70 kHz are possible. NTSC signals are displayed using a high resolution scan converter, which doubles the number of NTSC scanning lines through motion-adaptive frame combing. A personal computer output can be superimposed onto the double-scanned NTSC signal, thus widening the applications of the display.

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REPORT 476-1

COLORIMETRIC STANDARDS IN COLOUR TELEVISION

(Question 1/11)

(1970-1974)

1. In 1953, when the NTSC colour television system was adopted for transmission in the United States of America, the colorimetry of the system was based on three specific primary colours and a reference white. The coordinates of the primaries were: *

Red:	$x = 0.67$	$y = 0.33$
Green:	$x = 0.21$	$y = 0.71$
Blue:	$x = 0.14$	$y = 0.08$

The reference white chosen was standard

White C:	$x = 0.310$	$y = 0.316$

2. When the PAL and SECAM systems were first designed, they were based upon the colorimetric standards of NTSC. As a result, the coefficients used for determining the signals involved in coding PAL and SECAM (the luminance signal and the colour-difference signals) were directly based upon the chromaticities given in § 1.

3. However, it has been recognized that there have been continuing changes in the chromaticities of the phosphors used in making colour picture tubes over the years, and that those actually used do not have the same primary chromaticities as those which served to establish the coding of systems. Nevertheless, in all systems the coefficients used for determining the signals involved in coding (the luminance signal and the colour-difference signals) are directly based upon the chromaticities and white point given in § 1.

4. Several solutions have been proposed or implemented, in different countries, for compensating or correcting the effect upon colour reproduction of this difference between the receiver characteristics and the standards given in § 1.

5. The United States of America continues to base the colorimetry of its transmissions upon NTSC primaries whose chromaticities and white point are defined in § 1. Studio monitors are adjusted to a reference white of D_{65}. However, because picture tubes do not yet contain phosphors whose chromaticities are the same (or very nearly the same) as those defined in § 1, approximate corrections, involving operations upon the electrical signals, are made in receivers in order to achieve satisfactory colour reproduction. Further, to achieve greater consistency in colour transmissions, the United States of America recommends that the picture monitors used in studios should also contain correction circuits which cause the colour reproduction to approximate to that which would have been obtained if the picture tubes used in the monitors had contained phosphors with the primary chromaticities shown in § 1.

6. In Japan, the colorimetry of the system is based upon the primary chromaticities and white point given in § 1. Studio monitors are adjusted to a white point of D, 9300 K.

7. In the 625-line PAL and SECAM systems, the colorimetry is now based upon the three specific primary colours: **

Red:	$x = 0.64$	$y = 0.33$
Green:	$x = 0.29$	$y = 0.60$
Blue:	$x = 0.15$	$y = 0.06$

and reference white D_{65} **.

These chromaticities are closely representative of the phosphors incorporated in the picture tubes of many of the receivers and studio monitors used in those countries that have adopted the 625-line PAL and SECAM systems. Thus, in such receivers and monitors, no electrical corrections are required in order to achieve good colour reproduction. Further, in order to improve the consistency of colour reproduction, when the television receiver is switched from one programme to another, it has been suggested that the chromaticities of the phosphors used in studio monitors should be standardized. The assessment is based upon a method of tolerance which takes account of both the primary chromaticities of the tube phosphors and the effect of their combined chromaticities upon the reproduction of a typical skin tone.

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* The coordinates are given in the CIE system (1931).

** These coordinates are given in the CIE system (1931). For 625-line SECAM systems, it is provisionally permitted (for existing equipment), to use the chromaticity coordinates and reference white given in § 1.

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REPORT 801-4

THE PRESENT STATE OF HIGH-DEFINITION TELEVISION

(Question 27/11, Study Programmes 27A/11 and 27B/11)

(1974-1978-1982-1986-1990)

PART 1 - INTRODUCTION

Television is one of the most widely available means of communication. Large screen, high-definition television is the target for the next step in television, and may bring about a new standard system which will be common throughout the world. It will perform the same function better and will also provide a powerful tool for other uses. These will include film production for the cinema and for television, printing, medical applications and scientific work.

The move to HDTV production offers new opportunities to simplify programme exchange and to bring together the production of programmes for television and for the cinema. A single standard would be beneficial to producers, as well as broadcasting organizations.

Figure 1, which is based on a suggestion by Prof. Krivocheev, is a simplified schematic of the expected future environment for HDTV, as it relates to broadcasting. The central element is the HDTV production centre, whose activities in programme production and programme exchange will be similar to those of today's production centre. While most of these activities will be in high definition, provision must be made to work with a number of other contribution formats, such as current 525- or 625-line television in analogue or digital forms, film, etc. The introduction of high-definition television offers a new opportunity to simplify the exchanges of both recorded and live programme material.

A feature of HDTV production is the capability to produce films suitable for projection in the cinema. Thus a high-quality video-to-film transfer process will be particularly important for the production centre.

HDTV signals from the production centre will pass to the delivery network at the broadcast distribution interface. Delivery to the viewer may use one of a number of possible methods including terrestrial broadcasting (e.g., VHF or UHF), satellites, cables (e.g., coaxial or fibre - optical fibres are considered to be one of the most promising transmission media for wideband HDTV) or pre-recorded media (e.g., cassettes or disks). Each has particular characteristics and, as a consequence, the HDTV signal must be converted into a form appropriate for each delivery method. This will be accomplished in an encoder or converter between the HDTV signal at the broadcast interface and the delivery interface.

The definition of the potential broadcaster distribution and broadcast interface, as shown in Figure 1 together with the possibility of other interfaces yet to be described, provides opportunities to have different values for some parameters in different parts of the "global" HDTV system. Inclusion of frame memories in these interfaces can provide a more flexible future environment for HDTV, but the implications of this assumption need to be studied carefully [CCIR, 1986-90a].

The viewer's choice of delivery method may have some impact on the level of enhanced TV or HDTV service that he receives. The levels may include full-bandwidth HDTV, bandwidth-reduced HDTV, or enhanced 525- or 625-line television. (See also Report 1232)

The HDTV receiver in the home must be able to display the enhanced TV or HDTV services and it would be advantageous if it could also display other services such as 525- or 625-line television. Such a receiver would include the necessary signal processing to reconstruct, as accurately as possible, the image presented at the broadcast distribution interface. This processing may also include display up-conversion, noise filtering, etc. Depending on the broadcasting strategy adopted, 525- or 625-line home receivers may be able to derive a usable signal from the enhanced TV or HDTV service.

For operational considerations and from experience, it is clearly important that the interrelationships between each part of the HDTV network (from production, through contribution and distribution to emission) are taken into account in an overall evaluation of the complete HDTV system. Furthermore, it is necessary to form a view of how the new HDTV system would be implemented. This should bear in mind already existing arrangements for conventional television, and the operational and economic benefits/penalties that might arise under differing assumptions regarding studio, transmission emission standards and the distribution methods available.

Finally, the technology required for the complex signal processing involved in the broadcasting chain is keeping pace with the development of HDTV and benefits from its synergism with the technologies of data processing and of telecommunications. The evolution of suitable display devices for the home receiver still requires considerable effort.

At present, the first results on studies related to Study Programme 18U/11 have been collected [CCIR, 1986-90b]. It must be recognized that these studies must be intensified in close cooperation with such organizations as the IEC and ISO to take fully into account the requirements for implementation of HDTV for media other than broadcasting, i.e. cinema, printing, medical applications, scientific work and videoconferencing.

In addition, the transmission of HDTV signals via new digital transmission channels or networks has to be considered and taken into account, for instance, as defined in CCITT Recommendation I.121 "Broadband aspects of ISDN", adopted by the IXth CCITT Plenary Assembly at the end of 1988. For such new networks, the definition of new services, including those related to HDTV, have to be defined as expressed in a liaison statement [CCIR, 1986-90c] from CCITT Study Group I to CCIR Study Group 11.

Further progress in these studies may help the CCIR to complete the task of defining a full set of parameters of a single world-wide HDTV production standard.

This Report summarizes results of studies and experiments obtained in the world in technical developments under Question 27/11. See also Report 630 for video recording, and Report 1075 for satellite broadcasting.

Report 1218 on objective measurements, Report 1216 on subjective assessment, Report 1217 on future developments of HDTV and Report 1232 on the release of programmes in a multi-media environment are also relevant.

REFERENCES TO PART 1

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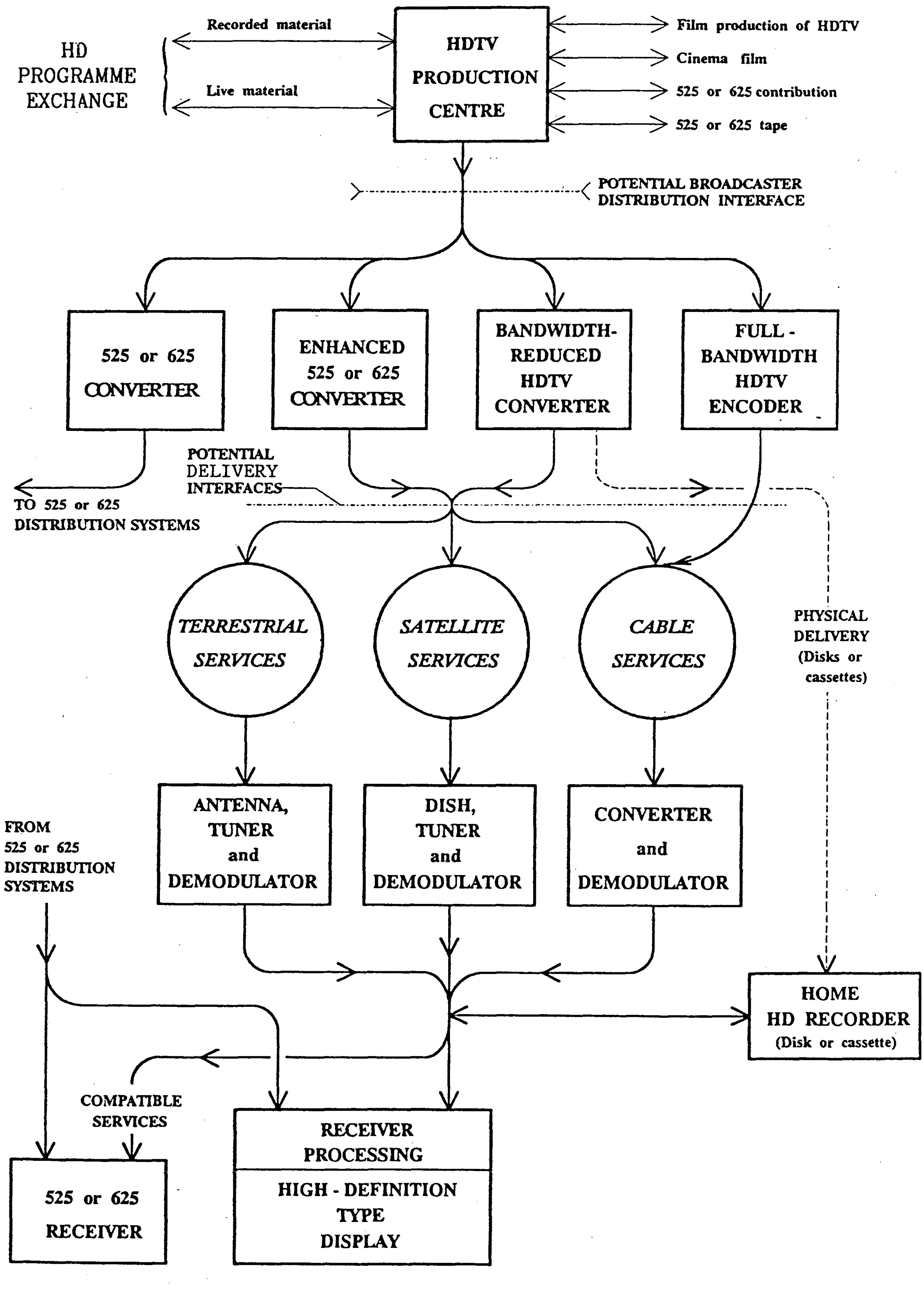

FIGURE 1 - *HDTV delivery - the future environment*

PART 2 - CCIR ACTIVITIES

The study of HDTV has been a concern in the CCIR for some years, with initial work on the basic principles of HDTV displays done during the 1974-1978 study period. The pace of the work has increased rapidly since that time and the study of all aspects of HDTV - from the camera, through recording, production, and emission, to the display - has been a serious and urgent concern. Work in the CCIR on HDTV has centred on Study Group 11, but recording and satellite emission studies are performed jointly with Study Group 10 in Joint Working Groups 10-11/R and 10-11/S, respectively. Transmission is studied in the CMTT.

The structures under which the work has been done, together with an indication of progress in the work, are briefly summarized as follows:

1. Early progress (1974-1986)

Work in the CCIR on HDTV began with adoption of Question 27/11 on high definition television.

Following adoption of Question 27/11, a number of Questions, Study Programmes, Resolutions and Decisions were adopted and/or modified to recognize, and to promote appropriate consideration of, HDTV.

In Study Group 11, two Study Programmes were created in response to Question 27/11: 27A/11, which concerns the compatibility of HDTV with existing standards and broadcast channel assignments, and 27B/11, which concerns display technologies for HDTV.

During the period 1974-1986, Questions 1/11 on colour television standards and 2/11 on the exchange of television programmes were modified to consider HDTV. Study Programmes 2B/11 on conversion among scanning standards, and 3A/11 on subjective quality assessments also took note of HDTV.

In addition, Study Group 11 adopted Decision 58, which established IWP 11/6 to study HDTV and made provision for HDTV in Decisions 60 (IWP 11/7 on digital television) and 66 (IWP 11/4 on subjective assessments), and in conjunction with Study Group 10, Decision 59 on video recording. The XVIth Plenary Assembly adopted Resolution 96, which anticipated the need for an Extraordinary Meeting on HDTV during the latter part of the 1986-1990 study period.

In conjunction with Study Group 10, Study Group 11 adopted two Study Programmes on HDTV recording, 18S/11 (Recording of HDTV programmes) and 18T/11 (Recording of HDTV on film). Furthermore, the Study Groups modified Questions 2/10 and 11 (System characteristics for satellite service) and created or modified Study Programmes 1E/10 and 11 (Sharing studies), 2F/10 and 11 (Satellite television standards), 2M/10 and 11 (Satellite broadcasting of HDTV and 2N/10 and 11 (Integrated services) to take account of the need for studies in HDTV. In addition, the Study Groups prepared Decision 51 (JIWP 10-11/3, Satellite broadcasting of HDTV) to stimulate studies on satellite broadcasting of HDTV.

2. Progress since 1986

Prior to the 1987 Interim Meetings, considerable work was done in Study Group 11 on HDTV, particularly in IWP 11/6. Moreover, at the Interim Meetings, the Chairman of Study Group 11 initiated a review of Questions, Study Programmes, and Decisions in order to stimulate and coordinate work in HDTV. As a result, Study Programmes 25H/11 (Filtering and sampling in digital encoding), 25M/11 (Measurement and monitoring) and 25J/11 (now AL/11, Bit rate reduction in digital coding) were modified to consider aspects of HDTV. Furthermore, two new draft Study Programmes were adopted to include aspects of HDTV: 25N/11 on interfaces for digital signals and 3E/11 on subjective assessment of HDTV. The Study Group also adopted Decision 74 which called for the Extraordinary Meeting on HDTV and modified Decisions 42 (IWP 11/5, Protection ratios), 58 (IWP 11/6, HDTV standards), 60 (IWP 11/7, Digital television) and 66 (JIWP 11/4, Subjective assessment) to permit additional work and coordination of activities.

At the Interim Meeting, Study Group 11 retained Report 801-2 (The present state of high definition television) which had been prepared in the previous study period. It also prepared four new Reports on aspects of HDTV: AW/11*(Approaches to a unified world-wide digital HDTV studio standard), AZ/11* (A progress report on high definition television), AU/11*(A global approach to HDTV systems) and 1216 (The subjective assessment of high definition television pictures). JWG 10-11/S updated Report 1075 (High definition television by satellite). JWG 10-11/R adopted Report 1229 (Recording of HDTV programmes on cinematographic film).

In conjunction with Study Group 10, Study Group 11 further modified Study Programme 18T/11 (Recording of HDTV on film) to take account of the need for international exchanges and prepared new Study Programme 18U/11 (Transfer of HDTV programmes to non-broadcast consumer media) to take account of non-broadcast uses. Furthermore, the Study Groups amended Decision 51 (JIWP 10-11/3, Satellite broadcasting of high-definition television (HDTV) signals and accommodation of several audio and/or data signals and/or picture signals in terrestrial and satellite broadcasting channels) to take further account of the need for greater study and coordination in HDTV. JIWP 10-11/5, in the context of Decision 72, presented contributions on data broadcasting in an HDTV environment.

At the Extraordinary Meeting, Study Group 11 reviewed existing Questions, Study Programmes and Decisions with a view to further responding to its responsibilities in HDTV. The specifics of the Study Group's progress at the Extraordinary Meeting are given in the remainder of this document.

* These texts were cancelled by Study Group 11 at its Extraordinary Meeting on High-Definition Television, Geneva, 1989.

PART 3 - GENERAL CONSIDERATIONS OF HDTV SYSTEMS

1. Definition of high-definition television

A high-definition system is a system designed to allow viewing at about three times the picture height, such that the system is virtually, or nearly, transparent to the quality of portrayal that would have been perceived in the original scene or performance by a discerning viewer with normal visual acuity. Such factors include improved motion portrayal and improved perception of depth.

This generally implies in comparison with conventional television systems:

- spatial resolution in the vertical and horizontal directions of about twice that available with Recommendation 601;
- any worthwhile improvements in temporal resolution beyond that achievable with Recommendation 601;
- improved colour rendition;
- a wider aspect ratio; and
- multi-channel high fidelity sound.

Note. - Sound systems for HDTV are the subject of Question 47/10.

2. Media outlets to be supplied by HDTV

HDTV production will be used to provide source signals for a variety of media outlets. These could include the following possibilities:

- BSS in the bands above 12 GHz;
- services in one or more WARC BS-77 channels;
- services in one or more RARC BS-83 channels;
- motion picture origination;
- electronic displays in theatres;
- terrestrial broadcast services or cable networks; and
- domestic tape or disc systems.

A single standard could be beneficial to programme producers as well as broadcasting organizations and viewers.

This Report summarizes results of studies and experiments obtained in the world in technical developments under Question 27/11. See also Report 630 for video recording, and Report 1075 for satellite broadcasting.

3. Picture presentation objectives

3.1 *Preferred angle of view*

When observers are closer to pictures, the area occupied by the pictures in their viewing field increases, and this gives observers an increased feeling of involvement in the space created by pictures. This increased sensation of reality becomes apparent when the viewing angle exceeds 20° [CCIR, 1982-86a].

3.2 *Viewing distance*

Experiments using still-picture slides show that viewing distances of $2H$ to $3H$ (H stands for the picture height) are preferred. This corresponds to a viewing angle of 40° to 30°. When pictures are moving, however, the preferred viewing distance is closer to $3H$, because of the additional factor of dizziness.

If the viewing distance is too small, observers experience eye fatigue after a certain time. It is therefore desirable to limit the minimum viewing distance to 2 m [CCIR, 1982-86a].

3.3 *Display size*

From subjective assessments on the sensation of reality with different sizes of picture and with various viewing angles, it seems that larger size pictures generate a larger sensation of reality for a constant viewing angle and a picture area of more than 0.8 m^2 can be considered appropriate for HDTV [CCIR, 1982-86a].

3.4 *Contrast and brightness*

From various experiments on television picture display, it is considered appropriate to take 50:1 as the minimum contrast ratio for HDTV.

Taking account of the effect of ambient illumination on the screen, a peak picture brightness of 150-250 cd/m^2 can be considered appropriate as the brightness for HDTV [CCIR, 1982-86a, b].

4. Fundamental considerations on basic parameters

4.1 <u>Definition of terms</u>

To clarify CCIR texts concerning HDTV the following definitions will be used in this report:

A <u>sample</u> is the value of an image at a defined point in horizontal, vertical and temporal space.

A <u>square sample distribution</u> results when the sampling points are equispaced on an orthogonal horizontal-vertical lattice on a time-discrete image plane, assumed to be vertical for the purpose of this definition.

<u>Pixel</u> is the abbreviation of "picture element". It is the smallest area of the optical image that can be faithfully reproduced.

A <u>square pixel</u> has equal size in the horizontal and vertical directions.

4.2 *Aspect ratio*

Wider aspect ratios increase the observers involvement in the pictures. Various psychophysical experiments have shown that, depending upon the size of the picture, a wider aspect ratio ranging from 5:3 (1.67:1) to 2:1 would be attractive for HDTV. Experimental equipment has been made with an aspect ratio of 5:3 [CCIR, 1982-86a].

Further studies by one administration have shown that by increasing the aspect ratio to 16:9 (5.33:3, 1.78:1) and using the traditional movie industry technique of "shoot-and-protect" (centering the action in the smallest common area), compatibility can be achieved with most current movie film of aspect ratios ranging from 4:3 (1.33:1) to 2.35:1 [CCIR, 1982-86c].

4.3 *Horizontal sampling*

The definition of HDTV given in § 1 of this Part defines the horizontal resolution for HDTV as being twice that of current conventional television systems. Recommendation 601 defines a sampling system for the current 625/50 and 525/60 television standards as requiring 720/360 samples (luminance signal/colour difference signal) for the digital active line period. To achieve twice the resolution would require 1440/720 samples per digital active line period for a picture with the same aspect ratio.

For the wider aspect ratio being discussed for HDTV, the number of samples per digital active line period must be increased by the ratio of the new aspect ratio to the current 4:3 aspect ratio. For example, in the case of an aspect ratio of 16:9, the corresponding number of samples per digital active line period would be 1920/960.

The total number of samples per line would include the number of samples required for the line-blanking period. Although the need for line-blanking period can be eliminated by the use of appropriate stores, there are practical limitations in electron-beam cameras and in display devices which make a line-blanking period essential in the short term [CCIR, 1982-86b].

4.4 *Vertical sampling (number of active lines per frame)*

Various studies, relating visual acuity to static vertical resolution and the viewing distance, have shown that the static vertical resolution, as viewed on a television monitor, is affected by the scanning method (interlace or sequential), the frame/field rate and the persistence of the display device.

In an experiment using a monochrome system with a 69 cm (27 in) high-resolution cathode-ray tube display, sharpness improvement by increasing the number of lines began to saturate at about 1500 lines with 2:1 interlace for a viewing distance of 3*H* [CCIR, 1978-82a], and with 2125 lines, sufficient sharpness was obtained at a viewing distance of 2*H* [CCIR, 1974-78].

For a television picture with 2:1 interlace and a viewing distance of three times picture height, at least 1000 active lines are required to achieve twice the vertical resolution of current television systems [CCIR, 1982-86b].

It has been shown in recent studies that with more than 1000 active lines, the resolution would compare favourably with that of 35 mm film theatrical presentation, which has historically been perceived as the high quality presentation format [Hayashi, 1981; Kaiser *et al.*, 1985].

If the number of active lines is greater than 1024, an additional bit is required in the address circuit of picture processing equipment [CCIR, 1978-82b].

4.5 *Temporal sampling (field frequency)*

There are two distinct issues associated with this topic. The first is dynamic resolution which refers to the spatial resolution for images which move. The second is repetition rate which is determined by the criterion of smooth motion portrayal.

The dynamic resolution is determined by the integration time of the photo-sensitive material used in the camera and the temporal sampling rate determined by the field frequency [CCIR, 1982-86b].

Tests by the BBC using unshuttered camera pictures sequentially scanned and displayed at 50, 60, 70 and 80 Hz frame-rates have demonstrated a progressive improvement in quality on moving picture detail as the field-rate is increased. On a five-point quality scale, picture quality at 80 Hz was judged to be two grades better than at 50 Hz and one grade better than at 60 Hz for representative rates of continuous motion [Childs and Tanton, 1985; CCIR, 1982-86d].

Dynamic resolution can also be improved by reducing integration time by shuttering. Experiments carried out with 60 Hz cameras have shown that the integration time can be reduced by 25% without impairing motion portrayal and with corresponding improvement in dynamic resolution. Similar improvements to signals from shuttered 50 Hz cameras have been reported [Stone, 1986]. Camera sensitivity and temporal aliasing penalties should be studied further [CCIR, 1982-86b, 1986-90a].

Document [CCIR, 1986-90b] refers to initial studies conducted in Canada to determine temporal sampling rate requirements that indicate that the sampling rate required for tracked motion remains almost constant at about 70 Hz, where as for non-tracked motion the sampling rate requirements increase rapidly with the velocity of the moving object [CCIR, 1986-90c].

The field and frame frequency of the television signal also determines, in a simple system, the refresh rate of the display. It influences the perception of large area flicker [CCIR, 1982-86e]. It is, however, not essential that the display refresh rate be the same as the studio or the emission signal field-rates. The use of motion-compensated processing enables the emission and/or display field-rates to be different to that of the camera [Thomas, 1987; Fernando and Parker, 1988]. The improvements obtained from camera shuttering are most marked when used in combination with display up-conversion. Display up-conversion is discussed further in section 4.9 below [CCIR, 1986-90a].

4.6 *Scanning structure (interlace or sequential scanning)*

It has been reported that the distraction caused by scanning lines with a 2:1 interlace is about the same as that caused by sequential scanning with 40% fewer lines [CCIR, 1978-82a]. However, under these conditions the sequentially scanned signal would require 20% more bandwidth.

The interlaced scanning structure under certain conditions may introduce a display artifact referred to as "interline twitter" and "line crawl"; these artifacts are also related to the sources and display characteristic as well as to the frame-rate and the number of scanning lines per frame. It is desirable to avoid the occurrence of these artifacts. In interlaced systems, the spatially adjacent lines are dislocated in time, thereby introducing complexities in signal processing [CCIR, 1982-86b].

In the case of a basic interlaced studio standard, the hierarchical progression of interlace to sequential scanning may be considered in two ways. It may be possible to use sequential scan in parts of the studio chain or in the display where the two-fold increase in bandwidth requirement can be accommodated. The other use of a hierarchical approach would be to evolve from interlace to sequential in the future as the technological constraints imposed by doubling the bandwidth requirement become less severe [CCIR, 1982-86b].

In Document [CCIR, 1986-90d] the amount of information picked up from a camera is calculated for interlace scan, progressive scan, and quincunx system with the same number of lines. As a result, it is argued that the amount of information picked up from the camera increases little in progressive scan, slightly decreases in quincunx system, compared with the interlace scan system. The signal-to-noise ratio of these systems is also calculated, which is 9 dB lower for progressive scan and 3 dB lower for quincunx system than that for interlace scan.

Document [CCIR, 1986-90d] claims further that considering the required hardware, implementation of a progressive scan system is difficult, because the horizontal scanning frequency and required signal bandwidth become twice that for the interlace scan system. Especially, the construction of the diagonal filter necessary for quincunx system is difficult in its hardware scale and operating frequency.

Document [CCIR, 1986-90e] reports the results of experiments made on interlaced and progressively scanned cameras: The horizontal resolution of a progressive camera is identical to that of an interlaced one. The vertical resolution of a progressive camera is superior to that of an interlaced one. In terms of dynamic resolution, progressive scanning provides better separation between spatial and temporal informations than does interlaced at twice the field rate. Document [CCIR, 1986-90e] asserts that because weighting filters and measurement methods have yet to be defined, direct comparisons of unweighted signal to noise ratios for both systems lead to unrealistic conclusions. In the same manner, the quantity of information picked up in both systems needs a more accurate definition in order to provide an objective basis for comparison.

The Document [CCIR, 1986-90e] also reports the successful implementation of a diagonal filter using present technology. It also argues that hardware related solutions for HDP/HDQ (see Part 5, Section 2.2.1) sources and processing, being very dependent on the amount of initial investment by the manufacturer, do not result in objective arguments when comparing systems.

Document [CCIR, 1986-90f] relates the benefits that can be obtained by using progressive scan with quincunx sampling for bandwidth reduction scheme in HD-MAC encoding. Progressive scan allows a more reliable motion estimation and compensation, and also a more reliable branch switching decision. This results in overall improvement of the picture quality delivered to the user through the HD-MAC transmission chain.

4.7 *Colorimetric aspects*

It is very important to establish an optimum colorimetric system within the HDTV system in order to provide high colour fidelity. Compatibility with existing conventional systems may be regarded as a second priority.

Discussions on the colorimetric aspects can be found in [CCIR, 1982-86b and f; Powell, 1985]. The following are the main issues considered:

4.7.1 *Choice of primary colours*

Sets of primary colours have been proposed which include XYZ primaries, the present EBU phosphors and the present NTSC phosphors.

It was suggested that the colour primaries selected should be widely separated so as to reproduce the widest possible range of colours, yet not so widely separated that they cannot be realized by available phosphors with sufficiently good conversion efficiency.

Further study is needed, preferably in association with manufacturers of picture tubes, to establish whether more recently developed phosphors can provide a better set of primaries, and if so, whether they would be sufficiently different from one of the two existing standards to justify change [CCIR, 1982-86b].

Document [CCIR, 1986-90g] reports the studies by an expert group of Interim Working Party 11/6 on the choice of a set of reference primaries.

4.7.2 *System reference white*

There seems to be general agreement to adopt illuminant D65 for the reference white of the HDTV system. An adaptively switched white balance has also been proposed [CCIR, 1982-86b].

4.8 Opto-electronic transfer characteristic

There is a reported convergence of studies about the optimum transfer characteristic regarding quantization and noise susceptibility; the ideal law should be logarithmic. But a main aspect of this transfer characteristic is also the available dynamic range. The currently recommended law, which is a power law at higher values of luminance and changes over tangentially to a linear law at low luminance levels, has the advantage of pre-correcting the present CRT display transfer characteristic. A dynamic range of about 55:1 is accurately (following the power law) reproduced [CCIR, 1986-90h,i].

In order to fulfill the constant luminance principle, a system having gamma correction only at the receiver has been considered in contrast to the current television system where gamma precorrection is applied before luminance and colour-difference signal matrixing [CCIR, 1982-86b]. When displays other than CRT are used, or inter-system conversion is required, the required additional corrections add further distortions [CCIR, 1982-86f].

In the new proposal, processing is carried out with signals which are linearly proportional to the light input. However, a non-linear transmission-reception amplitude characteristic must be introduced, otherwise dark areas of the picture become more sensitive to transmission noise. Further discussion can be found in [CCIR, 1982-86b; Schafer and Golz, 1984; Yuyama and Yano, 1984].

The influence of such a new concept on component signals is important and a background of this choice is given in [Melwig and Schafer, 1988]. The better separation, by constant luminance coding, of luminance and chrominance signals allows an increased sharpness in colour and increased resistance to interference on the chrominance channel. The concept opens the doors to an improved use of new display technologies with an enlargement of the reproducible colours. Full derivation of the E'_Y signal using the "constant luminance" principle is shown in [CCIR, 1986-90j]. The main difference, apart from the coefficient related to two sets of primaries, is in the derivation of the luminance signal where in one case a non-linear precorrection is applied before matrixing and in the other case after.

4.9 *Display flicker*

Subjective tests carried out by one administration have shown that, using CRT technology, for a screen brightness of 150 cd/m^2 and a field-rate 60 Hz, large area flicker is visible but not disturbing. At a field-rate of 50 Hz and a screen brightness of 60 cd/m^2 the flicker was judged annoying [CCIR, 1982-86b]. Another administration carried out tests using a light source and a variable duration shutter. The tests showed that large area flicker at a brightness of 200 cd/m^2 became imperceptible at frequencies greater than 80 Hz [CCIR, 1982-86e].

New display devices under development (e.g. light valves) show display characteristics different from those of CRT based systems and may therefore provide improved flicker behaviour.

Using frame stores and, when necessary, interpolation electronics, the display refresh rate can be higher than the television signal field-rate [CCIR, 1982-86b]. This allows for the possibility of removing large area flicker by display processing, however, it is likely to impose a cost penalty, and possibly a quality penalty [CCIR, 1982-86g].

4.10 *Lighting flicker*

In an environment where the shooting field-rate is not the same as the local electrical mains frequency, beat frequency flicker can occur in certain circumstances. This situation has long existed in Japan, and techniques used for reducing the visibility of this flicker have been reported [CCIR, 1982-86b and h]. This problem is probably solvable, and need not weigh heavily in the choice of field-rate, although further work is required to confirm this [CCIR, 1982-86g].

4.11 *Hum*

Power-supply hum effects on vision can be removed by proper design of equipment [CCIR, 1982-86i].

4.12 *Bandwidth and noise considerations*

Subjective evaluation tests regarding the required bandwidth were carried out for the 1125-line system as a first step of the study. Values of

20 MHz and 7 MHz were obtained for the luminance and colour-difference signal respectively [CCIR, 1974-78].

A noise weighting function which can be applied to systems which differ in the number of lines and in aspect ratio has been reported, and is being used for the calculation of transmission parameters [CCIR, 1978-82a].

5. HDTV operations including motion picture production

5.1 *HDTV productions*

Many documents describe or relate production experiences or commercial productions in North America, Japan and Europe, using 1125/60/2 HDTV equipment, in the range from sporting events to full-length features for cinematographic distribution [CCIR, 1986-90k and l] and more particularly, [CCIR, 1986-90m] reports that drama programme was produced film style, in a successful manner both technically and economically, with further satisfactory conversion into NTSC and PAL.

[CCIR, 1986-90n] reports CBS experience with drama production on location for release in the NTSC format. Results were also excellent on all accounts: resulting picture quality, cost, reliability of equipment, and the ability for film crews to conduct the field shoot.

[CCIR, 1986-90o] reports that another drama entitled "long way from home" was produced entirely by electronic means, giving to people from TV production the occasion to learn much about, not only the special effects, but also how to cope with HDTV including production techniques, control of production process and artistic designs.

In [CCIR, 1986-90p], it is also reported that 1250/50/2 HDTV equipment was used before the IBC 88 (Brighton) for programme production by the RAI, ITVA and the BBC.

Document [CCIR, 1986-90q] reports that during IFA'89 in Berlin (West) a series of productions were made in a fully equipped HDTV studio complemented with four OB-vans and a post production van (1250/50/2 system).

Twenty short ten minute compilations of those and other 1250/50/2 productions were shown to the public using four rear-projection displays.

These productions covered many hours and were produced by RAI (Italy),BBC (United Kingdom), ITVA (United Kingdom), NOB (Netherlands), SFP (France), NDR (Germany (Federal Republic of)), ORF (Austria), RTP (Portugal), VARA (Netherlands), RTVE (Spain), IHD (France).

A 90-min feature-length film, "Julia and Julia", produced on HDTV by RAI was converted into a 35 mm film shown on the screen throughout the world. In Japan, motion pictures, parts of which had been made through special effects on HDTV and montaged onto a 35 mm film, were released for theatres under the titles of "Saiyuki" and "Teito Monogatari", among others. HDTV was used to make a total of 10 to 20 min of each of these movies [CCIR, 1986-90r].

5.2 Presentation of HDTV programme material

At a restaurant in Tokyo, a drama on 35 mm film "Teito Monogatari" was shown through an HDTV telecine and 110-in rear-projection display. In another instance, HDTV programmes were transmitted from Tokyo to Nagoya through a communication satellite using the MUSE signal and shown on large screens for a test of programme distribution to remote theatres [CCIR, 1986-90s].

Document [CCIR, 1986-90t] describes the proceedings of the Second Electronic Cinema Festival held in Montreux (Switzerland) in June 1989. This was the first international event in which productions realized using HDTV production/post-production equipment competed on the grounds of their creative merit. The Festival was open to productions intended for release by television or in the cinema, and falling into five programme categories: dramas, documentaries, sports, music and advertisements. Out of 53 productions entered in the Festival, 33 productions were selected to be reviewed by the International Jury which conferred five Astrolabium Awards to the productions of its choice, in various programme categories.

5.3 *Non-broadcast applications*

[CCIR, 1986-90r] reports on the interest of non-television broadcasting industries in the application of high definition television technology. If the HDTV production standards can be established to meet the needs of the varied non-broadcast industries there can be significant benefits to all from the resulting larger market for HDTV equipment.

Printing

One publishing company has put on sale a book consisting of images originating on HDTV videotapes and transferred to magnetic data tapes for printing. Pictorial postcards made in a similar way are also on the market. An HDTV test chart for electronic publishing is also being provided.

Stereoscopic television

An experimental field sequential stereoscopic television system has been developed in Japan utilizing HDTV equipment. Tests [Isono, 1987] showed that the required field frequency was greater than 110 Hz for the field sequential stereoscopic television system. A system with a field rate of 120 Hz was demonstrated to the public with short programmes produced for this purpose [CCIR, 1986-90u].

5.4 *Cable distribution*

Document [CCIR, 1986-90v] describes the current status of television distribution in the United States of America and points out the importance of cable distribution in the HDTV environment. The document reports that in the United States of America approximately 83% of the television homes are passed by cable lines and could receive cable feeds if desired. At present, approximately 52% of these television homes subscribe to cable.

Document [CCIR, 1986-90w] describes experiences with MUSE CATV transmission. Two different transmission experiments are described, FM transmission and VSB-AM transmission. The FM transmission experiment was performed with 400 MHz frequency modulation. When a two-hop microwave link was connected in tandem with an optical fibre link and nine trunk amplifiers at the far end, the unweighted S/N was over 50 dB and the television pictures were said to be excellent.

An experiment on CATV transmission with VSB-AM modulation was also performed with no deteriorations observed either in the MUSE signal, or in the conventional television signals.

In [CCIR, 1986-90x], it is reported that AM/VSB and FM/VSB have been proposed for HDMAC cable distribution. AM/VSB is applied to the time multiplex baseband signal. The use of a channel spacing of 12 MHz has been demonstrated and is recommended as a common standard. The VSB Nyquist filtering is in the range of ≈ 500 kHz around the carrier and for compatible reception shall be the same as for MAC/packet distribution. The HD-Nyquist roll-off factor and the sharing between transmitter and receiver is under study. FM/VSB has also been demonstrated. It requires the use of a channel spacing of 16 MHz. Modulation parameters are under study.

6. Operational considerations and experiences

6.1 *Operational consideration on standards conversion in relationship with conventional TV and HDTV emission standards*

Decision 58 requests studies that will lead to a single world standard for the production studio and for the international exchange of HDTV programmes. Studies have concluded that there also exists an identifiable relationship between the parameters in § 1.1 of Part 5 and emission systems.

Only the problem of introducing a 60 Hz based HDTV studio standard into a 50 Hz broadcasting environment was studied [CCIR, 1986-90y]. The study had the objective of establishing whether the advantages of a common 60 Hz production standard would outweigh any technical, economic, or operational disadvantage of having different field-rates for production and emission.

For example, [CCIR, 1986-90z] argues that converting from 60 Hz to a 625/50 TV standard requires an expensive field rate standards converter, whereas the use of 50 Hz HDTV needs a line rate standards converter which is 10 to 40 times less expensive.

In Document [CCIR, 1986-90z] it is stated that broadcasting at 50 f/s of film originated material will lead to cascaded temporal interpolation (24 f/s to 60 f/s to 50 f/s). This could result in complex and possibly costly processing to avoid impairments.

This is why, over a period of several years, the EBU studied various aspects of standards conversion [CCIR, 1986-90aa]. Initially a technical appraisal was made which concluded that HDTV to HDTV frame rate conversion at high quality should be possible in future, though relatively expensive, through the use of motion estimation and compensation. This was followed by a study of the operational and economic consequences of using the same or different field rates for production and emission of HDTV in a 50 Hz environment. This concluded that of the scenarios examined the use of a 60 Hz field rate for HDTV production, in a 50 Hz environment, was the least favourable scenario. The extent to which a 50 Hz - 50 Hz situation was more favourable than a 60 Hz - 60 Hz situation depended on the broadcaster's configuration.

Document [CCIR, 1986-90ab] reports that similar studies have been pursued [CCIR, 1986-90p] on a simplified model of a national network and its evolution towards DBS programme provision. Two options for the choice of HDTV studio field rate are compared:

Option A: HDTV studio standard has the same field rate of the HDTV emission standard (i.e., 50 Hz);

Option B: HDTV studio standard has a different field rate from the HDTV emission standard (i.e., 60 Hz).

There were five possible standards conversions under these options.

A preliminary conclusion is that Option A is clearly more attractive than Option B since line-rate converters are both cheaper and capable of higher performance than field rate converters. Furthermore, the number of converters for category 5 is very much lower than for categories 2, 3 and 4.

Finally, it is noted that a similar argument would apply in 60 Hz countries, if there were a 50 Hz studio standard.

This preliminary conclusion raises the question for some administrations as to whether the relative benefits of a pair of production standards (based upon Recommendation 601) would exceed those of a single world-wide production standard [CCIR, 1986-90ac].

Results available in relation to option A show that high quality line rate conversions are feasible without the need for complex filter implementations [CCIR, 1986-90ad]. Preliminary subjective tests to evaluate conversions involving interpolation and decimation in conversions from 1080 lines to other line numbers show that satisfactory results can be obtained at reasonable levels of complexity [CCIR, 1986-90ae].

6.2 *Operational considerations on film-to/from-video transfers*

Document [CCIR, 1986-90af] reports on studies that show that when operated under the same conditions HDTV cameras have similar transfer characteristics of 35 mm colour film.

Document [CCIR, 1986-90ag] reports on the work of the SMPTE in their investigation of using 30 f/s for film production and distribution. The conclusions of the SMPTE Study Group are that the increase in frame rate from 24 f/s to 30 f/s significantly improves the quality of the projected images by virtue of permitting higher screen brightness without full-field flicker and by increasing the dynamic resolution.

Document [CCIR, 1986-90ah] states that in the production of programmes there is a trend in film production for television towards original capture at 30 f/s, so that there would be only one temporal conversion in going to a 24 f/s or 25 f/s system.

[CCIR, 1986-90ah] points out that 63% (3640 hours) of the total hours of programming produced in "Hollywood" are for "first run" TV distribution in the United States of America at a field rate of 60 Hz and then are distributed world-wide in various formats. The remaining hours of programming are for presentation in the cinema.

The document goes on to consider frame-rate-related performance parameters and concludes that the 1125/60 studio systems of Annex II of Report 801-2 (Geneva, 1986) is a superior system from the viewpoint of conversion to other formats.

HDTV to film transfer *

[CCIR, 1986-90ai] states that the converters from 1125/60/2:1 HDTV to 24-frame film system, have been developed and are currently being used satisfactorily.

[CCIR, 1986-90z] states that the combination of film and HDTV-60 Hz originated material for final release on film, will lead to the cascading of temporal interpolations (24 f/s to 60 f/s to 24 f/s) unless special precautions are taken to avoid impairments.

Document [CCIR, 1986-90z] also argues that the use of a 50 Hz studio standard would ease and therefore reduce costs of this process and more generally ease the combination of film and HDTV production. (In particular, no artifacts caused by cascading temporal interpolation should be foreseen.)

Document [CCIR, 1986-90aj] argues that there are very clear benefits for video-to-film transfer of originating video on a 50 Hz 1:1 HDTV standard in terms of picture quality. Due to the possibility to reproduce at 24 pictures/s material shot at 25 pictures/s the quality of motion portrayal of cinema films derived from 50 Hz 1:1 HDTV will be identical to that of films shot directly at 24 fps and will be free of additional disturbing low-frequency judder components.

Document [CCIR, 1986-90aj] argues that the 4% sound track pitch-change which results from presenting 24 fps film at 25 fps is already widely accepted by both broadcasters and the viewing public; it is only noticeable on certain and infrequent types of programme material to those viewers who are professional musicians and have perfect pitch. A comparable pitch-change will result from 24 fps presentation of film derived from 50 Hz video.

In a paper presented at the IREECON '89 Convention [I. Gilmour and W. Lazar, 1989] it is reported [CCIR, 1986-90ak]:

"Timbre is easily distinguished even by the untrained ear. A 2-3% change in pitch may not be noticed in isolation as a change of fundamental frequency but is often felt as a "change of personality" in spoken word records, or "a new voice or instrument" in music. The 4.2% change of speed which occurs when films are screened on T.V. is not only close to a semitone in pitch, but also means "new people, new voices, new instruments". The effect can be compared to physically scaling up or down the entire cast and set."

In the case of the transfer of electronically recorded signals onto film, the interlaced nature of conventional television standards causes additional problems, since vertically adjacent lines on the final film frame

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* For further information see Recommendation 713.

originate from different television fields. This results in "combing" being produced on the edges of moving objects; there is also an increased level of motion blur due to the effective exposure period produced when two television fields are combined. Alternatively, the combing and motion blur can be eliminated by recording only a single television field instead of a pair; in this case the penalties are a loss of vertical resolution and an increase in the visibility of line structure in the final image [CCIR, 1986-90al].

*Film to HDTV transfer**

The film frame rate used internationally for motion picture films is 24 f/s. Present-day practice for broadcasting such films varies between countries with 50 Hz field rate television systems and those with 60 Hz systems. In countries having a 60 Hz field frequency, two successive film frames are used to form five television fields; this is accomplished by repeating the first frame twice and the second three times. The effect of the repetition process is to produce beat-frequency judder at 12 Hz on moving objects; this is, of course, in addition to the normal 24 Hz judder due to the film frame rate itself. More sophisticated techniques have been reported [Childs, 1985], which use temporal interpolation to smooth out the judder, but a compromise between judder and excessive motion blur is always necessary.

In countries having 50 Hz field frequencies, films are almost invariably shown at a slightly increased speed of 25 f/s, in order to simplify the conversion process [CCIR, 1986-90al].

[CCIR, 1986-90am] reviews the HDTV-film interface in viewpoints of the difference between 24 and 25 f/s, degradation due to field repetition in 50 Hz system, and a possible solution with motion compensation technologies. It expresses a view that the interface issue cannot be a decisive factor to choose 50 Hz for the field rate of the world-wide unique HDTV studio standard.

Document [CCIR, 1986-90an] reports the result of studies concerning the scanned area of 35 mm motion picture filmm in HDTV telecine. This matter is reported in Recommendation 716.

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* For further information see Report 294 Recommendation 716.

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[1978-82]: **a.** 11/76 (CMTT/58) (Japan); **b.** 11/317 (USSR).

[1982-86]: **a.** 11/269 (Japan); **b.** 11/398 (IWP 11/6); **c.** 11/258 (USA); **d.** 11/283 (United Kingdom); **e.** 11/304 (France); **f.** 11/377 (Canada); **g.** 11/405 (EBU); **h.** 11/403 (Japan); **i.** 11/329 (EBU).

[1986-90]: **a.** IWP 11/6-1034 (CBS); **b.** IWP 11/6-2029 (CBS); **c.** IWP 11/6-1017 (Canada); **d.** IWP 11/6-2024 (CBS); **e.** IWP 11/6-2036 (Japan); **f.** IWP 11/6-2056 (Rev. 1) (Thomson CSF); **g.** IWP 11/6-2025 (CBS); **h.** IWP 11/6-2032 (Japan); **i.** IWP 11/6-2019 (USA); **j.** IWP 11/6-2041 (Japan); **k.** IWP 11/6-2096 (France); **l.** IWP 11/6-1040 (EBU); **m.** 11/160 (France); **n.** IWP 11/6-2008 (EBU); **o.** IWP 11/6-1033 (CBS); **p.** IWP 11/6-1062 (UK); **q.** IWP 11/6-2027 (CBS); **r.** 11/135 (CBS); **s.** 11/133 (CBS); **t.** IWP 11/6-1066 (Japan); **u.** IWP 11/6-2046 (Belgium et al.); **v.** IWP 11/6-2087 (Japan).

PART 4 - ASSESSMENT OF HDTV QUALITY

1. Introduction

Aspects of the subjective and objective assessment of HDTV were examined at the Extraordinary Meeting of Study Group 11. Ten documents were considered in addition to existing CCIR texts. Particularly significant to the work were the thorough contributions on subjective assessment received from Interim Working Party 11/4 and a draft new Report on objective measurement from IWP 11/6.

In the interest of presenting a concise and readable report of the activities of the Extraordinary Meeting of Study Group 11, in HDTV quality aspects: first, the meeting adopted Report AT/11 (MOD Ex) (The subjective assessment of systems associated with an HDTV environment) now Report 1216 and Report [XF/11] (Measurements in HDTV) now Report 1218.

The Extraordinary Meeting also adopted the following texts:

- Recommendation of subjective assessment methods for image quality in HDTV (Recommendation 710);
- Study Programme 3E/11 on subjective assessment procedures for signals originating in an HDTV studio;
- Study Programme 27C/11 on objective measurement in an HDTV environment.

The text of Decision 66-1 (MOD I) was also examined by the meeting, but was still found to be complete and relevant and no modifications were proposed.

2. Summary of Report 1216

Report 1216 is a dossier of current knowledge on subjective assessment methods for high-definition television. The document considers assessments of HDTV studio formats, of conventional studio pictures derived from HDTV studio formats, of HDTV emission systems derived from HDTV studio formats, and of compatible pictures received in HDTV emissions. The document also considers comparative assessments of HDTV studio formats and of HDTV emission formats.

2.1 HDTV studio formats

For assessments of basic quality, the double stimulus continuous quality scale method (DSCQ) is suggested. The reference should provide quality superior to that of the system under test (e.g., a directly viewed scene or performance). The test materials should permit attribution of subjective reactions to specific attributes, such as: static and dynamic resolution; luminance, colour, and motion rendition; flicker, etc.

For assessments of quality following various types of downstream processing, different methods are suggested. Assessments of colour matte could use the double stimulus impairment scale method (DSI), with test materials critical for colour matte operations. For slow motion and other picture manipulations, in the absence of a high-quality reference, the ratio scaling method has been suggested and alternative methods are under study. For HDTV-HDTV studio standard conversions, primary assessments might use the DSCQ method with briefly presented critical test materials, while auxiliary assessments might use the single stimulus continuous quality scale method (SSCQ) with lengthier presentations of less critical material.

In all cases, viewing conditions would be as given in Recommendation 710 (Subjective Assessment Methods for Image Quality in HDTV). In interpreting the results, however, it is necessary to allow for possible influences in the technical state of implementation of the HDTV studio system.

2.2 Conventional studio formats derived from HDTV studio formats

For evaluations of the small impairments and the limited range of impairments to be expected, the DSCQ method is thought the most useful. In the tests, assessors would view pairs of presentations, of which one would be prepared directly in the conventional format, while the other would be converted from the HDTV studio format. The viewing conditions should be in accordance with those given in Recommendation 500.

2.3 HDTV emission systems

For basic quality, primary assessments might use the DSCQ method with the studio system as reference, while auxiliary assessments might use the SSCQ method. In the former case, displays would be brief and use material that was "critical, but not unduly so" while, in the latter case, displays would be lengthier and would use material representative of normal programming.

For assessments of failure characteristics, echo behaviour, and interference, the DSI method might be used, with the studio system and/or the unimpaired emission format as reference. The test materials would be brief and "critical, but not unduly so".

For all evaluations, the viewing conditions would be as given in Recommendation 710 (Subjective Assessment Methods for Image Quality in HDTV).

2.4 Compatible pictures received in HDTV emissions

For basic quality, the DSCQ method might be used with material prepared directly in the conventional emission format and/or material converted directly from the HDTV studio format as reference. For failure characteristics, echo behaviour, and interference, the DSI method might be used, with material prepared directly in the conventional emission format (but not otherwise impaired) and/or material converted directly from the HDTV studio format (but not otherwise impaired) as reference.

The viewing conditions would be as given in Recommendation 500.

2.5 Comparative assessments of HDTV studio formats

For these assessments, three approaches may be considered.

In direct comparisons, candidate studio formats would be compared directly on a side-by-side basis. Issues have been raised concerning the appropriateness of such procedures; these are given in [CCIR, 1986-90a, b].

In indirect comparisons, candidate studio formats would be tested alternately against common, directly-viewed reference scenes. Depending upon the range of quality seen, either the DSCQ or the DSI method would be used. The viewing conditions would be as given in Recommendation 710. It should be noted that, in this case, it is essential to maintain constant source material across the systems tested. It is also considered useful to ensure that source scenes are composed to permit attribution of subjective judgements to particular factors in design (see § 2.1).

In theoretical comparisons, candidate studio systems are placed, parameter-by-parameter, in terms of degree of adherence to the relevant psychophysical ideals. Examples of this approach are given in [CCIR, 1986-90c, d].

It is thought essential in comparative tests to take account of possible influences of technical state of implementation.

2.6 Comparative assessments of HDTV emission formats

These might proceed as described in § 2.3, with the exception that the intent is to compare across systems, the basic quality, the failure characteristics, the echo performance, and the interference performance.

2.7 Test pictures

It is desirable to unify the assessment method and test pictures, because differences in these matters may cause different results in subjective assessment on the picture quality of HDTV.

Nine still pictures have been selected in Japan for standard test pictures to be used in assessments of HDTV picture quality. Some demonstrations to the public were carried out and much interest was expressed on an excellent picture quality provided by them. These are already being used for various tests in Japan. Sequences of moving pictures are to be studied in the next step [CCIR, 1986-90e].

3. Summary of Report 1218 on objective measurement

Report 1218 drawing on [CCIR, 1986-90f, g, h], considers the important topic of the objective measurement of high-definition television signal parameters. It addresses three areas for attention: first, the examination of the transfer characteristics of distortions occurring over a number of time-durations; second, proposals for the nature of the test signals to be used for characterizing the HDTV video signal; and third, suggestions for elements of test patterns for HDTV and examples of such patterns.

This Report is complemented by four detailed diagrams of example test signals and two pictures of example test patterns.

REFERENCES TO PART 4

CCIR Documents

[1986-90]: **a.** IWP 11/4-160(IWP 11/4); **b.** IWP 11/4-161 (France); **c.** IWP 11/4-146 (France); **d.** IWP 11/4-172 (Canada); **e.** 11/589 (Japan); **f.** 11/340 (USSR); **g.** 11/341 (USSR); **h.** 11/342 (USSR).

PART 5 - STUDIO STANDARDS AND ASSOCIATED EQUIPMENT

PART 5.1 - DEVELOPMENT REPORTS ON STUDIO STANDARDS AND ASSOCIATED EQUIPMENT

Considerable progress has been made in the production of studio equipment designed around two draft Recommendations which have been submitted to the CCIR. While neither set of parameters in those drafts have been agreed by the CCIR as being acceptable as a single worldwide standard, both have sufficient support for practical use in specific areas to encourage manufacturers to produce equipment.

1.1 Proposal based on an 1125/60 system

The following proposal for a draft Recommendation for an HDTV studio standard based on 60 Hz was submitted to the CCIR, initially in 1985 and has reached the level of implementation indicated in Tables [I to V].

CONSIDERING

(a) that an HDTV studio standards must provide pictures with approximately twice the horizontal and vertical spatial resolution of, and a larger aspect ratio than, studio sources using existing standards;.

(b) that there exists a broad range of applications for HDTV;

(c) that there has been substantial progress made in high-definition television technology for production equipment;

(d) that an HDTV studio standard should make possible a major improvement in quality over conventional 525/625 systems, when viewed on a large screen of 1 m diagonal size or larger;

(e) that an HDTV studio standard should make possible large-screen viewing with a spatial resolution comparable to 35 mm cinematographic film;

(f) that HDTV signals will be used as sources for current and proposed broadcast television systems and for motion picture film;

(g) that an HDTV studio standard must be specified in digital form with a simple relationship to Recommendation 601;

(h) that the transfer to and from film can be provided with adequate quality;

RECOMMENDS

that the following standard parameters be used for generation of signals in high-definition television studios

1.1.1 Basic characteristics of the video signal.

The video signal represents a scanned raster with the characteristics shown in Table I:

TABLE I - BASIC CHARACTERISTICS OF VIDEO SIGNALS

ITEM	CHARACTERISTICS	
1	Number of lines per frame	1125
2	Number of picture lines per frame	1035
3	Interlace ratio	2:1
4	Aspect ratio (H:V)	16:9
5	Field frequency (fields/sec)	60.00
6	Line frequency (Hz)	33750

Colorimetric characteristics.

TABLE II

ITEM	CHARACTERISTICS	
1	Assumed chromaticity coordinates (CIE 1931) for primary colours of display.	x y R 0.630 0.340 G 0.310 0.595 B 0.155 0.070
2	Chromaticity for equal primary signals. ($E'_R = E'_G = E'_B$ i.e. Reference white) (1)	Illuminant D_{65} x y 0.3127 0.3290
3	Electro-optical transfer characteristic of reference reproducer.	$L=((V+0.1115)/1.1115)^{(1/0.45)}$ for $V \geq 0.0913$ $L=V/4.0$ for $V < 0.0913$ (2)
4	Assumed gamma of ref. reproducer for which pre-correction of primary signal is made.	2.2 (approx.)
5	Opto-electronic transfer characteristic of reference camera.	$V=1.1115 x L^{(0.45)}-0.1115$ for $L \geq 0.0228$ $V=4.0xL$ for $L < 0.0228$

TABLE II (continued)

ITEM		
6	Transmitted signals	$\begin{bmatrix} E'_G \\ E'_B \\ E'_R \end{bmatrix} = \begin{bmatrix} 1.000 & -0.227 & -0.477 \\ 1.000 & 1.826 & 0.000 \\ 1.000 & 0.000 & 1.576 \end{bmatrix} \begin{bmatrix} E'_Y \\ E'_{P_B} \\ E'_{P_R} \end{bmatrix}$ $\begin{bmatrix} E'_Y \\ E'_{P_B} \\ E'_{P_R} \end{bmatrix} = \begin{bmatrix} 0.701 & 0.087 & 0.212 \\ -0,384 & 0.500 & -0.116 \\ -0.445 & -0.055 & 0.500 \end{bmatrix} \begin{bmatrix} E'_G \\ E'_B \\ E'_R \end{bmatrix}$ (1) (3)
7	Scaling of colour difference signals (derived)	$E'_{P_R} = \frac{E'_R - E'_Y}{1.576}$ $E'_{P_B} = \frac{E'_B - E'_Y}{1.826}$

Note 1: E'_R, E'_G, E'_B are the signals appropriate to drive the primaries of the reference reproducer (having been pre-corrected for the reproducer's electro-optical transfer characteristic).

Note 2: L - light level

V - video signal level

Note 3: E'_Y, E'_{P_R}, E'_{P_B} can be derived from E'_R, E'_G, E'_B through a linear matrix.

1.1.2 Analogue representation

The image is represented by three parallel, time-coincident video signals. Each incorporates a synchronizing waveform.

The signals shall be either of the following sets:

$$\begin{bmatrix} E'_G \text{ "green"} \\ E'_B \text{ "blue"} \\ E'_R \text{ "red"} \end{bmatrix} \qquad \begin{bmatrix} E'_Y \text{ "luminance"} \\ E'_{P_B} \text{ "blue colour difference"} \\ E'_{P_R} \text{ "red colour difference"} \end{bmatrix}$$

The video signals are fully described in Table III, IV and figure 1.

TABLE III

ITEM	CHARACTERISTICS		
1	Nominal levels of E'_Y and $E'_G E'_R E'_B$ with sync	Reference black level (mV) Reference white level (mV) Synchronizing level (mV) (1)	0 700 ±300 (Tri-level bipolar)
2	Nominal levels of E'_{P_R} E'_{P_B} with sync	Reference zero level (mV) Reference peak level (mV) Synchronizing level (mV) (1)	0 ±350 ±300 (Tri-level bipolar)
3	Bandwidth	E'_R, E'_G, E'_B	30 MHz (Nominal)
		E'_Y	30 MHz (Nominal)
		E'_{P_B}, E'_{P_R}	15/30 MHz (Nominal) (2)

Note 1: Based on a 75 ohm (nominal) circuit impedance.

Note 2: 15 MHz applies when derived from digital sources.

1.1.3 Analog timing and synchronization.

TABLE IV

ITEM	CHARACTERISTICS		
1	Synchronizing signal form	Tri-level bipolar	
2	Nominal line-blanking interval (µs)	3.77	
3	Field-blanking period	45 H	
4	Reference clock frequency (MHz)	74.25 ± 10 ppm	
5	Reference clock period t (nsec)	t = 13.47 = H/2200	
6	H line timing (see figure 1)		
	Rising edge of sync (timing reference)	0	
	Trailing edge of sync	44	
	Start of active video	192	
	End of active video	2112	
	Leading edge of sync	2156	
	Figure 1:	Reference clock periods	time (derived) (µsec.)
	a	44	0.593
	b	88	1.185
	c	44	0.593
	d	132	1.778
	e	192	2.586
	f (Sync rise time)	4	0.054
	Total line	2200	29.63
	Active line	1920	25.86

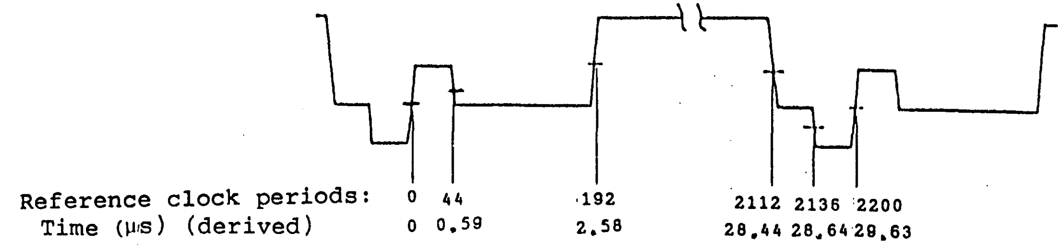

Figure 1(a). Timing of events within a video line.

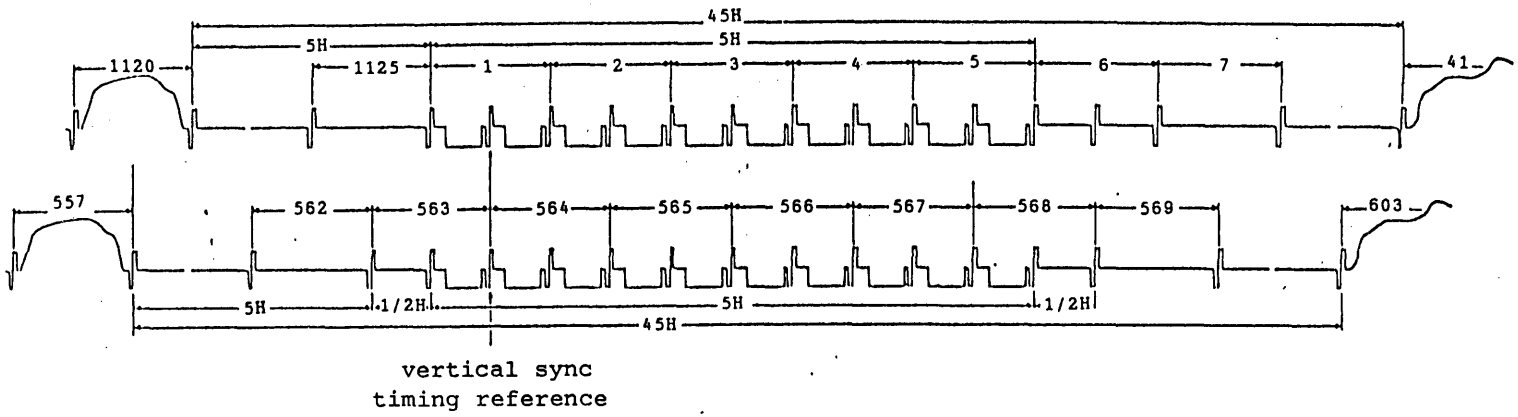

Figure 1(b). Detail of field blanking periods.

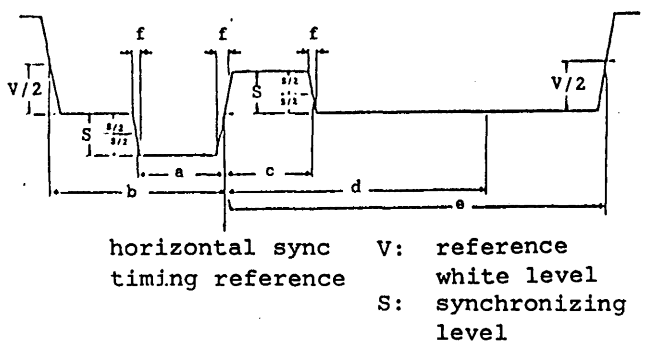

Figure 1(c). Detail of line blanking period

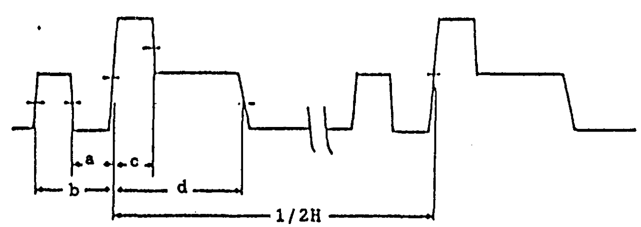

Figure 1(d). Detail of field synchronizing pulse.

FIGURE 1 - Analogue synchronizing signal waveform

1.1.4 Digital representation

The video signals are represented in digital form by table V.

TABLE V

ITEM	CHARACTERISTICS	
1	Coded signals: Y, C_R, C_B	These signals are obtained from gamma pre-corrected signals, namely: E'_Y, $E'_R-E'_Y$, $E'_B-E'_Y$
2	Number of samples per total line: - luminance signal (Y) - each color-difference signal (C_R, C_B)	 2200 1100
3	Sampling structure	Orthogonal, line, field and frame repetitive. C_R and C_B samples co-sited with odd (1st, 3rd, 5th, etc.) Y samples in each line.
4	Sampling frequency: - luminance signal (MHz) - each colour-difference signal (MHz)	 74.25 (nominal) 37.125 (nominal)
5	Form of coding	Uniformly quantized PCM, N bits per sample, for the luminance signal and each color-difference signal (1)
6	Number of samples per digital active line: - luminance signal - each color-difference signal	 1920 960

TABLE V (continued)

ITEM	CHARACTERISTICS	
7	Analogue-to-digital horizontal timing relationship: - from end of digital active line to 0_H	To be determined
8	Correspondance between video signal levels and quantization levels: - scale - luminance signal - each color-difference signal	 0 to (2^N-1) (1) Study required Study required
9	Code-word usage	Study required

Note 1: N is number of bits required. (Required further study)

1.2 Proposal based on a 1250/50 system

The following proposal for a draft Recommendation for an HDTV studio standard based on 50 Hz was submitted to the CCIR, initially in 1987 and has reached the level of development indicated in Tables [I-VII] /̲CCIR, 1986-90a̲/.

CONSIDERING

(a) that an HDTV studio standard must provide pictures with approximately twice the horizontal and vertical spatial resolution of, and a larger aspect ratio than studio sources using existing standards,

(b) that there exists a broad range of applications for HDTV,

(c) that there has been substantial progress made in High Definition Television technology for production equipment,

(d) that a multiplicity of standards will cause difficulties among broadcasters in the future,

(e) that HDTV sources will also be used for current and currently proposed broadcast television systems,

(f) that a conversion to existing 625/50 and 525/60 standards can be provided with good quality,

(g) that an HDTV studio standard must be specified in digital form with a simple relationship to Recommendation 601,

(h) that a 50 Hz field rate has advantages for the transfer to and from the existing film standard, which will continue to be an exchange format,

(i) that motion portrayal is satisfactory with field rates of 50 Hz or greater,

(j) that for a given bandwidth and interlace factor a 50 Hz field rate provides greater spatial resolution that higher field rates,

(k) that a majority of countries currently use emission standards based upon a 50 Hz field rate,

(l) that HDTV emission, transmission and studio standards are being considered in parallel,

(m) that all parameters of an HDTV studio standard should be optimized with regard to conversion into the respective HDTV emission standard (either based on 50 or 59.94/60 Hz).

RECOMMENDS

That the following standard parameter values be used for generation of signals for High Definition Television production and for the international exchange of High Definition Television programmes :

1.2.1 SCANNING PARAMETERS

TABLE I

Item	CHARACTERISTICS *	
1.1	Total number of lines per picture	1250
1.2	Number of active lines per picture	1152
1.3	Scanning method	Progressive 1 : 1
1.4	Aspect ratio	16 : 9
1.5	Field frequency	50 Hz
1.6	Line frequency	62,5 kHz

* This is the target standard. The first implementation may be based on a bandwidth reduced system. A bandwidth reduced system is described in § 2.2.2.

1.2.2 COLORIMETRY AT THE STUDIO INTERFACE

The content of section 2, 3 and 4 is in line with studies under completion, but the confidence given to these results, still subject to confirmative tests, is high enough now to introduce this information.

TABLE II

Item	CHARACTERISTICS			
2.1.	Chromaticity coordinates of primaries at the studio interface (1) (2)	Red Green Blue	x 0.6915 0.0000 0.1440	y 0.3083 1.0000 0.0297
2.2.	Chromaticity coordinates of reference white : illuminant D_{65} (2)	D_{65}	x 0.3127	y 0.3290

Note 1
Red and blue primaries are monochromatic (620 nm and 460 nm) real colours. "Green" is a non-real colour called "green" for reason of simplicity.

Note 2
Figure 1 gives the position of the studio interface where primaries are labeled R, G, B and the signals balanced for a D_{65} white reference.

1.2.3 TRANSFER CHARACTERISTICS

See section 2 heading.

TABLE III

Item	CHARACTERISTICS	
3.1.	Opto-electronic transfer reference source	Linear Gamma = 1
3.2.	Overall electro-optical transfer characteristic of the HDTV Chain	Gamma = 1.26 (3)
3.3.	Non-linear preemphasis of the primaries and luminance signals at the studio interface	Gamma = 0.45

Note 3
It assumes a conventional CRT display having a gamma of 2.8 and source signals precorrected with the same law than the non-linear preamphasis given in item 3.3.

1.2.4 ANALOGUE SIGNAL REPRESENTATION

See section 2 heading

The analogue picture signal comprises 3 parallel, time-coincident voltage signals from one or other of the two following sets (fig.2) :

(i)	E_R	"red"	or	(ii)	E'_Y	"luminance"
	E_G	"green"			E'_{C1}	"colour difference 1"
	E_B	"blue"			E'_{C2}	"colour difference 2"

* The impedance of the source is 75 ohms.

* The mark ' denotes non-linear pre-emphasis of the linear primary or luminance signals (see parameter 3.3)

* Generally, it is necessary to precorrect the primary signals E_R, E_G and E_B before applying them to a display : in practice 4 gamma-correctors are used in a camera to obtain E'_Y, E'_R, E'_G and E'_B.

TABLE IV

Item	CHARACTERISTICS	
4.1	Pre-emphasis equation for primary signals	$E'_R = E_R^{0.45}$ volts $E'_G = E_G^{0.45}$ volts $E'_B = E_B^{0.45}$ volts
4.2	Luminance signal equation	$E'_Y = (0.3392\ E_R + 0.6217\ E_G + 0.0391\ E_B)^{0.45}$ where E_R, E_G, & E_B vary from 0.0 to 1.0
4.3	Colour-difference signal equation	$E'_{C1} = 1.8\ (E'_R - E'_Y)$ $E'_{C2} = 0.8\ (E'_B - E'_Y)$
4.4	Nominal signal levels of E'_Y, E'_R, E'_G, & E'_B	Reference black level 0 mV Reference white level 1000 mV
4.5	Nominal signal levels of E'_{C1} & E'_{C2} (Note 4)	Reference achromatic level 0 mV Reference peak level +/-650 mV
4.6	Nominal signal bandwidth	E_R, E_G, E_B & E'_Y 60 MHz E'_{C1} & E'_{C2} 30 MHz

Note 4

* E'_{C1} & E'_{C2} represent E'_{C1} & E'_{C2} clipped to the peak level.

1.2.5 DIGITAL SIGNAL REPRESENTATION

Only set (ii) is considered presently for digitization. The necessary number of bits per sample for E_R, E_G, E_B signals in still under study.

TABLE V

Item	CHARACTERISTICS	
5.1	Coding form and word-length for Y, C_1, C_2.	E'_Y, E'_{C1} & E'_{C2} uniformly quantized PCM with at least 8 bits/sample for Y 8 bits/sample for C1 or C2
5.2	Sampling structures : - Luminance signal - Colour-difference signal	 Orthogonal line and picture repetitive. Line quincunx, picture repetitive. C1 and C2 samples cosited each other and with odd numbered Y samples on odd numbered lines, with even numbered Y samples on even numbered lines.
5.3	Number of samples per digital active line. - Luminance signal - Colour-difference signal	 1920 960
5.4	Total number of samples per full line - Luminance signal - Colour difference signal	 2304 1152
5.5	Sampling frequency - Y - C_1 & C_2	 144 MHz 72 MHz
5.6	Analogue-to-digital horizontal timing relationship from end of digital active line to O_H	Under study
5.7	Correspondence between video signal levels and quantization levels : - Scale - Luminance signal - Colour difference signal	Under study
5.8	Code-word usage	Under study

1.2.6 ANALOGUE SYNCHRONIZING WAVEFORM

1.2.6.1 *Details of the line synchronizing signals (see fig. 3)*

a) **Synchronizing waveform**

— Bipolar tri-level sync
— Amplitude ± 300 mV peak into 75 ohms.

b) **Timing**

Reference clock frequency : 2,25 MHz

TABLE VI

Symbols	CHARACTERISTICS	μs	2,25 MHz periods
H	Nominal line period	16	36
a	Line blanking interval	2.667	6
b	Interval between time datum (O_H) and back edge of line-blanking pulse	1.778	4
c	Front porch	0.889	2
d	Synchronizing pulses	0.444	1
f	Build up times (10 % to 90 %)	Under study.	

1.2.6.2 *Details of the frame synchronizing signals (see fig. 4 and 5)*

Reference : line period H = 16 μs

TABLE VII

Symbol	CHARACTERISTICS	Time	Line periods
v	Frame period	20 ms	1250
j	Frame blanking interval	1.568 ms	98
q'	Duration of frame synchronizing pulse.	8 μs	1/2

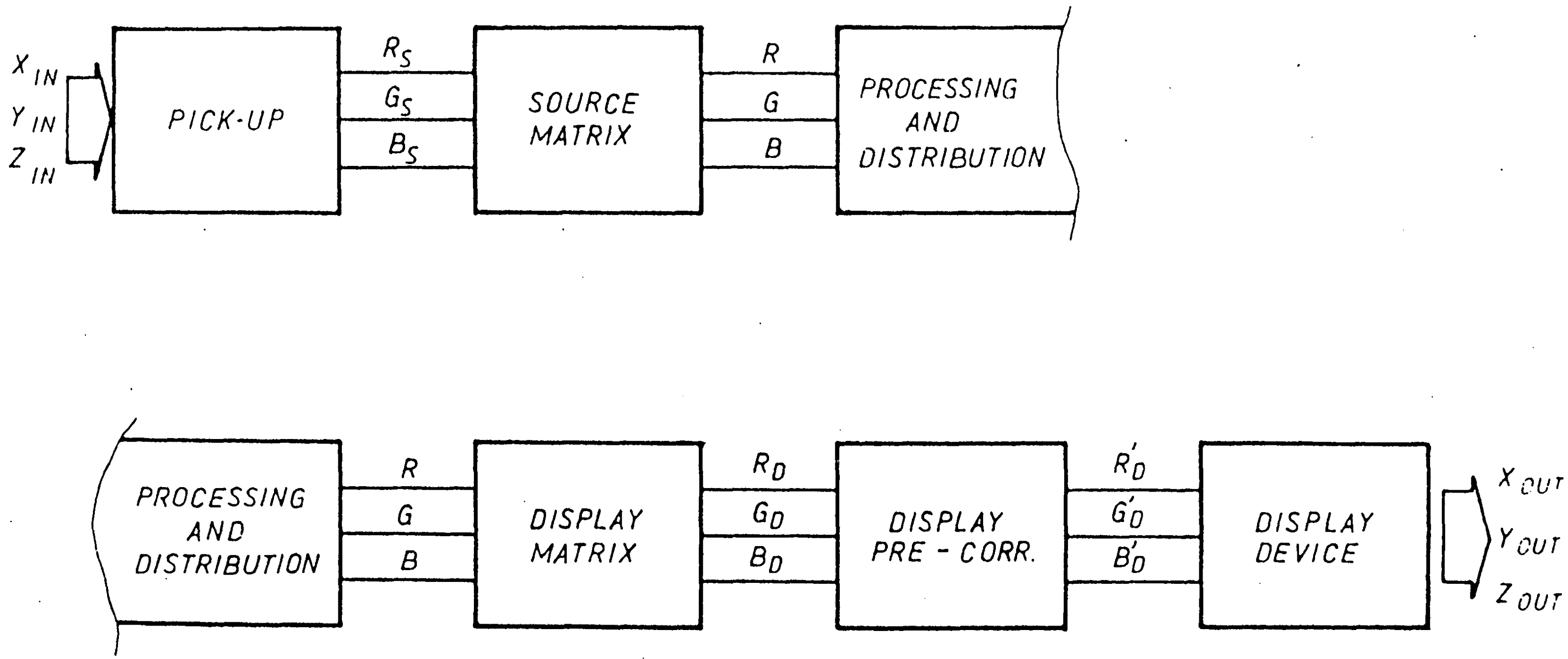

FIG. 1 A COLORIMETRIC SCHEMATIC OF A TELEVISION CHAIN

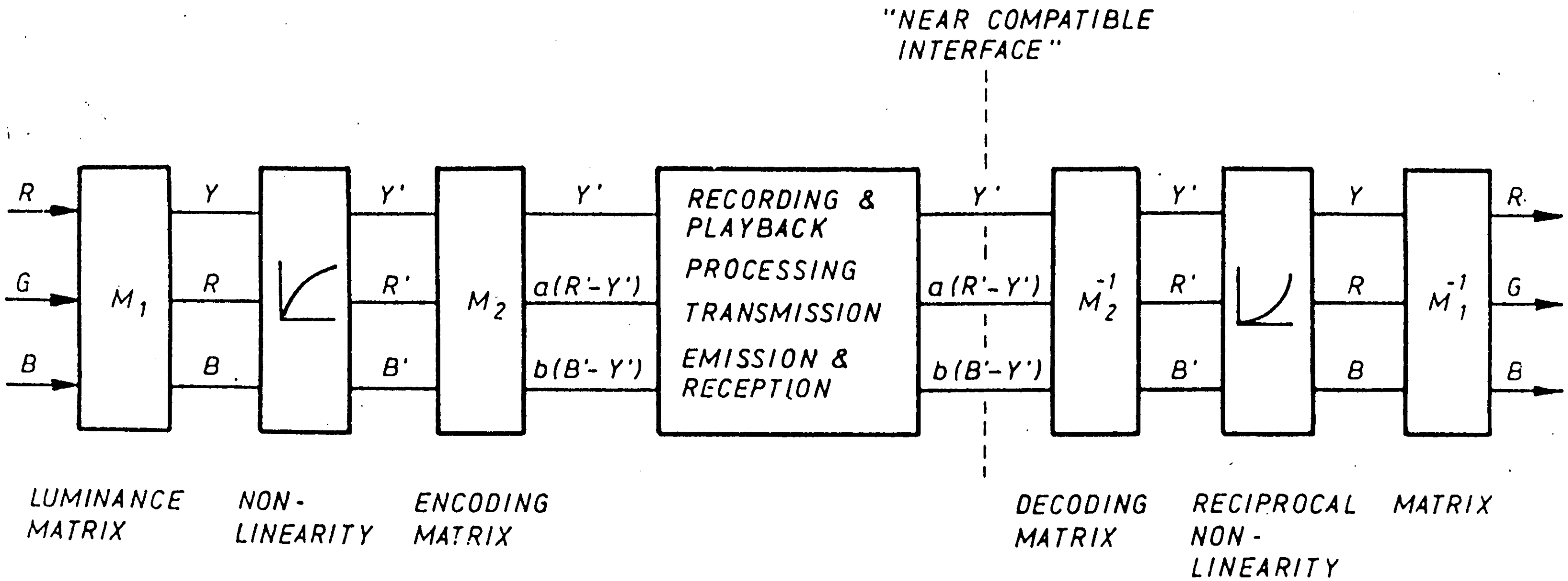

FIG 2. PROCESSING AND DISTRIBUTION

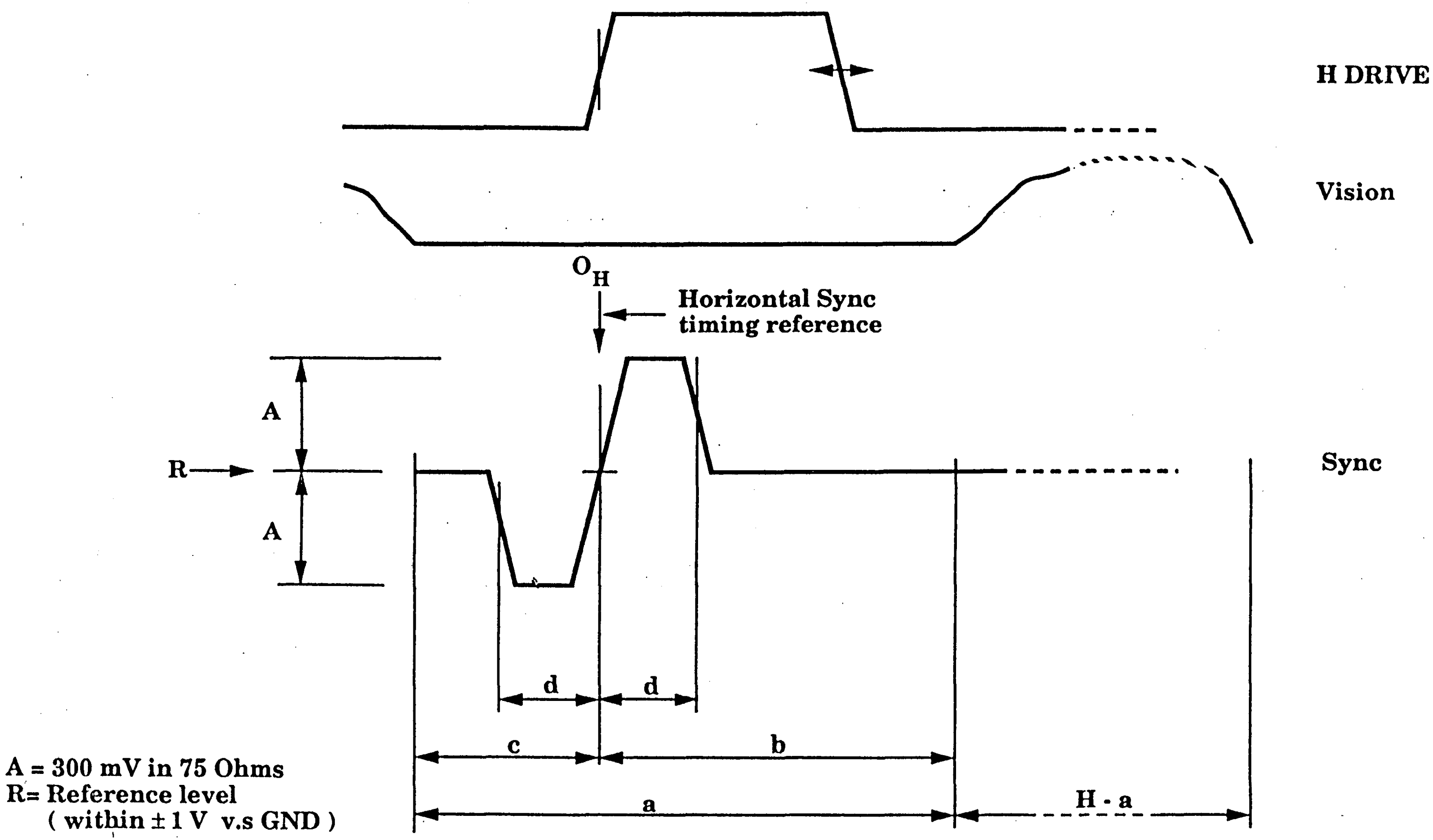

Figure 3 : Detail of line synchronizing signal

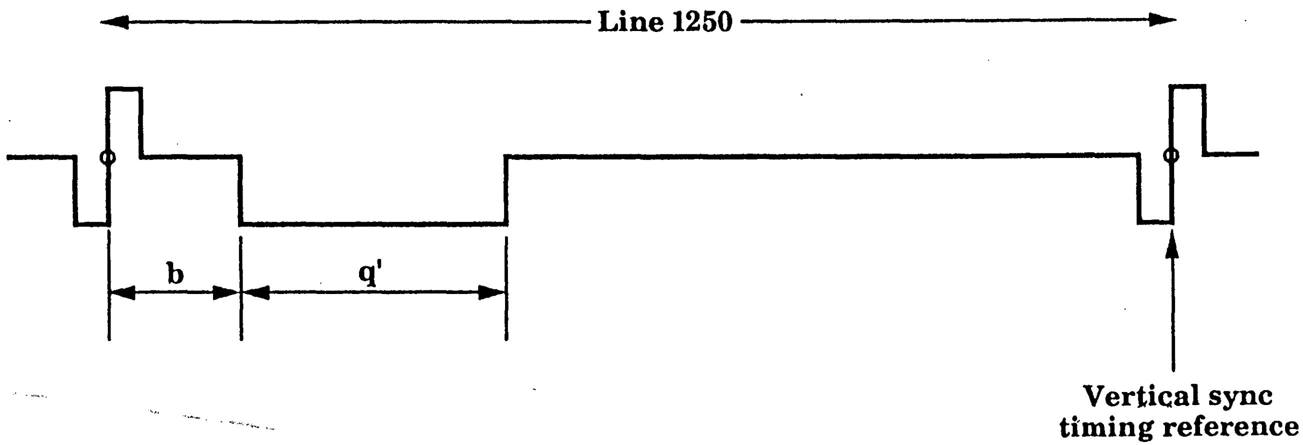

Figure 4 : Detail of frame synchronizing signal

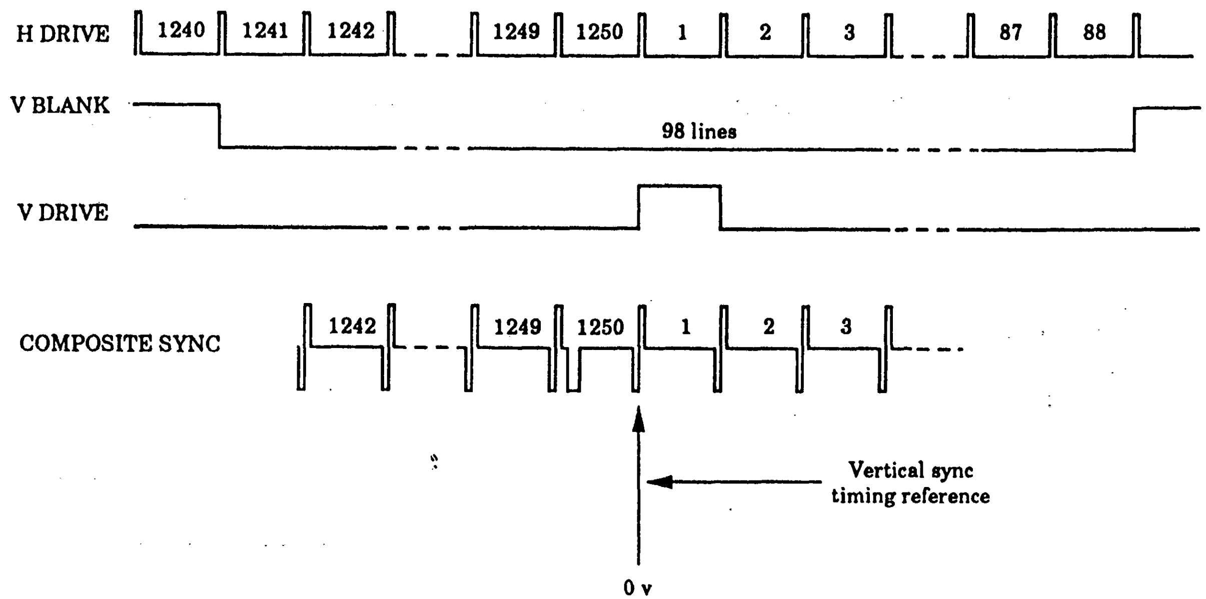

Figure 5 : Detail of vertical blanking interval and derived signals.

PART 5.2 - DEVELOPMENT OF EQUIPMENT (EXCEPT FOR CONVERTERS AND RECORDERS)

2.1 Studio equipment of the 1125/60 HDTV system

An HDTV programme production facility has been implemented which provides production capabilities needed for HDTV experimental broadcasting of one hour each day. The 1125/60/2:1 HDTV system used, and standards conversions between HDTV and conventional television systems are incorporated. This equipment has been implemented by NHK over several years based on a long-term schedule [CCIR, 1986-90b].

The developments described in the following sections complement a full range of production equipment including cameras, recorders, special effects devices, etc., that are commercially available [CCIR, 1986-90c].

2.1.1 Cameras

a) HDTV portable camera

An HDTV portable camera using Saticon tubes has been developed. Features of it include a high resolution of 1200 lines with a high sensitivity of F:4.5 at 2,000 lux, compact and light weight of only 8 kg and an economical power consumption of only 35 W.

One-inch Saticon tubes with static focussing and static deflection have been employed. The photoconductive layer used is an improved one, and its sensitivity is 1.5 times in the green channel, 2 times in the red channel compared to the conventional Saticon layer. The preamplifier has also been improved by using a high performance JFET.

b) HARP* cameras for HDTV

An HDTV hand-held camera using 2/3-inch HARP tubes has been developed. The sensitivity of it is ten times greater than that of conventional HDTV cameras, and it can be operated at F:2.8 under 200 lux. This camera provides high quality pictures even in such cases with low levels of illumination as outdoor sporting events, show stages in areas of theatres.

A low noise GaAs FET preamplifier is used to obtain good signal-to-noise ratio (45 dB). Ease of registration adjustment has been realized employing an automatic on-line system. Applications of LSI technology and compact circuit design realized a light weight hand-held camera (6.5 kg).

c) Solid-state pick-up devices

Solid-state image pick-up devices which meet the 1125/60 studio standard have been developed. They include a one-inch format CCD image sensor with two million picture elements, and a laminated CCD image sensor. A next-generation solid-state HDTV colour camera using one of those has been developed. It is compact and twice as sensitive as conventional models.

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* HARP: High gain avalanche rushing photoconductor.

2.1.2 HDTV video-matte system

An HDTV video-matte system has been developed. This system provides a new production technique in HDTV picture synthesis. A key signal for the synthesis is generated by means of computer graphics and displayed on an HDTV monitor. So it is possible to synthesize two pictures without any blue background, for example, taken at remote locations.

The equipment has already been put into practical use in drama production, and feature film production using HDTV techniques, and creates a synthesized picture so real and natural that it makes viewers feel as if they are watching a real scene.

2.1.3 OB van for HDTV

A recent HDTV OB van is designed for use in live broadcast and in real time editing with such programmes as sporting events, theatrical performances and festivals. It is made so as to be able to move easily from one site to the other, and yet has the necessary environment for long time production to be maintained with a wide production room (3 m in its length) and large monitors (30 in in diagonal).

It is equipped with three cameras with an extension up to 1,500 m by optical fibre transmission, two VTRs, one opaque scanner, an analogue video switcher with eight inputs including three-mix, wipe, superpose and soft chromakey functions, a four channel audio mixer with eight inputs and an FPU transmitter of 42 GHz with TCI video encoder.

2.1.4 Stereoscopic television

An experimental field sequential stereoscopic television system has been developed in Japan utilizing HDTV equipment.

Production equipment such as cameras and VTRs used were those of 1125/60/2:1 HDTV system.

A newly developed video projector was used to display these right and left images alternately at a field frequency of 120 Hz, with 1,125 lines for a whole right or left frame. The screen used was of 110 inches in size. Observers wore a pair of glasses comprising liquid crystal shutters which alternately did open and close depending on the field for the right or the left eye [CCIR, 1986-90d].

2.2 Studio equipment for the 1250/50 HDTV system [CCIR, 1986-90e]

Document [CCIR, 1986-90f] proposes a hierarchy of formats within the studio, simply related to Recommendation 601. All members of the hierarchy are evolutive with a high level of compatibility at least from one member to the next.

2.2.1 Progressive (HDP and HDQ) equipment*

This studio equipment at prototype level included:

- a monochrome camera that was demonstrated in Montreux, 1987 [CCIR, 1986-90g; Boyer and Eouzan, 1987];

- two colour cameras with different lens type, and one inch Saticon pick-up tube, demonstrated at the Brighton IBC 88.

  The development of the HDP camera was a milestone of the EU95 project, in particular, its sensitivity is nearly the same as that of an interlace camera, with a weighted S/N ratio quite equivalent. It includes a 2D digital aperture correction system on the channel, working at 144 MHz with 8 bit quantization and a convolution mask of 3 lines x 5 pixels;

- 144 MHz A/D and D/A conversion equipment;

- HDP/HDQ and HDQ/HDP converters (filter and interpolator). Converters include luminance and colour difference processors. The luminance processor is a bidimensional diagonal filter that allows subsequent quincunxial subsampling. The colour processor is a vertical filter that allows vertical subsampling. At the filter output, luminance samples are interleaved and a 16 to 32 μs line rate conversion is carried out. This provides at the output of the filter an HDQ multiplex, with the structure and clock frequency conforming to that of the HDI multiplex;

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* Explanatory note for description of studio equipment for the 1250/50 HDTV system:

HDP standard [CCIR, 1986-90h]

High-definition progressive scan with orthogonal sampling for the luminance signal and quincunx sampling for each colour-difference signal.

HDQ

High-definition progressive format that is derived from the HDP standard by luminance diagonal prefiltering resulting in spatial quincunx sampling and by colour-different vertical prefiltering resulting in orthogonal sampling. It allows to save half the bandwidth or data rate of HDP.

HDI

High-definition interlace format with orthogonal sampling for luminance and colour-difference signals. The data rate of HDI is equivalent to the data rate of HDQ.

- for interconnection of equipment within a production centre and for point-to-point interstudio links, commercially available equipment with a 60 MHz bandwidth has been used for RGB parallel transmission of 1250/50/1:1 HDTV signals in analogue form. Transmission equipment for HDTV signals in digital form with bit rate reduction has also been implemented [CCIR, 1986-90i].

Document [CCIR, 1986-90j] gives the characteristics of the HDQ format which is a bandwidth limited digital implementation of the HDP standard, in order to use the current digital recording and processing technology within the studio. The document further explains that HDQ and HDI, having the same bit rate, achieve a high degree of commonality and could use the same digital signal interface and that therefore many pieces of equipment, such as switchers, mixers and recorders can be used in both HDI and HDQ environments.

2.2.2 Interlaced (HDI) equipment*

- Cameras

Cameras including 2-dimensional digital aperture and contour correction units with performances in sensitivity and S/N ratio according to the present state-of-the-art using either one-inch Saticon or Primicon pickup tubes or 30 mm Plumbicon tubes have been developed [CCIR, 1986-90k].

- Mixers and switchers

Simple switchers and mixers in analogue components were demonstrated. New mixers, characterized by two mixing levels, three inputs in each level, with fade, wipe and colour-matte facilities, four programme and two preview outputs, allowing for full 30 MHz bandwidth processing have been developed [CCIR, 1986-90k].

Graphic Paintbox

A paintbox has been adapted to operate at 1250/50/2 standard and was demonstrated at Montreux (June 1989). It incorporates 1250/50 inputs and outputs, that with the development of new software, allow frames to be grabbed, retouched and output in the classic paintbox manner, bringing vital graphics capability to 1250/50 high definition production [CCIR, 1986-90k].

- OB vans

A set of operational equipment was demonstrated at the IBC 88 and was based on two OB vans including cameras, mixers, telecines and VTRs mentioned in other sections.

An HDTV OB van in the interlaced version of the 1250/50 standard as described in [CCIR, 1986-90l] is currently being built up for RTVE. This OB van is designed for the production of experimental HDTV programmes in general and mainly for sports events. It has synchronization and monitoring facilities to work together with another OB van of similar characteristics [CCIR, 1986-90m].

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* See footnote on previous page and the footnote to Table I, Part 5 §2.1

A new HDTV OB-van built for recording purposes was demonstrated at Montreux (1989) and the IFA '89 in Berlin (West). The equipment in this van includes three HDTV cameras, two HDTV analogue VTR systems, an HDTV mixer and HDTV monitors. The van will include an effects device and a character generator. A stereo sound system with an audio mixing deck has also been installed for production operation. A conversion system is also included providing:

- components Y.CR CB in digital or analogue forms at 625/50/2:1 standard with 4/3 aspect ratio;

- conventional PAL signal (4/3 aspect ratio); and

- PAL signals (16/9 aspect ratio) for displaying HDTV pictures in its full width on low price standard PAL monitors.

Another OB-van for post production of the video recording was demonstrated at the IFA '89 in Berlin (West). It houses three HDTV analogue VTR, an HDTV mixer, HDTV monitors, and an editing system for processing at the video and audio levels. These two OB-vans are planned to operate either independently or linked to each other [CCIR, 1986-90k].

[CCIR, 1986-90l] describes the parameters of the interlace version of the 1250/50 studio standard currently used in Europe on an experimental basis (see § 1.2 of Part 5).

2.2.3 Components

Some critical components for HDTV have been studied and future developments are in progress. They include zoom lenses for HDTV cameras, CCD line arrays for slide scanners and for telecines with 2048 pixels, a one-inch Primicon* pick-up tube with electromagnetic focalization and electrostatic deflection. A 30 mm Plumbicon tube has been developed to equip cameras allowing improvements of sensitivity and lag characteristics. The main features of this tube which used lead oxide photoconductive layer are a new type of electron gun (tetrode) for high resolution, high electron beam reserve, low lag of maximally 2.5% after 60 ms, a low output capacitance (typically 5 pF), electrostatic deflection, magnetic focus and a short tube length of maximum 172 mm [CCIR, 1986-90k]. A CDD line array with 5184 pixels for slide scanners is under development.

2.2.4 Interfaces for the digital environment

Document [CCIR, 1986-90n] suggests that with a simple and powerful motion estimator located within the studio close to the source, each equipment whose performance is affected by motion knowledge will use "motion vector" information to an appropriate degree by means of hierarchical processing. The target is to reach by this way a reduced bit rate for the motion information depending upon the application to avoid loss of relevant motion information when cascading processing is necessary.

Examples of related applications in production areas, especially at input/output interfaces, are field rate standard conversion, slow-motion, film transfer and coding for transmission or emission. The motion data can, for example, be inserted into the vertical blanking interval of the video signal, recorded on tapes and used for programme exchange.

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* Primicon: Trade mark from TCSF.

2.2.5 Other developments

Submissions were received reporting that a progressive scanning implementation affects mainly the camera, the A/D conversion equipment and the recorder within the studio. For the other items of studio equipment, mainly the mixer and associated special effects, little change is necessary when going from interlace to progressive scanning [CCIR, 1986-90o]. As said in [CCIR, 1986-90p] a first implementation will be based on digital HDQ format to use 1.15 Gbit/s digital VTR whose feasibility has been demonstrated.

[CCIR, 1986-90q] states that improved motion performance for a 50 Hz HDTV camera can be obtained with synchronous shuttering and that this improvement will be most marked when used in combination with motion compensated display up-conversion.

2.3 Displays

Note - For consumer-use displays, see Part 10, section 2.

2.3.1 Directly-viewed tube displays

CRTs are being developed in Japan giving priority to an enlargement in size and an improvement in resolution. With regard to the size enlargement, a 40 in CRT was developed in 1985 and introduced at "EXPO 1985", Tsukuba, Japan. This CRT weighed about 80 kg and had an aspect ratio of 5:3. In 1987, a 41 in CRT with an aspect ratio of 16:9 was developed. It weighed 105 kg and achieved a brightness of 95 cd/m^2 for all-white signals. Equipped with digital convergence, a display using this CRT achieved a reduced convergence error of 0.5 mm or less in all parts of the screen. The total weight and external dimensions of the display were 170 kg and 1,030(W) x 760(H) x 850(D) mm.

In 1987, a 32 in CRT was developed with the shadow mask of the Invar steel. It attained a peak brightness of 230 cd/m^2 [CCIR, 1985-90r].

[CCIR, 1986-90s] describes the basic characteristics of displays for the 1125 line 60 field high-definition television system. The document also reports that direct view CRT displays with brightness of over 100 cd/m^2 are currently available in sizes up to 750 mm measured diagonally.

CRT displays with a diagonal dimension of 931 mm are also available with brightness values in the order of 68 cd/m^2.

Colour picture monitors using 51 cm, 76 cm and 81 cm (20-in, 30-in and 32-in) tubes with the 16:9 aspect ratio were developed in 1988 in Belgium, the Federal Republic of Germany, France, Italy, the Netherlands, and the United Kingdom. Using phosphor dot pitches of around 0.3 mm and video bandwidths of about 60 MHz in the first available designs, horizontal resolutions of 1000 lines, or greater than 1400 picture elements per active line, and vertical resolution commensurate with 1250 total scanning lines were achieved. The approximate picture peak-luminance and contrast ratios were up to 90 cd/m^2 and 50:1 respectively. Apart from providing 2:1 interlaced scanning with 1250 lines per picture and 50 Hz field rate (1250/50/2:1) with a line scan frequency of 31 kHz, operation at 62 kHz was also demonstrated to give 1250 lines progressive scanning at a 50 Hz field rate (1250/50/1:1) or 1250 line, 2:1 interlaced scanning at 100 Hz field rate (1250/100/2:1) as options to eliminate interline flicker or large area flicker, respectively. The techniques used included bidirectional scan techniques [CCIR, 1986-90e and t].

2.3.2 Projection type displays

Projection displays using small CRTs (7-9 in) for the picture source are available with screen sizes up to 3,000 mm and with a peak luminance of over 100 cd/m^2 and a screen gain of 13 [CCIR, 1986-90s].

A 50 in rear projection display, using 7 in projection tubes, has attained a peak luminance of 400 cd/m^2 while the depth of equipment remains as small as 65 cm. In addition, a high contrast ratio of 35:1 or higher is attained by filling the gaps between the projection tubes and lenses with a material which has almost the same refractive index as glass. From 50 to 110-in displays of this kind were developed with a simplified automatic convergence alignment.

A 180-in display, using three 12-in projection tubes, shows a peak luminance of 55 cd/m^2 with a screen gain of 3.5. This display can be used with other projection sizes of up to 200 in. A 200-in display has also been developed using six 9-in projection tubes. It showed a peak luminance of 40 cd/m^2 [CCIR, 1986-90r].

Very large screen displays using light valve and Schlieren optic technology suitable for use in electronic theatres are available from several sources [CCIR, 1986-90s].

Whether for consumer or for professional applications, displays with a diagonal dimension greater than about 100 cm are currently provided by projection systems. Several cathode ray tube projection systems were completed in 1988, in Belgium, the Federal Republic of Germany, Italy and the Netherlands.

The nature and parameter values of a typical example designed with consumer requirements taken as a high priority are as follows: a rear projection technique was chosen to enhance stability, brightness and contrast, and to maximize the dimensional suitability of the equipment for use in the home; the picture diagonal was 127 cm (50 in) with a 16:9 aspect ratio and a 1250 line interlaced scanning system operating at the 50 Hz field rate (1250/50/2:1); the peak luminance of 400 cd/m^2 was nearly as high as that available with conventional 625-line receivers. Of perhaps more importance was the stable attainment of a relatively high contrast ratio of 50:1.

A 70-inch rear projection display has been demonstrated at the IFA '89 in Berlin (West) [CCIR, 1986-90u].

A second example has been a front projector designed to give a large screen diagonal with a 16:9 aspect ratio; 250 cm (98 in) was achieved. The use of an automatic deflection circuit, ranging from 16 kHz to 62 kHz line rate and from 50 Hz to 100 Hz field rate, enabled the display of both 1250/5/2:1 and 1250/100/2:1 scanning. A peak luminance of 300 cd/m^2 with a screen gain of 10 and a modulation transfer function of 10% at 1000 TV lines are reachable in performance [CCIR, 1986-90e and t].

2.3.3 HDTV displays under development

A flat tension mask CRT has been developed in the United States that, it is claimed, increases brightness by up to 80% and contrast ratio by up to 70% over conventional designs. The thin metal mask is stretched and held flat under tension behind the tube's flat glass faceplate. This arrangement should be more stable during high mask temperatures. There are plans to apply this technology to large size HDTV displays.

The United States is developing a solid-state light valve. An array of thin film CMOS transistors laid down in the form of a television raster produces a 20 V electrostatic deforming field. On top of the integrated circuit is a deformable layer and a reflective thin film. Electrostatic forces deform these layers producing a physical representation of the television image. A separate light source and Schlieren optics could project the image on the screen. A colour projector would use three simultaneous modulators into a single objective lens [CCIR, 1986-90s].

A flat-panel display is desirable to assist the spread of HDTV receivers into many homes. Gas-discharge displays offer the highest feasibility for realization of such panels from the viewpoints of produceability of large size panels, the fast operating speed applicable to HDTV. A 20-in DC gas-discharge panel with internal memory has recently been fabricated in the first step towards the development of an HDTV flat-panel display. This study showed the possibility of realizing a larger flat panel HDTV display. A 4-in liquid crystal colour display using amorphous silicon TFTs has also been developed [CCIR, 1986-90c and v].

A 33-inch (84 cm) panel with the same structure as that of the 20-inch panel has been developed to establish fabrication techniques for larger panels of the order of one metre.

Application of the same method of driving based on the pulse memory scheme was assumed for the 33-inch panel, and the design of the panel also followed after that of the 20-inch panel which exhibited superior performance in both stability and uniformity. At present, however, the 33-inch panel is driven by means of a simple line-sequential addressing, and only a colour-checker pattern including eight colours without saturated variations of intensity can be displayed on the panel.

Although the luminance obtained with this panel was not sufficient due to the simple driving method used, uniform luminescent characteristics as well as a high colour purity were obtained over the entire screen [CCIR, 1986-90w].

2.3.4 Display up-conversion

[CCIR, 1986-90x] discusses the problems of reducing full field flicker resulting from a temporal sampling rate by increasing the display refresh rate. This approach requires the use of motion adaptive temporal rate conversion to minimize motion artefacts. It further points out the need for this technology in all studio receivers where it may not be practical to use digital assistance signal approach.

One problem associated with large CRT displays is that of large area flicker. Larger and wider screens make this an important area of concern in HDTV viewing and it may be necessary to display the received picture at a different field rate from the transmitted field rate of 50 Hz. Subjective tests have indicated that display field frequencies of about 80 Hz and above are necessary in order to eliminate the effect of flicker at the screen luminances and distances that are likely to be encountered [Bourguignat, 1985].

To remove both large area flicker and interline twitter, picture repetition can be used instead of field repetition. This algorithm, known as AB-AB up-conversion, is successful in displaying still elements of the picture but, as information is being presented in the wrong order, the portrayal of moving objects is not satisfactory, due to judder.

MAC and High Definition MAC channels are capable of carrying significant amounts of data and so DATV [Storey, 1986] can be used, which offers the possibility of enhanced, more sophisticated forms of up-conversion while keeping receiver cost increases low. The presence of DATV channel allows the studio to pass instructions to the receiver which can overcome the problems of simple field or picture repetition up-conversion.

One way in which this has been achieved is by using motion adaptive conversion. In this system the up-converter can select either the field repetitive or picture repetitive mode of display on receipt of information passed via the DATV chain. The field repetitive mode can be used for the moving elements of the picture and the picture repetitive mode for the still areas. Studies have also been carried out on the use of pre-processing to improve the movement performance of the AB-AB mode in areas of slow movement.

Equipment from the Netherlands, the Federal Republic of Germany and Italy was demonstrated in 1988 which included several types of 50/100 Hz display up-converter. One employed a fixed AA-BB up-conversion algorithm which had no accompanying DATV information. A second up-converter used a motion-adaptive AA'-B'B/AB-AB algorithm, with the mode switching controlled by the transmitted DATV signal. Both equipments operated digitally at HDTV clock rates on component signals [CCIR, 1986-90t].

ANNEX

(to Part 5.2)

THE FIRST IMPLEMENTATION OF THE 1250/50 HDTV PRODUCTION SYSTEM

The 1250/50 HDTV studio standard is based on a progressive scanning method. The first implementation of this target standard may be based on a bandwidth reduced system which takes into account the present status of available technology. The 2:1 interlace version described in this Annex in both analogue and digital forms meets this criteria.

Equipment operating according to these parameters has been demonstrated and is currently used in Europe for the production of experimental HDTV programmes. The specific parameter values for the interlace version are given below (the numbers between parentheses relate to the items in § 1.2):

a) line frequency (1.6) - 31 250 Hz

b) Colorimetry (2) - according to EBU specification (EBU Tech. 3213)

c) Pre-emphasis (4.1) - according to Recommendation 601

d) luminance signal equation (4.2) - according to Recommendation 601

e) colour-difference signal equation (4.3) - according to Recommendation 601

f) nominal signal levels (4.4/4.5) - according to EBU specification (EBU Technical Standard No. 10)

g) nominal signal bandwidth (4.6) - half those of the target standard

h) sampling structure of the colour-difference signal (5.2) - according to Recommendation 601

i) sampling frequencies (5.5) - half those of the target standard

j) analogue-to-digital horizontal timing relationship from end of digital active line to 0_H (5.6) - 128 T (T = sampling period)

k) correspondence between video signal levels and quantization levels (5.7) - according to Recommendation 601

l) code word usage (5.8) - according to Recommendation 601

m) frame period - 40 ms (1250 line periods)

n) frame blanking interval - 1.56 ms (49 line periods)

o) duration of the frame synchronizing pulse - 8 μs (¼ line period)

All other parameter values - according to the target standard (§ 1.2)

PART 5.3 - STANDARDS CONVERSION

3.1. HDTV-HDTV standards conversion

Whatever the HDTV studio standard is in the future, high quality standards conversion will be necessary: on one hand, in the case of a single world-wide HDTV studio standard, standards conversion is required where different field rates apply for the studio and for emission. On the other hand, if different HDTV studio standards coexist, standards conversion will be inevitable between these HDTV standards.

These algorithms have been then subjectively evaluated by means of a double stimulus continuous impairment scale method using 45 non expert observers in three European laboratories. The Document [CCIR, 1986-90y] reports that the difference between the ratings obtained by an unconverted 50 Hz picture and the 50 Hz sequences after conversion to 59.94 Hz are less than 0.4 on a five grades impairment scale for the best algorithm tested. The mean difference for the four sequences used (a still picture and three moving sequences containing complex motions on detailed textures) is about 0.16 of a grade.

[CCIR, 1986-90z] reports that a study of the conversion from 1250 lines 50 Hz to 1050 lines 59.94 Hz has been performed to assess the quality of converted 59.94 Hz pictures originally produced according to the European production proposal.

For such a conversion, it is obvious that conventional converters do not perform satisfactorily: these converters create important visible defects especially on moving objects, which represent the normal situation in TV scenes. That is why a motion compensation technique must be introduced to cope with the interpolation of moving objects (particularly with fast and complex motions).

Algorithms have been developed in parallel with hardware architecture design, according to the following functions or blocks.

a) Interlaced to sequential conversion

The input format of the standard converter is 1250/50/1:1; it is issued either from a progressive source or from the output of an interlaced to sequential converter.

b) Motion estimation

It consists of a description of motion measured between two successive images in the 50 Hz sequence; the input format to the motion estimator is 1250/50/1:1. Among the different classes of motion estimators, the differential method is attractive because it offers a good compromise between complexity and performance. Two recursive schemes using the differential method have been developed to compute local displacements like those encountered in rotating or zooming scenes on either a block basis or a pixel basis [Robert et al., 1988].

c) Motion assignment

One motion vector is assigned to each pixel of the image to be generated. Linear motion is assumed between two successive input images.

d) Failure detection

It has to identify the pixels where measured motion is not reliable in the sense that some risks of visible defects created by the corresponding motion compensating interpolation exist.

e) Motion adaptative interpolation

Two types of interpolation are considered corresponding to the motion compensating mode and the fall back mode. The choice between these two interpolators is driven by the failure detector; pixels for which motion is relevant (no failure detection) are generated by the motion compensating interpolator. Pixels where motion is not reliable (failure has been detected) are generated by the fall back mode.

Results

To assess the performance of the algorithmic procedure, a large number of representative picture sequences in a down-scaled format (625/50 to 525/59.94) has been processed using computer simulation. The results of these have been submitted for expert advice and demonstrated at IBC 88 in Brighton. The opinion of experts and visitors is that these results are excellent with performance superior to any previously demonstrated work in this field. The demonstrated processing shows very good performance from the point of view of both sharpness and motion rendition with no perceptible artifacts even when reduce speed (slow-motion) is used after conversion to look at pictures. These results form the basis of a transparent standard conversion.

In addition it must be repeated that the computer simulations have been carried out under the constraint of hardware design. This hardware is now in its built-up phase.

3.2 HDTV - conventional TV standards conversion

Tests by the BBC on the field-rate conversion of picture signals, using time-invariant (non-adaptive) interpolation, have demonstrated that an appreciably higher quality of converted picture is attainable with conversion from an 80 Hz field-rate to 60 or 50 Hz than when converting between 60 and 50 Hz. Conversion from 80 Hz was judged to give a picture quality up to two grades better than 60 to 50 Hz or 50 to 60 Hz conversion with similar picture material. In each case however, converted pictures were deemed to be inferior to pictures originated on the output standards [Childs and Tanton, 1985].

A new standards converter from 1125/60/2:1 HDTV to 625/50/2:1 PAL, based on motion-adaptive techniques has been developed in Japan. In the system, a sequentially scanned 625/60 signal is obtained first from the original 1125/60 signal by means of a two-field interpolator or an intra-field line interpolator. Then, field-rate conversion from 625/60 sequential to 625/50 sequential is achieved by means of a complex system, which selects the output of either one of four motion compensated processes or a linear-interpolation process. The selector is controlled by a motion signal. Finally, the signal undergoes sequential-to-interlace conversion [CCIR, 1982-86a].

In the Netherlands a down-converter has been made for use in the broadcast studio environment between the HDTV 1250/50/2 system and the normal definition 625 lines system. This function will have to be performed quite often, when mixing material originating from an HDTV source with material shot on the 625 lines system.

The converter contains a vertical filter and a horizontal sampling rate converter. It has both a digital Y,U,V and an analogue R,G,B input. The digital output conforms with CCIR Recommendation 656. The change in aspect ratio from 16:9 to 4:3 is achieved by discarding the side panels.

In the broadcast studio environment there will also be a need to up-convert the existing 625/50/2 signal to an HDTV 1250/50/2 signal. This up-conversion can be done by a line doubling circuit which will first compress the line time from 64 μs to 32 μs. Thereafter, a vertical interpolator will interpolate the missing lines.

The up- and down-conversion between HDTV and normal definition television will frequently be needed in a broadcast studio environment. The simple relation between the 1250/50/2 and 625/50/2 standards has the advantage that conversion from one to the other can be carried out with simple two or three tap filters, the hardware complexity of which is insignificant [CCIR, 1986-90aa].

Subjective tests have been carried out in several countries using a single stimulus subjective assessment technique and the five-grade quality scale. Since movement rendition was a critical issue, the test pictures consisted of moving sequences classified as "critical but not unduly so" [CCIR, 1982-86b and c].

During tests in Japan, the motion portrayal of the converted pictures was assessed to almost the same as that of direct PAL pictures except for the rotating disc sequences (the appearance of scenes similar to the rotating discs was measured as 0.04% of programme time in two Japanese television channels during one week). In some sequences, the converted pictures were evaluated higher than the direct PAL pictures. On average, the converted pictures were scored approximately 4.2, and the difference between the converted pictures and the direct PAL pictures was approximately 0.35 using the five-grade quality scale in the assessment made by experts [CCIR, 1982-86a].

Similar tests carried out in Europe have shown that the motion portrayal quality difference between PAL direct and the converted pictures was still perceptible (between zero and one grade). However, considering the future, the results of the subjective assessments and an initial analysis of potential areas of evolution of the performance of this converter, lead the EBU specialists to believe that a quality essentially equivalent to PAL quality will be possible within a reasonable period of time [CCIR, 1982-86c].

It was also reported that the motion portrayal quality of the PAL converted pictures was significantly between (between 1.5 and 3.5 grades) than motion portrayal at 25 Hz picture update rate (representative of film as scanned by a telecine) [CCIR, 1982-86c].

Conversion from 1125/60/2:1 HDTV to the 625/50 4:2:2 digital studio standard has been done and the subjective assessment of the quality of conversion with respect to motion portrayal has been accomplished recently [Wood and Habermann, 1986]. Document [CCIR, 1986-90ab] states that for the seven scenes studied, the loss of quality introduced by standards conversion varies from 0.56 of a grade (scene 12) to 0.98 of a grade (scene 2), the mean impairment being approximately 0.7 of a grade. Compared to the conversion from 1125/60/2:1 to PAL previously evaluated, the 4:2:2 conversion results show a higher average degradation. (A mean degradation of 0.7 of a grade for conversion to 4:2:2 compared to a mean degradation of 0.5 of a grade for conversion to PAL for the same seven scenes.) This may be attributed to the concealing effects of PAL (e.g. cross-colour, cross-luminance) on small errors in the presentation of motion.

A production made in Canada, generally based on the parameters noted in Report 801-2, Annex II, will be shown in the 525-line NTSC television standard and has already been purchased by four national broadcasters, two of which operate in the 625-line 50 Hz PAL standard [CCIR, 1986-90ac].

In Japan, HDTV has been implemented in accordance with 1125/60.00 standard, whereas NTSC system defines its field frequency as 59.94 Hz. In order to tackle this field frequency difference between HDTV and NTSC, 1125/60.00 to 525/59.94 standard converters have been developed and put into actual use. In carrying out that conversion, after the line rate conversion from 1125/60 to 525/60, the image data are written into frame memory storage and then read out according to 59.94 NTSC sync by the frame skips which can be done during a transition to commercial message, a fade to black, a scene cut, and a still picture [CCIR, 1986-90ad].

When temporal aspects are set aside standards conversion reduces to line rate conversion. Document [CCIR, 1986-90ae] shows that the complexity of digital filters required for this purpose is related to the conversion ratio, L/M, where the length of the filter is a function of the highest value of either the interpolation factor, L, or the decimation factor, M. It was shown that with polyphase filter structures the complexity of the conversion filter only increases marginally in relation to the values of these factors. Document [CCIR, 1986-90af] indicates that aliasing effects caused by decimation and interpolation can be reduced by proper filter design and that the minimum filter requirements can only be judged through subjective assessment.

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[1982-86]: **a.** 11/270 (Japan); **b.** 11/398 (IWP 11/6); **c.** 11/405 (EBU).

[1986-90]:
a. 11/356 (Spain); b. 11/582 (Japan); c. IWP 11/6-2032 (Japan); d. 11/585 (Japan); e. IWP 11/6-2056 (Thomson-CSF); f. 11/298 (Thomson-CSF); g. 11/164 (IWP 11/6); h. IWP 11/6-2023(Rev.1) (Belgium et al.); i. 11/28 (Thomson-CSF); j. 11/312 (Thomson-CSF); k. 11/507 (Thomson-CSF, Philips); l. 11/297 (Italy and Spain); m. 11/351 (RTVE); n. 11/27 (Thomson-CSF); o. IWP 11/6-1055 (Thomson-CSF); p. IWP 11/6-2054 (Thomson-CSF); q. IWP 11/6-2091 (UK); r. IWP 11/6-2037 (Japan); s. IWP 11/6-2022 (USA); t. IWP 11/6-2047 (Belgium et al.); u. 11/547 (Belgium et al.); v. IWP 11/6-2038 (Japan); w. 11/588 (Japan); x. IWP 11/6-2026 (CBS); y. IWP 11/6-3046 (France, Netherlands, UK); z. IWP 11/6-2053 (Thomson-CSF); aa. 11/457 (Netherlands); ab. IWP 11/6-1010 (EBU); ac. IWP 11/6-1017 (Canada); ad. IWP 11/6-2035 (Japan); ae. 11/358 (Canada); af. 11/562 (Canada).

PART 6 - RECORDING OF HDTV PROGRAMMES

Note - For consumer use recorders, see Part 10, section 5 and Report 1233.

1. Tape systems

Note - Further information is contained in Report 1230.

a) Analogue VTR

An open-reel analogue VTR system based on a one-inch type C format has commonly been used as the first-generation studio-use HDTV VTR. Made up of VTRs and a time-based corrector/processor unit, this system records for a maximum of one hour on a one-inch oxide-coated tape loaded in an 11.75-inch reel. The system uses component signals for input/output, and records RGB signals so that an excellent picture quality is secured.

The analogue VTRs, based on a B-format tape deck perform component recording featuring a 20 MHz bandwidth for the luminance component and 10 MHz for each colour difference. One hour recording is provided on a 12.5-inch open reel with 26 μm tapes. Time code based editing is provided. Within a window of 20 μs, the residual time base error is ± 3.5 μs. S/N ratio is $\geq$ 40 dB unweighted. Operating modes are record, play, shuttle, assemble and insert. Three audio channels are available, one of them time-code compatible. Further detailed technical information is to be found in [CCIR, 1986-90a].

b) Digital VTR

A digital VTR using metal particle tape, which has a high recording capability of 1.188 Gbit/s has been developed. The transport mechanism used is of one-inch C type. The sampling frequencies of the input/output signals are 74.25 MHz for the luminance signal and 37.125 MHz for the two colour difference signals as they are specified in the 1125/60 studio standard. This VTR is capable of having eight digital audio channels, and is the first HDTV VTR which is facilitated with slow-motion function.

c) Analogue cassette VTR

Analogue HDTV VTR using a ½-inch cassette is being developed and some prototype machines have already been completed. Major areas of application aimed at with this equipment are, in addition to broadcast applications, distribution of HDTV programmes for video theatres, educational purposes, medical uses, printing industries and so on.

It can accommodate a luminance signal of 20 MHz bandwidth, line-sequential colour signals of 7 MHz bandwidth and four channels of PCM sound with 48 kHz sampling and 16 bit/sample resolution. This equipment will be available on the market around the summer of 1989.

2. Disc systems

a) HDTV video disc player

A video disc player which offers a wide bandwidth high definition video and two channel PCM audio has been developed. It provides a 15 min playback per one side of 30 cm CLV disc (in contrast to 8 min/side with CAV disc). The bandwidths are 20 MHz for the luminance signal (Y), 6 MHz each for the colour-difference signals (Pb/Pr). A high signal-to-noise ratio of 42 dB (Y) has been obtained.

For the audio signal, the bandwidth of 20 Hz to 20 kHz, and the dynamic range of 90 dB are attained. The harmonic distortion is less than 0.05% and the channel crosstalk is -80 dB.

b) HDTV still picture disc system

A digital disc system which reproduces HDTV digital still pictures with CD-ROM type disc has been developed.

One disc of CD-ROM type can store 240 still pictures.

For the audio signal, such separate CDs as available on the market can be used in a synchronous operation mode provided by the system.

Such functions are also included as cut-change, wipe-change, up/down scroll and a multiplexing with segmented pictures, and enable us to give vividness in effect as if they were moving pictures.

3. Film systems

3.1 Telecines

A frame-rate converter for HDTV laser telecine has been developed using an experienced motion compensation technology which had been studied originally as a development of HDTV to PAL standards converter.

In the new converter, the amount and the direction of motion in the picture are detected from two consecutive frames of a film in a form of motion vectors. For the detection, the pattern matching method was used.

It has been found that the problem of motion judder due to field repetition or 2-3 pull-down in conventional telecine can be solved by using this type of converter so that natural smooth motion in the picture can be reproduced on video displays.

A flying spot telecine using 35 mm print film running at 25 film frames per second, with full horizontal and vertical aperture correction, and an advanced frame store has been developed. This offers the facility to supply the ready made programmes from 35 mm films in the 1250/50/2:1 HDTV standard [CCIR, 1986-90b].

[CCIR, 1986-90c] reviews the progress in the development of equipment for television scanning of film. Of particular significance is the introduction of adaptive motion compensation to provide a major improvement in the portrayal of motion. With the introduction of motion compensation the question of the best "interface" between film and video becomes a non-issue. JIWP 10-11/4 has proposed a revision to Report 294 to include the recent developments in television film scanners.

3.2 CCD slide scanner

Scanning is performed progressively using a 2048 pixel/line array sensor. Digitizing of RGB signals with 12 bit quantization is carried out. A digital gamma correction function is implemented. The system also includes storage and colorimetric processing operating at 72 MHz.

REFERENCES TO PART 6

CCIR Documents

[1986-90]: **a.** 11/456 (Germany (Federal Republic of), Netherlands); **b.** 11/507 (Thomson-CSF, Philips); **c.** IWP 11/6-2028 (CBS).

PART 7 - EMISSION OF HDTV SIGNALS

1. Satellite broadcasting

1.1 Introduction

In this Chapter a progress report of a general nature is presented related to studies on radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV broadcasting primarily from the point of view of satellite broadcasting undertaken in consultation with competent Interim Working Parties of Study Group 11. Such studies were undertaken concerning the following aspects:

- narrow RF-band system with FM;
- wide RF-band system with FM;
- digitally-modulated system;
- inter- and intra-service sharing aspects from the viewpoint of the broadcasting-satellite service;
- broadcasting techniques for several audio signals and/or data signals associated with HDTV signals in satellite-broadcasting channels.

1.2 HDTV signal emission techniques

1.2.1 General

The important features of HDTV studio systems as envisaged in Part 3 of this Report and relevant to the design of broadcasting systems are:

- spatial resolution in the vertical and horizontal directions of about twice that available with Recommendation 601;
- improvements in temporal resolution beyond that achievable with Recommendation 601 with no significant cost penalties;
- improved colour rendition;
- separate colour-difference and luminance signals;
- a wider aspect ratio with display on a large screen;
- multi-channel high fidelity sound.

The radio frequency bandwidth required is a function of the baseband bandwidth of the coded signal. Satellite systems are power limited and it is important that the spectral efficiency be optimized as far as possible.

The objective of any HDTV emission standard is to reproduce as faithfully as possible the signals derived in the studio.

The emission standards may be subject to the restrictions of planning as is the case for the 12 GHz band which uses channel bandwidths of 24 or 27 MHz.

Alternatively, other constraints may apply if a new frequency band is allocated in accordance with Resolution COM5/3 of the WARC ORB-88.

The technology used in these two cases may differ.

The main problems to be addressed in relation to emission techniques are:

- noise;
- interference;
- channel distortion.

The main source of degradation to picture quality is caused by the increased levels of noise during times when the signal is attenuated by hydrometeors (see § 4 of CCIR Report 1075). Careful attention must be paid to the question of trade-off between signal quality (carrier-to-noise ratio) and the time this is achieved or exceeded. Different trade-offs may be appropriate in different rain zones.

In the 12 GHz bands, the BSS Plans have stringent protection ratios so that interference, at worst, is just perceptible. Any HDTV signal in these or other bands will also have to respect this requirement. However, the sensitivity to interference may be different because of the different type of coding and changed viewing conditions. Also the effect of interference on digital signals may need to be treated differently. This is discussed further in § 11 of CCIR Report 1075.

The effect of channel distortions on the quality of the received signal must also be included in the system design. Quality objectives are given in § 2 of CCIR Report 1075.

The effects of noise, interference and channel distortion will each vary, depending on the emission standard adopted.

The following sections describe HDTV signal emission techniques, leading to examples of emission formats and their required radio frequency characteristics.

1.2.2 Multiplexing and bandwidth reduction techniques

Multiplexing of luminance and colour-difference signals may be FDM or TDM, but TDM signals are less susceptible to FM noise and differential gain and phase when applied to BSS (see Report 1074). For this reason, most of the proposed HDTV transmission formats use a TDM scheme.

Compression ratios of luminance and chrominance are between 2:1 and 4:1. Colour-difference signals are multiplexed with the line-alternating method. Adoption of quasi-constant luminance processing is effective for reduction of the impairment caused by noise in the transmission path.

Currently proposed HDTV studio standards have a video bandwidth or bit rate 4 to 5 times higher than the conventional analogue (Report 624) and digital standards (Recommendation 601). There is insufficient radio spectrum to permit a 4 to 5 fold increase in RF bandwidth, and compression techniques which enable an HDTV signal to fit into a relatively narrower bandwidth channel, of the order of once or twice the width of those already planned in the 12 GHz bands, are required.

Sub-sampling is a widely used approach for bandwidth reduction of a signal by discarding some of the information present in the original signal without causing serious picture quality degradation. Diagonal or quincunx sub-sampling in the two-dimensional spatial domain is most common for this purpose. Temporal domain sub-sampling can be applied to the diagonal sub-sampling when further reduction of bandwidth is required for narrow-band transmission. This method is called multiple sub-sampling or 3D sub-sampling.

Two-dimensional spatial filtering for band-reduction is also possible without using sub-sampling technique as follows:

a sequence repeating in several line periods (e.g. 2 to approximately 4) at horizontal rate is used in which each line has a different horizontal bandwidth. For transmission, each line is time expanded, uncompressed or compressed depending on the horizontal bandwidth.

Line-column conversion (line or field shuffling) is proposed for the purpose of increasing the vertical sampling rate combined with sub-sampling in case of using a rather small number of scanning lines such as 525 or 625 lines for transmission in compatible HDTV emission systems.

In this case compatibility improvement for edge crawling in stationary areas is done by vertical intra-field filtering.

It is also possible using appropriate digital filters to reduce the number of lines in the transmission format (typically by 35%), by interface to sequential scan conversion. The principle is based upon the fact that interlace scanning, in particular, does not provide the full quality potential which can theoretically be attributed to the relevant number of lines.

Reduction of information for the colour-difference signal is proposed by reducing the frame rate to 12 or 15 f/s (frames per second). The same technique is also applied for luminance signals by transmitting high spatial components with a low temporal rate of 7.5 to approximately 15 f/s.

Motion adaptive control of pre-and post-filtering and/or sampling structure is widely used for better picture quality.

The most simple motion adaptive coding scheme is a 2-branch scheme: one branch for low temporal activity picture areas and another branch for higher temporal activity picture areas.

The choice of the branch, which achieves for each small sub-area of the picture, the best possible combination of spatial and temporal information, is signalled to the decoder via the digitally-assisted television (DATV) channel. The choice of the branch for each pixel can also be done by motion detection at the receiver. The 2-branch coding scheme could be improved by increasing the number of branches.

Motion compensation techniques are also effective for the temporal interpolation of sub-sampled signals in case of uniform motion such as camera panning or tilting. The effectiveness of motion compensation techniques can be further enhanced using more extensive digital assistance, DATV, to control the receiver.

Motion detection and measurement are performed at the coder on the uncorrupted source signal and a digital motion control signal is transmitted with the compressed (analogue) video signal to select the decoding mode in the receiver. Most of the complexity is now moved to the broadcaster's transmitter which should permit the manufacturing of lower cost, higher performance receivers.

For all digital HDTV transmission systems, additional compression techniques such as predictive coding (intra- and inter-field/frame DPCM), transform coding and entropy coding can be applied, as already with conventional digital television transmission (see Report 1089). However the higher data rates involved with HDTV require state-of-the-art technology and studies are at an early stage.

1.2.3 Sound and data multiplexing techniques

Due to requirements of quality and the need for secure scrambling, sound information should be transmitted in digital form. The sound/data multiplex may comprise several sound channels and auxiliary data for other purposes.

Adequate transmission capacity should be reserved for data services (i.e., teletext, multilingual subtitling and others; see CCIR Report 802) which could offer enhanced presentation features and require the adoption of suitable error protection strategies.

The currently required bit rates are in the range from 1.35 to 3.4 Mbit/s, depending on the coding scheme and the error protection method used. A certain amount of capacity for additional data should be provided, including that required for any digitally-assisted television control systems and auxiliary data intended for service identification and conditional access purposes.

1.2.4 Conditional access

Conditional access systems are necessary to make access reliably available to those authorized to receive some, or all, of the programmes and information carried by broadcasting satellites, while preventing unauthorized access. Information on conditional access is contained in CCIR Reports 1074 - Satellite transmission and 1079 - General characteristics of a conditional access broadcasting system.

The entire system architecture of a conditional access system must be designed to provide an extremely high level of security.

Many system elements are essential to provide this security. Among them is the use of a "strong" encryption algorithm (i.e. it should not be possible to deduce the algorithm even when both the clear and encrypted versions of a message are known).

Typically conditional access data will consist of a number of layers of encrypted key information. It is sent to each subscriber in turn and is known as "over-air addressing data". The required amount of data may be reduced if subscribers share the same key.

1.2.5 Modulation techniques

CCIR Report 1075 gives information about various modulation techniques for satellite broadcasting. Both analogue FM and digital modulation techniques are discussed.

1.2.5.1 FM systems

For analogue FM, pre-emphasis is normally used to improve the S/N by compensating for the triangular nature of the demodulated noise spectrum. New developments have taken place which allow signal-to-noise ratio improvements for FM by means of non-linear pre/de-emphasis. Adaptive emphasis may also be employed for the same purpose.

Non-linear emphasis for MUSE system

When the MUSE signal is transmitted with frequency modulation, a non-linear emphasis is effectively used. The non-linear emphasis characteristics can be defined by the composition of the de-emphasis circuit to be used in receivers. (See Annex II of Report 1075). An improvement of 9.5 dB in the received unweighted signal-to-noise ratio was reported.

Compatible non-linear emphasis for C-D-D2MAC and HDMAC

E7 is a frequency dependent instantaneous compander system. It is "compatible" in the sense that it has no effect at low video frequencies, so the static deviation of the FM signal is not affected. Receivers not equipped with E7 de-emphasis can display a virtually unimpaired picture from a transmission with E7 pre-emphasis. In this situation there is a slight crispening of the picture. Most observers appear to judge this as an improvement of the picture quality. An improvement equivalent to 4.5 dB in the received carrier-to-noise ratio was reported.

1.2.5.2 Digital systems

Taking into account the impact of digital technology on the broadcast field and the consumer TV market, digital modulation could be the most appropriate technique for providing a future world-wide HDTV emission system.

Typical bit rates for coded signals range between 140 and 160 Mbit/s (CCIR Report 1075) calling for the use of modulation with high spectral efficiency. Suitable modulations are 4 PSK, 8 PSK, 16 QAM and even possibly 64 QAM, which give a range of trade-offs between power, bandwidth requirement and ease of sharing.

A fundamental characteristic of these modulation methods is their greater ruggedness against interference compared with FM modulation. However, further studies are necessary to evaluate the influence of a non-linear satellite channel on system performance, especially as to high-order digital modulation (16-64 QAM).

Another important feature of digital systems is their capability to provide a constant high picture quality, provided a suitable margin against noise and interference is assured, to maintain a sufficient bit error ratio.

1.2.6 Formats for HDTV broadcasting

At the present time administrations studied the relative merits of a number of alternative approaches to the introduction of HDTV broadcasting. The following sub-sections are intended to reflect the views which are being considered in each case. A consensus on one approach world-wide could be in the public's interest and assist standardization.

1.2.6.1 Introduction of HDTV via existing conventional scanning formats

Document [CCIR, 1986-90a] explains that, along with alternative strategies, a study is being made of what is termed an evolutionary approach to HDTV broadcasting. In essence, an HDTV emission format would be used (termed HDMAC) which would still allow reception, virtually unimpaired, on 625/50/MAC/packet DBS receivers. In other words the system would be compatible to the European DBS services planned to begin in 1987/1988. For minimum impairments to picture quality, a single HDTV studio standard having adequate headroom, using a field frequency conforming to the MAC/packet standard, and having preferably twice the number of active lines, is desirable [Sandbank and Stone, 1987; Storey, 1986].

1.2.6.2 Direct introduction of HDTV via a non-compatible scanning format

Document [CCIR, 1986-90b] notes that for HDTV broadcasting using a scanning format as specified in § 1.1 of Part 5.1, the MUSE system has been developed. Some administrations believe that by this method few limitations are imposed for full utilization of the system, as restrictions due to compatibility do not exist and as a result, new technology can be used to optimize the emission system; the picture quality is expected to be superior to that of the compatible approach within the same RF bandwidth.

1.2.6.3 Introduction of HDTV via agile conventional receivers

Documents [CCIR, 1986-90c and d] describe a scenario which could lead to a common world-wide HDTV broadcasting chain, and, nevertheless, give room for an evolutionary development of present day television systems. If receivers were developed, and made publicly available, which could automatically configure to either a 625/50 MAC/packet or a 525/60 MAC/packet signal, then, at a later date, a 60 Hz/HDMAC system could be introduced, in the confidence that normal receivers would still receive a normal service from the HDMAC signal. Conventional television production and emission could be at either 50 or 60 Hz.

1.3. HDTV satellite-broadcasting systems and spectrum considerations

1.3.1 Narrow RF-bandwidth

Narrow RF-band HDTV systems are intended for transmission in the planned 12 GHz bands where both channel bandwidth and protection ratio requirements need to be met. These kinds of systems require extensive signal processing, thus added system complexity, to achieve relatively high degrees of bandwidth compression in order to allow the HDTV signal to fit into a single 24/27 MHz channel. However, for these systems, the resolution in moving areas of the picture will be approximately one half of the resolution for static pictures. Studies indicated that an extremely high bit rate compression (10:1) would be needed to fit a fully digital HDTV signal in a 24/27 MHz channel. Narrow RF-band HDTV systems are therefore considered to use analogue modulation.

1.3.2 Wide RF-bandwidth

In order to be free from the limitations inherent in narrow RF-band systems and to be able to provide improved system performance (e.g., picture quality and motion portrayal as close as possible to that of the studio signal), it will be necessary to increase the video baseband bandwidth and consequently the RF bandwidth. Such wide RF-band systems, for which both analogue and digital modulation are considered, require an RF channel bandwidth typically in the order of 50-120 MHz. These bandwidth requirements are such that wide RF-band systems could only be implemented in a frequency band not subject to the planning constraints of the 12 GHz bands except for some countries in Region 2.

1.3.3 Inter- and intra-service sharing

The study of sharing will put constraints on HDTV emission standards, but there is no evidence to link sharing considerations directly with any choice of studio standard.

When considering interference into other systems, the most important parameter is whether analogue or digital modulation is used. Other factors are less important.

Interference into HDTV systems will be affected not only by the choice of analogue or digital modulation, but also by the receiver processing associated with any bandwidth reduction or bit rate reduction techniques which may be used.

Some guidance may be appropriate to help in the choice of the studio standard. It is important to avoid low useful energy content in specific time or frequency slots of the emission signal format.

Sections 1.3.3.1 and 1.3.3.2 give results of recent studies on sharing.

1.3.3.1 Interference within the same service

Sharing within the HDTV service is discussed in Report 1075 and the CCIR report to the Second Session of the WARC ORB-88.

Not all protection ratios for the various candidate HDTV systems have yet been determined. Further study is required on this important subject not only for the case of interference assessment between HDTV transmissions but also for interference assessment between HDTV and conventional formats such as NTSC, PAL, SECAM and MAC. For HDTV systems intended for use in the 12 GHz band, protection ratios must comply with the requirements of the WARC BS-77 and the RARC-83.

It is expected, however, that for analogue HDTV systems, the co-channel protection ratios will be of the same order as for coventional systems and will also be less as the frequency deviation is increased.

HDTV systems using simple digital techniques (e.g., BPSK or QPSK) will be more tolerant to interference and cause less interference to analogue systems than analogue systems. High order digital systems (such as 16 QAM) may not show the same advantages. The main parameter that needs to be considered in the digitally modulated systems that may have some bearing on spectrum usage is the required bit rate. Reducing the bit rate would be in line with efficient spectrum use.

1.3.3.2 Sharing with other services

Sharing with other services is discussed in Reports 631, 807 and 951, and in the CCIR report to the Second Session of the WARC ORB-88.

In Resolution COM5/3, the WARC ORB-88 extended the range of frequencies to be considered as possible candidates for a new HDTV band to include 12.7 to 23 GHz.

Studies of sharing with the services in this range have not been completed. Recent studies by ESA at frequencies of 20 GHz provide new information on the prospects, as well as the problems, of sharing between the BSS and other services.

1.4. HDTV receiving techniques

1.4.1 Satellite broadcasting receivers

Note - For consumer-use receivers, see Part 10, section 3.

1.4.1.1 Required figure-of-merit for the receiver

The link budgets of the HDTV satellite broadcasting down link and its general equation are described in § 9 of Report 1075.

According to examples of link budget for various transmission systems, as shown in Table IX of Report 1075, it is considered that receiver figure-of-merit is appropriately 13 dB for 12 GHz, and 17 dB for 23 GHz.

Required power flux-density which gives an acceptable quality of reception depends on various parameters such as satellite e.i.r.p., size of the service area, acceptable time of service degradation vs. rain attenuation. It is noted that the choice of the required e.i.r.p. of the figure-of-merit depends on the emission signal format and type of modulation, including the effect of emphasis.

In order to achieve the desired e.i.r.p., a high power travelling wave tube (TWT) is necessary. Recent studies predict that an output power of 500 W will be possible for space-qualified TWTs in the 20 GHz band within a ten year time-scale.

1.4.1.2 Figure-of-merit

The figure-of-merit of the receiving equipment depends on the antenna gain and noise figure of the receiver.

There is a compromise to resolve the problem of using higher frequencies: if the antenna diameter is maintained constant, there is a rapid increase in the pointing accuracy needed. Whilst, if it is reduced in proportion to the wavelength, there is a severe reduction in antenna aperture. It is also noted that the effect of the noise increase due to rain attenuation shall not be neglected for calculation of the figure-of-merit.

Referring to Report 473, the most commonly accepted receiver noise figure in the 12 GHz band is between 2.5 and 4 dB. With recent advancement of semiconductor devices such as the high electron mobility transistor (HEMT), 1.5 dB noise figure is now available. Therefore, a figure-of-merit based on a 2.5 dB noise figure is appropriate as a conservative value, and even 1.5 dB would be possible, enabling the use of smaller antennas.

A large number of low-noise amplification elements which can be applied for the 20 GHz range are being developed, with special interest in the HEMT. At 20 GHz using HEMTs, a single-element noise factor (NF) of 1 dB and amplifier NF of 2 dB have been achieved.

Results of figure-of-merit calculation based on the above conditions are given in Table I, calculated according to the definition of the usable figure-of-merit given in Annex I to Report 473 neglecting, however, pointing loss, polarization effects and equipment aging.

TABLE I

Example of figure-of-merit

Frequency (GHz)	12	23	42
Antenna diameter (m)	0.9	0.9	0.5
Half power beamwidth (degree)	1.9	1.0	1.0
Antenna gain (dB) (η = 65%)	39.2	44.6	44.2
Noise figure (dB)	2.5	4.0	7.0
Figure-of-merit (dB(K^{-1}))	13.1 (1)	17.0 (2)	12.2

(1) A 16 dB (K^{-1}) figure-of-merit is expected assuming 1.2 m diameter antenna and 2.5 dB noise figure in clear sky.

(2) An 18 dB (K^{-1}) figure-of-merit is expected assuming 0.9 m diameter antenna and 4 dB noise figure in clear sky.

1.4.1.3 IF and demodulator stage

For the analogue system, the IF and demodulator stage for HDTV reception is very similar to the conventional TV demodulator, as has been verified with a number of receivers and field tests. Whereas a conventional discriminator is commonly used, a threshold extension demodulator (phase-lock loop or adaptive filter, etc.) may also be used and offers up to approximately 3 dB of threshold improvement for FM systems.

For an overall digital signal, it is expected that the error performance can be improved by using complex decoding strategies.

1.5 Example of HDTV satellite emission systems

1.5.1 Example of HDTV formats and their required RF bandwidth

Table II gives examples of HDTV transmission formats. The first two examples are for narrow RF bandwidth systems described in § 1.3.1.

TABLE II

Characteristics of example HDTV satellite broadcasting systems

Parameter	System 1 (MUSE)	System 2 (HD-MAC)	System 3	System 4	System 5	System 6
Aspect ratio	16:9	16:9	16:9	16:9	16:9	16:9
Picture rate (Hz)	30	25(1)	25	30	25	30
Active lines/picture	1032	1152	1152	1035	1152	1035
Basic sampling frequency (MHz)	Y:44.55/C:14.85	54	54 or 72	Y:59.4/C:29.7	72	Y:74.25/C:37.125
Active samples/line:(4)						
luminance	1122	1440	1440 or 1920	1536	1920	1920
colour difference	376	720	720 or 960	768	960	960
Type of coding	analogue	analogue	analogue possibly with digital assistance (DATV)	analogue	digital	digital
Compression method	motion-adaptive sub-sampling motion-compensation	motion-adaptive sub-sampling with motion compensation	motion-adaptive sub-sampling possibly with motion-compensation	motion-adaptive sub-sampling	sub-sampling and adaptive-predictive transform variat length coding	adaptive predictive DCT transform, block variable length coding
Maximum luminance band width (MHz)(2)	20	21	21 or 24	27	21-24	33
Maximum colour difference bandwidth (MHz)(2)	7	10.5	10.5 or 12	13.5	10.5-12	15
Luminance sub-sampling (horizontal)	3:1	2:1	2:1	2:1	3:2	none
Colour difference sub-sampling (horizontal)	4:1	2:1	2:1	4:1	3:1	none
Colour difference sub-sampling (vertical)	2:1	2:1	2:1	2:1	2:1	none
Luminance compression	12:11	3:2	3:2	25:22	8:3(7)	8:1.33
Colour difference compression	48:11	3:1	3:1	50:11	8:2(7)	8:0.67
Transmitted base bandwidth (MHz)(3)	8.1	10.125	18	16.875	-	-

TABLE II (continued)

Characteristics of example HDTV satellite broadcasting systems

Parameter	System 1 (MUSE)	System 2 (HD-MAC)	System 3	System 4	System 5	System 6
Digital assistance (Mbit/s)	-	1-2	up to 8	-	included in video bit rate	-
Coded video bit rate (Mbit/s)	-	-	-	-	127-147	128
Digital sound/data multiplex (Mbit/s)	1.35	1.5 or 3	1 to 4	2.7	2.5	3.872
Sound signal bandwidth (kHz)	20/15	15	≥ 15	20/15	To be specified	20
Sampling frequency (kHz)	48/32	32	≥ 32	48/32	To be specified	48
Number of sound channels	2/4	2/4 or 4/8	-	4	To be specified	4
Coding/modulation method	DPCM/ternary	PCM/duobinary	≥ 2/4	DPCM/PCM /ternary	To be specified	PCM
Companding law	16-to-11 (6 ranges) 15-to-8 (8 ranges)	Linear 14/ 14-10 NICAM	Linear 14/14-10 NICAM or to be specified	16-to-12/16	To be specified	none
Digital time compression	13.5:1	6.6:1	6.6 or 6:1	13.5:1	-	-
Error protection coding	included above	included above	included above	included above	10.5	about 12Mbit/s
Symbol rate (Mbaud)	12.15 ternary	-	-	24.3 ternary	-	-
Instantaneous bit rate (Mbit/s)	-	10.125(5) 20.25(5)(6)	54(4) or 72(4,5)	-	140-160	135
Type of modulation and deviation, ΔF_L (MHz)	FM 10.2	FM 9.55	FM or FM + 4 PSK family 9.55 to 18	FM 12-21	Digital (a) 4PSK (b) 8PSK (c) 16QAM	Digital (a) 4PSK (b) 8PSK (c) 16QAM
Required RF bandwidth (MHz)	21-24	27	45-54	41-54	(a) 105-120(8) (b) 70-80(8) (c) 52.5-60(8)	a) 81 b) 54 c) 17

Notes to Table II:

(1) Display in an HDTV receiver would normally be after suitable up-conversion, for example, 1250/100/2:1, (lines/field rate/interlace).

(2) Some loss of resolution will occur in moving areas of the picture, related to the nature and/or speed of motion, this will be much less for wideband systems.

(3) -6 dB point for overall transmission path.

(4) Source format.

(5) During digital transmission periods.

(6) Compatible with MAC/Packet family of CCIR Report 1073.

(7) Reduction in mean quantization accuracy, bits/sample.

(8) Shaping factor 1.5.

The remaining examples are for wide RF-bandwidth systems described in § 1.3.2 and require a wider bandwidth which could possibly be accommodated in the 23 GHz band (in Regions 2 and 3) or in a suitable new world-wide frequency band yet to be allocated.

The third and fourth columns show the possibilities for various analogue systems (including MAC/packet compatible systems) intended to give good quality but their bandwidth requirements are such that they could only be implemented in a frequency band not subject to the planning constraints of the 12 GHz band. A band in the 20 GHz range suitable for wide RF-bandwidth systems is therefore suggested.

1.5.1.1 MUSE (system 1) [Ninomiya et al., 1987]

System 1 is the MUSE system developed in Japan for HDTV broadcasting using a single planned channel.

Properties of the human visual system are effectively taken into the design. The technique of motion compensation is applied for the purpose of improving the effect of subsampling in the case of uniform movement in the picture.

The baseband signal bandwidth is 8.1 MHz. It uses 4:1 dot-interlaced subsampling which employs inter-field and inter-frame offsets.

A technology for analogue sampled value transmission is used including automatic waveform equalization at an encoder and a receiver.

Basic video characteristics of MUSE system are summarized in Table III.

TABLE III - Basic video characteristics of MUSE system

System description		motion-compensated multiple subsampling system (multiplexing of Y and C signals is done in TCI format)
Scanning rate		1125 lines/ 60 fields/ 2:1 interlace
Bandwidth of transmitting baseband signal		8.1 MHz
Sampling clock rate		16.2 MHz
Reproduced signal bandwidth	Y signal	22 MHz (for stationary portions of picture) 14 MHz (for moving portions of picture) *
	C signals	7.0 MHz (for stationary portions of picture) 3.5 MHz (for moving portions of picture) *
Synchronizing signal		positive polarity with respect to video signal polarity

* These values should be 16 MHz for Y and 4 MHz for C respectively, if a perfect digital two-dimensional filter could be used.

Figure 1(a) shows the filter arrangements for the luminance signal, in which different paths are illustrated for stationary portions and moving portions of the picture. Figure 1(b) shows the filter arrangement for the colour-different signals. These are shown separately just for simple explanation. In the actual encoder, however, the luminance and the colour-difference signals are combined into a TCI signal, and processed simultaneously. The luminance signals for stationary portions and for moving portions are also mixed into a single signal in the process. Therefore, the output signal is a single MUSE signal.

Figure 1(c) intends to show the sampling pattern applied in the MUSE system, and original sampling frequency is taken as 48.6 MHz. However, in the actual encoder, a frequency conversion from 44.55 MHz to 48.6 MHz takes places before the original sampling. This is shown as "TC" in Figures 4(a) and 4(b).

Figure 2 shows transmissible range in the spatial frequency domain. In this case, the frequency conversion mentioned above has already been taken into account.

Figure 3 shows the video signal in TCI format used in the system.

Figure 4 shows structure of MUSE signal.

The control signals, including motion vector, and digital sound/data signals are multiplexed into the baseband video signal during the field-blanking period as shown in Figure 4.

Sound/data signals are transmitted by inserting them into the field-blanking period. The baseband multiplexing has been adopted with advantages including suitability to cable distribution systems. The bit rate is 1.35 Mbit/s, and either four channels of 32 kHz sampled sound signal or two channels of 48 kHz sampled signal can be transmitted by the use of the technique.

In this system, differential PCM signal is near-instantaneously companded. The sound quality of the resulting signal with 32 kHz sampling and 15-to-8 bit companding is slightly better than that of 14 bit uniform PCM with 32 kHz sampling.

With this method, two channels of 20 kHz bandwidth, 16 bit PCM quality sound can also be transmitted as an alternative by 48 kHz sampling 16-to-11 bits companding within the same channel capacity.

A synchronization system which provides an accurate resampling phase is used. A positive synchronization signal eliminates the synchronization pulse loss of 3 dB. The line-sychronizing signal is shown in Figure 5(a) and the frame-synchronizing signal in Figure 5(b).

Non-linear emphasis is applied to improve emphasis gain, up to 9.5 dB.

Quasi-constant luminance processing is applied.

Using this method, crosstalk between the chrominance and the luminance signal can be reduced remarkably, and the S/N for highly colour-saturated pictures can be improved. This leads to a lower necessary received C/N of about 17 dB at the threshold perceptible level of noise.

Characteristics of non-linear emphasis and quasi-constant luminance processing of the MUSE are described in Annex II to Report 1075.

An experiment of HDTV transmission through a single television channel (27 MHz bandwidth) of BS-2 is being carried out in Japan using the MUSE system as shown in § 1.5.2

This technique of bandwidth compression can also be applied to other HDTV equipment. Such equipment of consumer use as VTRs and video-disc players using MUSE, have already been developed.

Relationship between picture quality and waveform distortion of the MUSE signal has been investigated. It has been made clear that for the MUSE system the relationship between distortion in the transmission path and the received picture quality can be formularized by an application of the logistic function [CCIR, 1986-90e].

Two measuring instruments have been developed for the purpose of making measurement easier during HDTV broadcasting through a broadcasting satellite.

A new instrument for checking C/N ratios has been developed in which the noise power is measured at a little bit outside the band of the channel. This instrument can be used with any television system including HDTV.

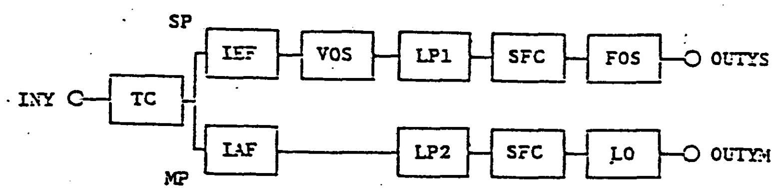

FIGURE 1(a) - Filter arrangement for the luminance signal

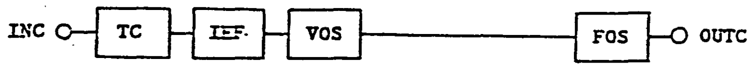

FIGURE 1(b) - Filter arrangement for the colour-difference signals

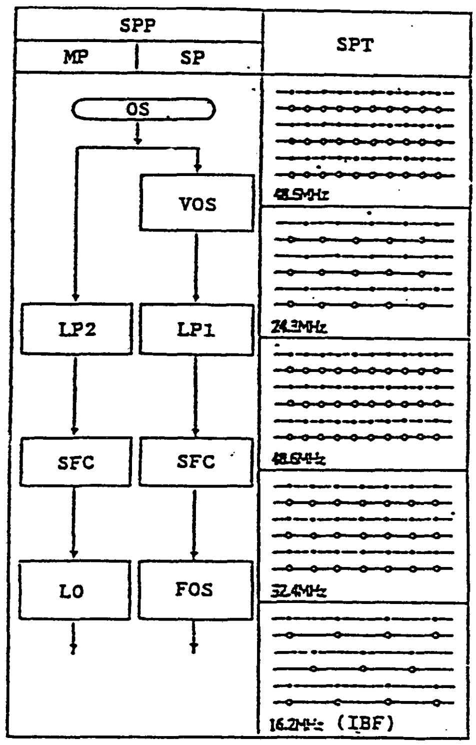

FIGURE 1(c) - Sampling pattern

FIGURE 1 - Principle of MUSE system

TC	:	time compression
SP	:	stationary portion
MP	:	moving portion
IEF	:	interfield prefiltering
IAF	:	intrafield prefiltering
VOS	:	field-offset subsampling
LP1	:	12 MHz low-pass filtering
LP2	:	16 MHz low-pass filtering
SFC	:	sampling frequency conversion
FOS	:	frame-offset subsampling
LO	:	line-offset subsampling
INY	:	luminance signal input
INC	:	colour-dffierence signal input
OUTYS	:	luminance signal output for staionary portions
OUTYM	:	luminance signal output for moving portions
OUTC	:	colour-difference signal output
SPP	:	signal processing procedure
SPT	:	sampling pattern
OS	:	original sampling
(IBF)	:	invert by frame
- O -	:	odd field
--●--	:	even field

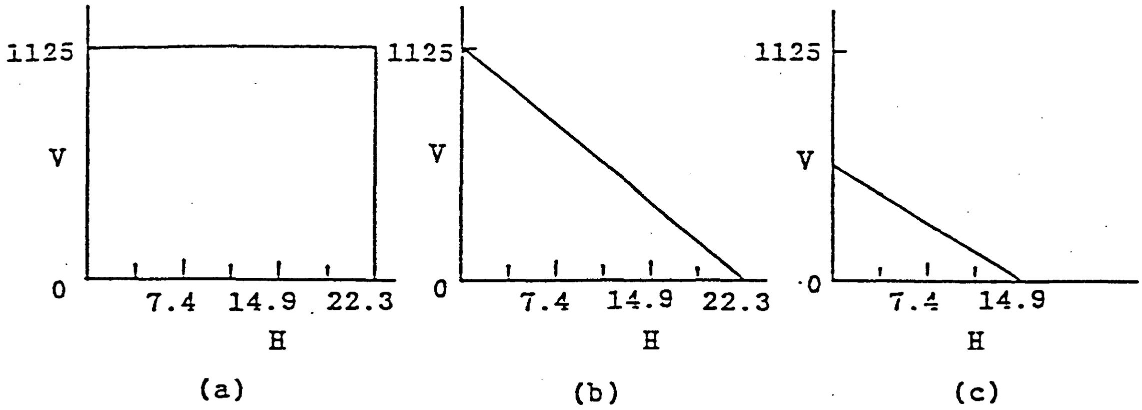

FIGURE 2 - Transmissible range in spatial frequency domain

(a) Original sampling
(b) Interframe and interfield interpolation for stationary portions
(c) Intrafield interpolation for moving portions
H : horizontal frequency (MHz)
V : vertical frequency

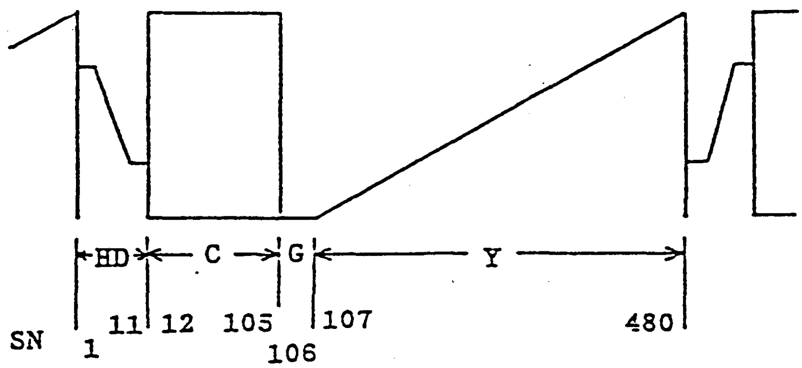

FIGURE 3 - Video signal in TCI format

HD : line-synchronizing signal
C : colour-difference signals (line-sequential)
G : guard area
Y : luminance signal
SN : sample number

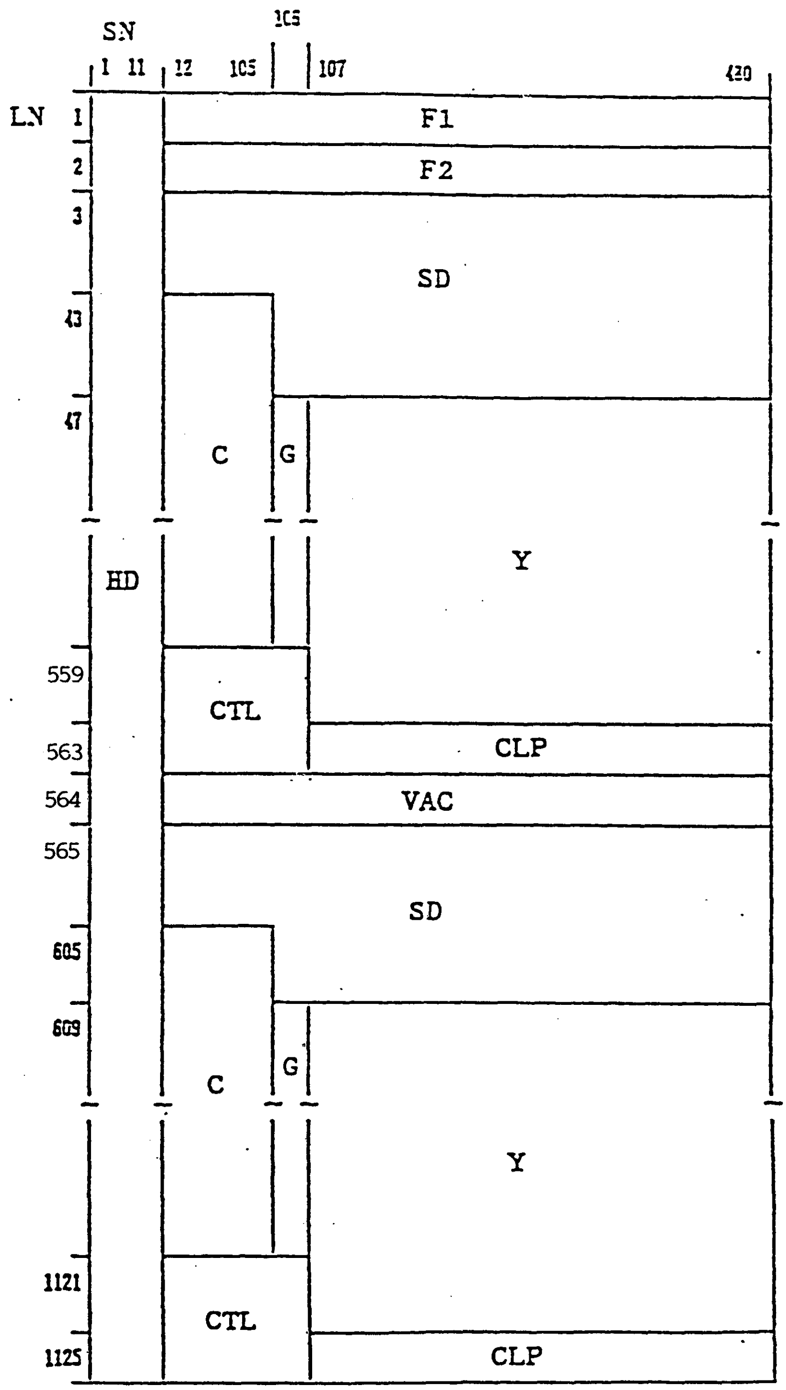

FIGURE 4 - Signal allocation map

SN : sample number
HD : line-synchronizing signal
SD : sound and data signals
C : colour-difference signals (line-sequential)
Y : luminance signal
CLP : clamp level (128/256)
LN : line number
F1 : VITS No. 1 and Frame Pulse No. 1
F2 : VITS No. 2 and Frame Pulse No. 2
G : guard area
CTL : control signals
VAC : vacant

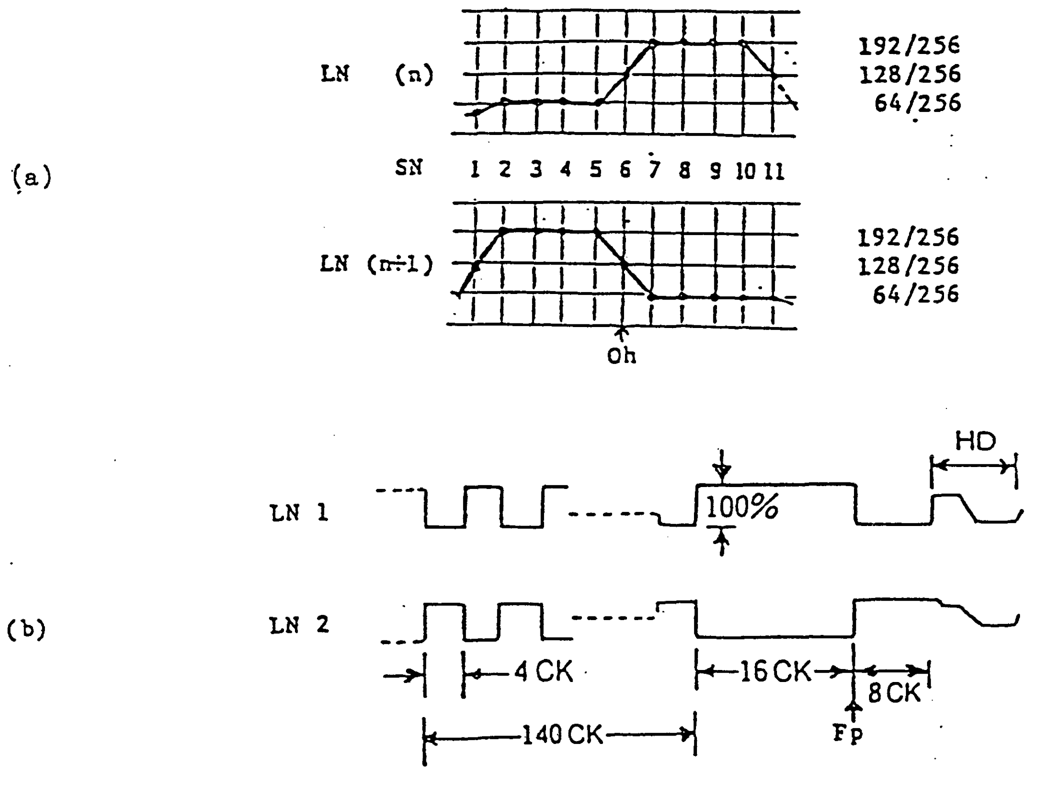

FIGURE 5 - Synchronizing signals

(a) Line-synchronizing signal

LN (n): n th line

LN(n+1): (n+1) th line

SN : sample number

Oh : timing reference for line synchronization

(b) frame-synchronizing signal

LN : line number

HD : line-synchronizing signal

Fp : frame-pulse point

CK : one clock-time duration at 16.2 MHz

In order to measure audio bit error rate on receiving a normal broadcasting a new instrument has been developed. It is equipped with two modes of measurement. One utilizes the frame synchronizing code, the other the error-correction code. The former counts error bits of the frame synchronizing code of a 16-bit fixed pattern which is transmitted during an interval of one millisecond. The latter counts error bits detected with the error-correction code in each audio data block which is transmitted at a rate of 16 blocks/millisecond [CCIR, 1986-90f].

The digital transmission of MUSE signal is possible. For this purpose, a MUSE DPCM system has been developed as described in section 3.3.3 of Part 9 [CCIR, 1986-90g].

1.5.1.2 The HDMAC/packet system (system 2)

1.5.1.2.1 Design consideration

HDMAC is designed to meet the highest quality criteria to allow the introduction of HDTV services on existing MAC/packet services, or directly as new services. [CCIR, 1986-90h,i] describe the design consideration of HDMAC bandwidth reduction.

These include the performance of the system with respect to the received HDTV picture quality, the full utilization of current technological capabilities, the feasibility of system development as technology advances, and the economic viability and suitability of the system with respect to its adoption, and subsequent use, by broadcasters and viewers. As a consequence, receiver manufacturers can produce and market HDMAC receivers as an extension to their product range, without making existing products obsolete. Additionally, the HDMAC product range is broadened by the potential for display up-conversion. The use of DATV significantly reduces the complexity of HDMAC decoders, and therefore their cost; and makes their behaviour uniform, regardless of channel distortions.

HDMAC is optimized to allow HDTV services on WARC BC-77 emission channels (1), while preserving the compatibility with the MAC/packet system.

These constraints involve the EUREKA 95 project in global tradeoffs between the receiver complexity, the quality of the high-definition picture, generated with the 1250 line/50 field scanning standard, and the quality of the compatible picture viewed on domestic MAC/packet receivers.

This system is designed to employ spectrum folding, subsampling and motion adoption to preserve the resolution of both static and tracked motion for high-definition reception [Hurault and Arragon, 1988].

1.5.1.2.2 System description

The specification in Europe of a high-definition television system (HDTV), studied in the context of the European EUREKA 95 project, is based for its complete description, on the specification of the MAC/packet family which is presented in Report 1073 [CCIR, 1986-90k].

The time division multiplex is used for picture/sound/data multiplexing for HDMAC transmissions which include two members of the MAC/packet family: D-HDMAC/packet and D2-HDMAC/packet systems. These two systems are suited for use in satellite broadcasting and any transmission medium which guarantees a baseband of about 11 MHz.

1.5.1.2.2.1 Structure of the multiplex

The structure of the multiplex is based on a 40 ms digital frame which contains 625 lines of 64 μs each. The multiplex is composed of three main components (see Fig. 6):

- the HDMAC vision signal;
- the line blanking interval (LBI) data burst, which carries the sound/data multiplex;
- the field blanking interval (FBI) data burst, which carries the DATV/data multiplex.

1.5.1.2.2.2 Sound

Sound is coded according to the MAC/packet specification. The available capacity in the LBI is equivalent to four high-quality or eight medium-quality sound channels compatible with MAC/packet for the D2 system and eight high-quality or sixteen medium-quality sound channels compatible with MAC/packet for the D system.

1.5.1.2.2.3 Vision

Document [CCIR, 1986-901] gives the baseband characteristics (summarised in Table IV). The modulation parameters of the emitted HDMAC signal are given in Tables II and V.

1.5.1.2.2.4 General video characteristics of the HDMAC vision signal

See Table IV.

1.5.1.2.2.5 Bandwidth reduced signal

Multi-branch coding is used for HDMAC band reduction [Vreeswijk et al., 1988; Arragon et al., 1988; Pele and Choquet, 1988].

In order to select the optimum HDMAC BR (bandwidth reduction) algorithm, the subjective assessment of picture quality, together with other factors has been considered.

Document [CCIR, 1986-90h] reports on the subjective assessments that were performed by five laboratories throughout Europe and that led the Eureka EU 95 project to select the final HDMAC bandwidth reduction system. Seven candidates' algorithms were evaluated. Eight scaled-down moving picture sequences were used covering a range of possible source material (originated in 1250- and 625-line interlaced video cameras, 25 and 50 pictures/s film). For the tests a double stimulus method was used with continuous graphical quality-scaling (in line with IWP 11/4 methods). The ranking order for the seven algorithms was generally the same for each of the five laboratories that undertook the tests and there was a high degree of correlation for the quantitative differences between the mean grades. The results gave confidence in the method and the validity of the ranking order.

The HDMAC BR codec uses three luminance coding branches, all using quincunx subsampling lattices;

- an 80 ms branch with HD resolution for stationary areas;
- a 40 ms motion compensated branch for velocities up to 12 samples per 40 ms;
- a 20 ms branch for rapid motion and sudden picture changes except when in 25 picture/s film mode.

The transmissible range of spatial frequency is given in Fig. 7 for all modes. To carry the information contained in a 1250 line HD system through a 625 line MAC/packet channel, a process, termed "shuffling", is used.

The 40 ms branch is motion compensated. One motion vector is emitted for each block of 16 samples by 16 lines on the HD grid via the DATV data.

The HDMAC BR codec uses three colour-difference coding branches, the first and third using a quincunx, the second an orthogonal subsampling lattice:

- an 80 ms branch with HD resolution for stationary areas;
- a 40 ms branch for rapid motion and sudden picture changes;
- a 20 ms branch for rapid motion and sudden picture changes, except when in 25 picture/s film mode.

The transmissible range of spatial frequency is given in Fig. 8 for all the modes. Intra-field shuffling is used for the 80 and 20 ms branches and inter-field for the 40 ms branch.

A film mode option is implemented, which only activates the 80 and 40 ms branches. In this way maximum benefit is taken from the knowledge that 25 pictures/s film is the source material.

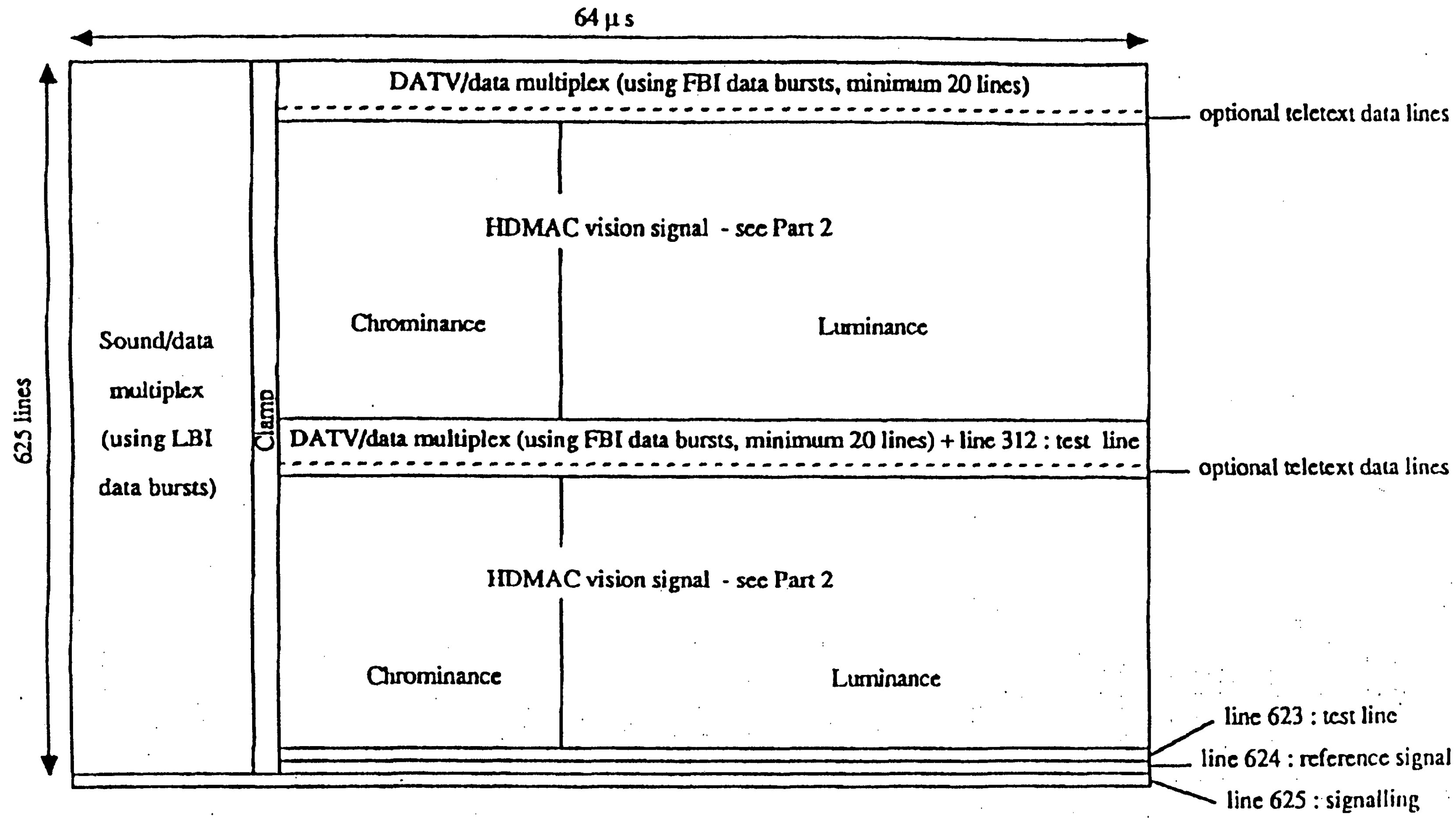

FIGURE 6 - General HDMAC/packet TDM structure

TABLE IV - General video characteristics of the HDMAC vision signal

Number of emitted lines per picture :	625
Number of fields per second :	50
Interlace ratio :	2:1
Analog bandwidth approximately :	11 MHz[1]
Aspect ratio :	16:9 (associated with panning information for compatible 4:3 displays).
Compression ratios	
luminance :	3:2
colour difference :	3:1
Sampling frequency :	20.25 MHz[2]
High definition reception :	
Luminance resolution	
horizontal	
static and tracked motion :	620 c/apw[3]
untracked motion :	310 c/apw
vertical	
static :	400 c/apw[3]
motion :	200 c/apw
Compatible reception :	
Samples per active lines	
luminance :	697
colour difference :	349

Note 1 : Allowing for practicable Nyquist filter

Note 2 : Conventional MAC sampling frequency

Note 3 : Cycles per active picture width/picture height

TABLE V - HDMAC modulation parameters for DBS

Nominal vision signal bandwidth :	10.125 MHz at -3 dB
Nominal channel bandwidth :	27 MHz
Modulation :	FM
Polarity of frequency modulation :	positive
DC component :	preserved
Pre-emphasis characteristics:	non linear process applied only to HDMAC samples and linear applied to all the multiplex (same as for MAC)
Frequency deviation :	13.5 MHz at the cross-over frequency of the linear pre-emphasis network (1.37 MHz).
Energy dispersal :	triangular frame synchronous waveform (corresonding carrier deviation : 600 kHz peak-to-peak)

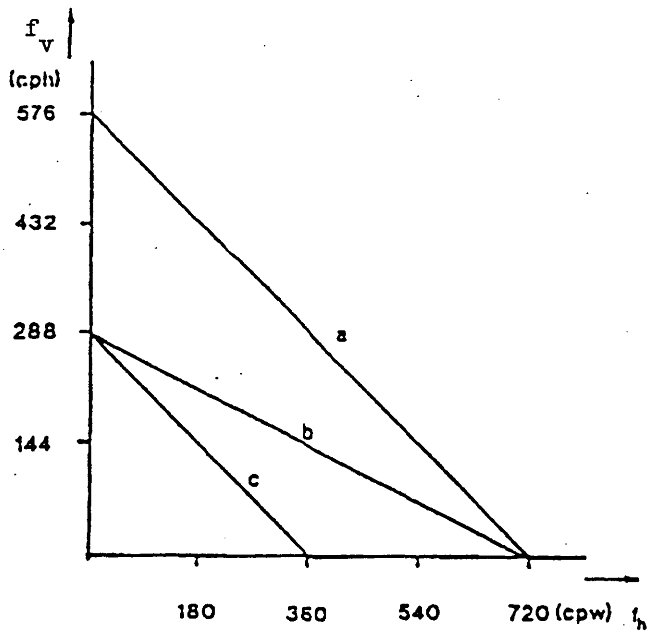

FIGURE 7 - Transmissible range in spatial frequency domain for the luminance sampling patterns

(a) 80 ms mode
(b) 40 ms mode
(c) 20 ms mode

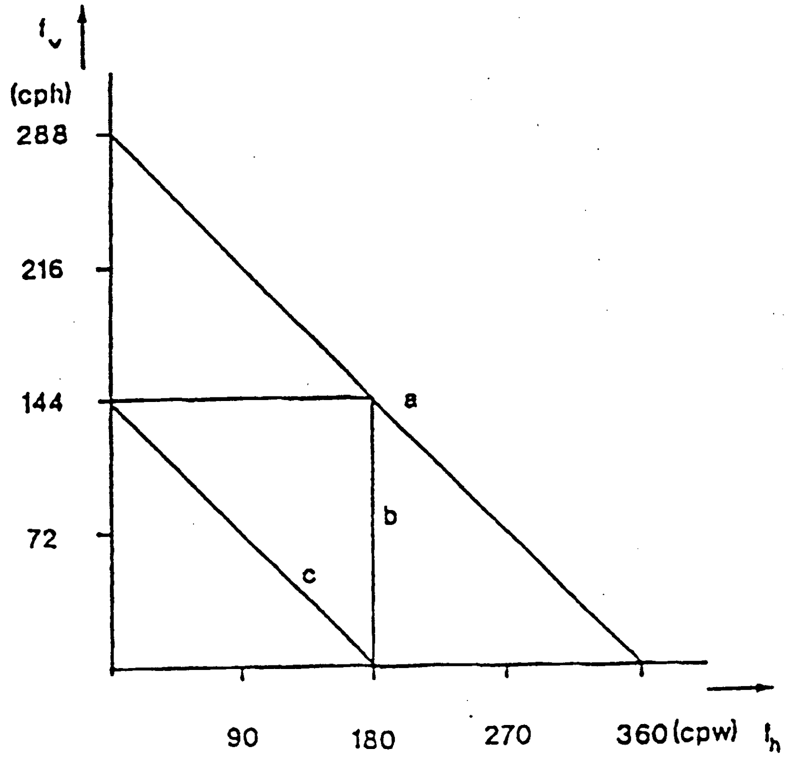

FIGURE 8 - The transmissible range of the colour-difference spatial frequency spectrum

(a) 80 ms mode
(b) 40 ms mode
(c) 20 ms mode

The branch selection information is conveyed, after formatting by the DATV data [Storey, 1986].

DATV information that contains the branch switching signal allows for 1,700 possibilities, coded in 11 bit long codewords. The five route/80 ms period coding results in a bit rate of 891 kbit/s. The colour-difference switching information is derived from the luminance DA data.

Compatibility improvement for edge crawling in stationary areas is done by vertical intra-field filtering, with an attenuation of 6 dB.

The HD-MAC scheme has been optimized to meet the highest quality criteria for both the high definition picture and the compatible picture, based on an interface scan picture input.

Document [CCIR, 1986-90m] reports how the use of progressive scan picture with quincunx sampling at the input of an HD-MAC encoder (the input stages of which have been modified to handle both interlace and progressive inputs) produces improvement of both the high definition and compatible picture quality.

In particular, progressive scan input allows the removal of certain vertical/temporal aliasing from the signal passing through the 20 and 40 ms branches and increases the stability of the motion estimation and branch decision (by this way, a lower proportion of the moving pictures uses the 20 ms branch).

It is stressed also that a progressive input affects to a limited extent the architecture of the HD-MAC encoder, but does not affect the HD-MAC specifications at all.

The experiments carried on simulation and taking into account the hardware architecture modifications (allowing at the same time interlace and progressive inputs) result in a perceptible improvement of the high definition global picture quality and a noticeable improvement of the compatible picture quality, especially in the areas where 40 ms and 20 ms branches are used [CCIR, 1986-90m].

1.5.1.3 <u>System 3</u>

System 3 is proposed as a development of HD-MAC for a wideband RF-channel of up to twice the bandwidth of the existing planned channels. It would provide improved high-definition quality, possibly with a simplified receiver. There are two options, one based on 54 MHz sampling which would be compatible with System 2 HD-MAC receivers and one based on 72 MHz sampling which would provide higher performance with much greater use of DATV, but is not completely compatible.

1.5.1.4 <u>System 4</u>

System 4 is a non-compatible 60 Hz based system using 2-field offset sub-sampling. This system offers higher spatial resolution both for static and moving area compared to MUSE. Required RF bandwidth is between 45 to 54 MHz [Document CCIR, 1986-90n].

1.5.1.5 <u>System 5</u>

System 5 is an all-digital example which is not compatible with MAC/packet receivers, but retains compatibility at source with the CCIR Recommendation 601 625-line standard. Using 4-PSK modulation, the required bandwidth could be as high as 120 MHz, but if 16 QAM were used an RF-bandwidth between 50 and 60 MHz is possible.

1.5.1.6 System 6

System 6 is an all-digital example based on the combination of predictive coding and DCT for emission of 1125/60 studio signals. Total bit rate of this system is 135 Mbit/s. Using 4-PSK and 8-PSK modulation, the required RF bandwidths are 81 MHz and 54 MHz respectively. However RF bandwidth of about 40 MHz is possible using 16-QAM. This system can be applied for the transmission using H_4 level of B-ISDN [CCIR, 1986-90n].

1.5.1.7 Other systems under development

1.5.1.7.1 HDS-NA

This is a time multiplexed analogue component satellite transmission format. A sequence repeating in four line periods at horizontal rate is used to transmit the components which result from processing. These components include: 16.8 MHz luminance information (time-expanded), reduced bandwidth uncompressed (9.5 MHz) luminance, two line difference signals representing luminance minus the average of the line before and the line after, low pass filtered, two alternate line chrominance signals compressed 2:1 and 4:1 alternatively, and a burst of digital audio for two stereo pairs with two level coding. Resolution is 480 lines per picture height (L/PH) vertical and 495 L/PH horizontal. The baseband bandwidth is 9.5 MHz, recommended deviation is 12 MHz/V peak in an IF bandwidth of 27 MHz. Weighted S/N of 48 dB is produced by a C/N of 17.7 dB.

1.5.1.7.2 HD-B-MAC

Intended for satellite transmission, an enhancement of the CCIR B-MAC standard, it is compatible with standard B-MAC decoders, which produce an NTSC output. Pan/scan compatibility is implemented. 2:1 decimation is performed to provide a high resolution 525-line signal which is sub-sampled at alternate sites on adjacent lines, filtering diagonal information. Spectrum folding provides extended luminance resolution while reducing baseband bandwidth. Luminance multiplexing compression is 3:2. Similar processing is applied to the chrominance signals, which are compressed 3:1. Luminance resolution is claimed at 954 L/PW horizontal and 480 L/PH vertical. The receiver is expected to employ adaptive line doubling. Baseband bandwidth is 10.7 MHz.

1.5.1.7.3 Spectrum compatible HDTV

This system is designed for use on terrestrial channels. Proposed is transmission of HDTV processed from a 787.5/59.94 progressively-scanned source through two 3 MHz bandwidth component pairs and a data channel.

For satellite transmission, these components, of which there are 262.5 pairs, each 63.5 μs, are time division multiplexed, with a maximum baseband bandwidth of 6 MHz.

A data channel, which is time division multiplexed in the equivalent of the NTSC vertical blanking intervals, describes low frequency component video below 200 kHz, synchronization, and a stereo pair with SAP channel. Luminance is processed in four spatio-temporal bands, from 59.94 Hz frame rate for low frequencies, to 11.988 Hz for high frequencies. Colour difference signals are refreshed at 11.988 Hz and at one third horizontal and vertical resolution of luminance. The system, designed for a 5:3 aspect ratio with 16:9 possible, claims static resolution of 720 L/PH vertical and 1020 L/PW horizontal.

As a result of the spectrum efficiency obtained through the digital transmission of low frequency average picture information, a 3 to 5 dB improvement in noise performance over the same NTSC transmission link is claimed.

1.5.1.8 Downward compatibility

Compatibility is defined as follows:

A new emission standard is "compatible" with an already existing emission standard if signals according to the new standard can be received and displayed, without additional equipment, with receivers designed for the existing standard. The quality should be about the same as the quality when a signal according to the already existing standard is emitted.

One approach for compatibility between conventional television and high-definition television is two-channel transmission systems. All signals necessary for receiving by conventional receivers are carried out by one of the two channels. The augmentation channel carries the additional information to permit picture reconstruction of HDTV.

In a system proposed in North America by the New York Institute of Technology (VISTA), an augmentation channel providing high spatial and low temporal resolution is proposed, to be combined with the high temporal resolution of the NTSC picture. Aspect ratio is 16:9 or 5:3, achieved by reducing horizontal blanking and decreasing the number of active lines. Static resolution is 800 lines horizontal and 900 lines vertical. The augmentation channel is transmitted as time multiplexed components, with a bandwidth of 5.3 MHz. Two satellite channels are suggested for transmission.

In Europe, active studies are under way concerning HDTV systems which can be received compatibly by MAC/Packet receivers, with the normal quality of the latter signals. If the high-definition television signal possesses characteristics at the low frequencies of the spectrum identical to those of the existing MAC signals as in two of the examples of Table II, compatibility between the two types of service will be possible.

[CCIR, 1986-90o] indicates that the choice in the European Community is for a system which is compatible with the MAC/packet family of transmission standards. Compatibility with the European DBS emission standard is considered vital for the commercial introduction of high-definition television programmes, allowing consumers to see HDTV broadcasts on their conventional DBS sets and to make a choice of when to upgrade to HDTV. MAC/packet compatible HDTV (HDMAC) was demonstrated at IBC Brighton and with further use of digital assistance techniques. Experts in Europe are confident that compatible HDTV can at least match the quality of non-compatible systems using similar bandwidth transmission systems. With the development of consumer equipment to this HDMAC standard, probably with displays operating at 100 Hz, the options of the consumer receiving DBS programmes will range from 4:3 PAL/SECAM and MAC to 16:9 MAC and HDMAC.

The EBU [CCIR, 1986-90p] would support the HDMAC system provided that it achieves an acceptable balance between HDTV and compatible MAC picture quality, provides full service continuity for data services, provides compatibility with the WARC-77 Plan and provides compatibility with MAC/packet receivers.

Although the MUSE system is not downwardly compatible with conventional TV systems, MUSE to 525-line standards converters intended for use with consumer receivers have been developed by using VLSIs (see Part 10, section 4). The resultant 525-line picture from this converter has, on average, higher quality than the normal picture originated with NTSC standard, although it has some edge flicker, with less interference than that caused by the NTSC cross-colour. It has a simple circuit construction and it will be made available at a lower price. The development of this MUSE to 525-line standards converter gave some prospect to HDTV broadcasting in the 1125-line systems which can be received utilizing conventional 525-line receivers [CCIR, 1986-90q].

1.5.2 Experiment and demonstrations of HDTV satellite broadcasting systems

A satellite transmission experiment of the MUSE signal was carried out in 1986 on a single 12 GHz WARC BS-77 channel by using the 100 W Japanese broadcasting satellite in operation, BS-2.

Modulation parameters and link budget for transmission are reported in Tables III and IV.

In this way a C/N of around 17 dB was obtainable for 99% of the worst month in most of Japan with antennas in the range of 0.7-0.9 m in diameter. This gave good picture quality. Further details are described in Annex V of Report 1075.

The experiment was also carried out in seven rounds from 1987 to 1988, using the BS-2b broadcasting satellite in operation.

The eleven Japanese television receiver manufacturers and NHK took part in the experiment. The MUSE signals were received and measured in Tokyo, Osaka, Nagoya, and their vicinities.

All the receivers produced by the manufacturers participating in the experiment showed good reception capability of MUSE signals. The signals were received with little aliasing and little ringing. Tests for sound mode switching controlled with codes also went well.

The tests produced received C/N ratios of 17 to 21 dB under clear weather, which were corresponding to, or better than, the limit of perception for noise impairment. The S/N ratios of baseband signal demodulated with the tuners were almost coincident with theoretical values (C/N + 11.9 dB).

Bit error ratios of digital sound/data signals were 10^{-3} or better at a C/N of 10 dB. They were measured under a low C/N condition deliberately provided with an attenuator inserted after the receiving antenna. No extreme picture degradation was observed with this C/N condition of 10 dB.

Picture quality was evaluated as more than grade 4 in the 5-grade scale using test materials extracted from HDTV programmes and still pictures. The sound was evaluated as grade 5 for all cases.

The modulation parameters used in this experiment were confirmed as adequate for practical use.

It was also confirmed that the DBS tuner developed for the reception of conventional television could be used for that of HDTV with minor modifications.

Further demonstrations took place in Japan in 1987 using the present BS-2b on a time-sharing basis with the current transmission of the conventional television broadcasting service and another demonstration in Canada and the United States in October 1987 using Anik-C and RCA-K1 communication satellites delivering the signal to seven cities.

Among other programmes broadcast in HDTV, the most attractive event was the Seoul Olympic Games in 1988. At opening and closing ceremonies, live satellite broadcasting using BS-2b was carried out with HDTV programmes relayed through the Intelsat to Japan from Seoul, Korea. Other sporting events were recorded on video tape and also broadcast in HDTV through the BS-2b satellite the next day. The total amount of broadcasting was 73 hours 20 minutes in 17 days.

The broadcasts were received with parabolic antennas of 75 cm to 160 cm in diameter depending on the location, and pictures were demonstrated at 81 locations throughout Japan in department stores or public facilities by using 205 various display equipments. About 3.7 million people in total observed HDTV, and were impressed with the excitement of the games conveyed by HDTV.

TABLE VI

Modulation parameters for MUSE to supplement Table II

Sound and data signal modulation	ternary PCM multiplexing in field-blanking period
Polarity of frequency modulation	positive
DC component	preserved
Pre-emphasis characteristics	Non-linear emphasis
Energy dispersal (kHz)	triangular frame synchronous waveform

TABLE VII

Link budget for MUSE transmission of 1125/60 system

Frequency	(GHz)	12
Type of modulation		FM
Equivalent RF bandwidth	(MHz)	27
C/N (exceeded for 99% of the worst month)	(dB)	17.0
S/N unweighted	(dB)	39.0
Figure of merit G/T	(dB/K)	16.0
Required power flux-density (edge of beam - exceeded for 99% of the worst month)	(dBW/m^2)	-110.5
Free-space attenuation	(dB)	205.6
Rain attenuation	(dB)	2.0
Atmospheric absorption	(dB)	0.1
Feeder-link noise contribution	(dB)	0.3
Edge of coverage of area factor	(dB)	3.0
Required e.i.r.p. from satellite (beam centre)	(dBW)	57.7
Satellite antenna beamwidth (-3 dB)	(degrees)	1.3 x 1.8
Satellite antenna gain (beam centre)	(dBi)	40.0
Losses (feeder, filters, etc.)	(dB)	2.3
Required TWTA power	(dBW)	20.0
	(W)	100

[CCIR, 1986-90r] describes the D2-HDMAC compatible emission system. This document reports on transmission by means of the French satellite Telecom 1C during the IBC demonstration in September 1988. The D2-HDMAC/packet multiplexer, demultiplexer and the satellite transmissions are outlined. Furthermore, the document gives the structure of the data multiplex, where the available bit rate for the digital assistance data is 1.164 Mbit/s. A 656+ interface, the synchronization, Nyquist filtering, non-linear pre-emphasis and de-emphasis are discussed.

[CCIR, 1986-90s] summarizes the technical investigations concerning HDMAC satellite broadcasting within a 27 MHz channel of the 12 GHz WARC 77 plan. The results obtained with the first experimental HDTV chain were in the framework of the HDTV European project Eureka 95.

Most of the tests have been done with a satellite simulator.

Also, experiments of D2-HDMAC transmission through a real satellite have been carried out in France using the DBS satellite TDF-1. The D2-HDMAC/packet signal was sent to the TDF-1 earth station through an FM microwave link with 14 hops. The signal was received by a commercially available receiving station with a 55 cm parabolic antenna. The noise figure of the SHF converter was equal to around 2 dB.

With regard to the effect of noise on the decoded (baseband) signal, the picture impairment has been evaluated by means of the satellite simulator for different values of the C/N ratio in a 27 MHz bandwidth. The tests have been done only with still pictures and with the 88 algorithm either in the static mode (80 ms branch) or in the moving mode (20 ms branch). The method which has been used was the EBU method with non-expert observers as described in CCIR Recommendation 500. The results obtained are given in Figure 9. The dashed lines indicate the confidence interval (5%) of the mean results (continuous line) obtained from 15 observers. The measured C/N was equal to 21 dB in a 27 MHz bandwidth, which corresponds for the HDMAC signal to a grade better than 4.5 on the impairment scale.

With the French satellite TDF-1, a received C/N of 17 dB is obtainable for 99% of the worst month in all the national coverage with a 55 cm receiving antenna. Thus an HDMAC signal of quite excellent quality can be received with a small receiving antenna using a 12 GHz WARC channel.

[CCIR, 1986-90t] deals with the compliance of the HDMAC signal with the protection ratios for the broadcasting satellite service in the 12 GHz band.

Measurements of first adjacent channel (+/- 19.18 MHz) and co-channel interference levels giving just perceptible impairment on vision have been done in the two following configurations:

a) HDMAC interfering with HDMAC;

b) HDMAC interfering with the reference WARC-77 system (SECAM with a sound sub-carrier).

From these tests, the following conclusions can be drawn:

a) When the wanted signal is the WARC reference signal, then the minimum protection ratios required by the WARC-77 are met with a margin greater than 9 dB. The HDMAC signal is not more critical than a conventional MAC signal.

b) Two HDMAC signals can coexist in the WARC-77 broadcasting Plan.

From 25 August until 3 September 1989 the general public witnessed live HD-MAC transmissions and emissions from the Eureka-95 booth at the Internationale Funk-Ausstellung (IFA) 1989 in Berlin (West). The signal was received by individual dish antennas and, being compatible, was viewed by the owners of D2-MAC receivers throughout a large part of Europe.

After the HD-MAC bandwidth reduction encoder (BRE) the video signal was time multiplexed with the audio/data signal into both a D2-MAC and D-MAC signal format. (In the case of D-MAC the signal was fed to a satellite simulator and then to the decoders.) The HD-MAC signal was transmitted via a 140 Mbit/s digital link to a mobile satellite feeder link on the exhibition premises. Also a parallel 70 MHz IF link was sometimes used. From there the signal was transmitted to the DFS-Kopernicus satellite. This signal could be received within the footprint of the Kopernicus, which is a medium power telecommunication satellite.

The signal was also received at the ground station of Usingen, from where it was again relayed to the TDF-1 and the TVSAT-2 satellites of France and the Federal Republic of Germany respectively. Both the TDF-1 and TVSAT-2 are true DBS satellites. This signal could be received throughout France and the Federal Republic of Germany and outside these countries as the footprints indicate.

During the period of exhibition also a three hop experiment has been done, whereby the TVSAT-2 signal was received in France and then fed to the TDF-1.

At the IFA'89 in Berlin (West) the HD-MAC signal was received by means of dishes of 90 cm and 1.5 m dish antenna, since Berlin is outside the basic footprint of TDF-1. In the Eureka booth the satellite receiver, demultiplexer and bandwidth reduction decoders were used to deliver and reconstruct the high definition (HD) output signal for the various high definition displays [CCIR, 1986-90u].

Summary and conclusions

It is found that techniques exist for the broadcasting by satellite of HDTV over a range of frequencies up to about 23 GHz. Several separate possibilities exist and have been studied in detail. These techniques comprise bandwidth reduction, channel coding, multiplexing, modulation and reception. The technology for implementation of these techniques is available now, and technology for the satellite either is available now (as is the case for the 12 GHz band) or is expected to be available within the next ten years if high power levels are needed at 23 GHz.

Indications are that RF parameters and sharing may put constraints on the emission format. Nevertheless neither the characteristics of satellite broadcasting systems, nor their interference susceptibility should directly restrict the characteristics of the studio standard used as source of programme material. However, definition of that studio standard should precede the definition of any subsidiary standards if signal degradation and the costs of conversion are to be minimized.

For satellite broadcasting, the 12 GHz bands have been planned based on channel widths of 24 MHz in Region 2 and 27 MHz in Regions 1 and 3. In order to transmit HDTV within these channels, the source signals must be reduced in bandwidth through extensive signal processing. Two narrow RF-band systems (MUSE, HD-MAC) provide such signal compression at the expense of some reduction in the resolution of moving areas of the picture. Any HDTV studio standard should allow for the implementation of the kind of compression techniques described in this report.

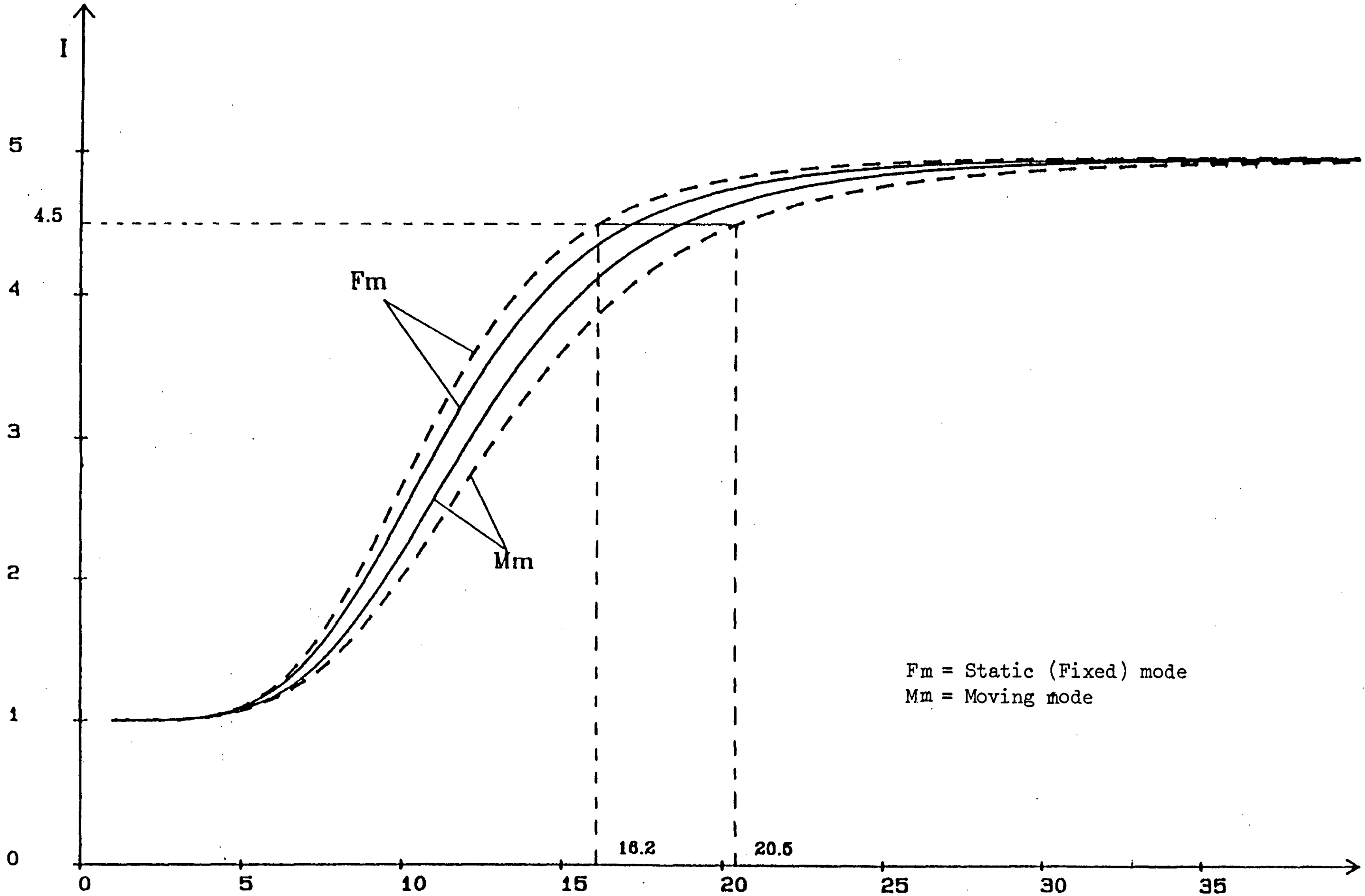

FIGURE 9

Impairment grade of the HDMAC picture signal as a function of the C/N ratio in 27 MHz

For satellite broadcasting of wider RF-band HDTV service on a world-wide basis, potentially providing quality close to that of the studio standard, it was recognized at the WARC ORB-88 that a new frequency band would be required as the bandwidth of the channel required to broadcast a wide RF-band HDTV signal is not yet determined, there is flexibility to accommodate a range of system parameters. This means that no specific constraint would need to be imposed on the HDTV studio standard to allow satellite emission in such band. However, it is preferable that an HDTV studio standard be specified before developing the world-wide satellite broadcasting standard considered desirable by WARC ORB-88.

Techniques which will allow the broadcasting of HDTV by satellite have been identified. These techniques make use of technology which is now available in the case of bandwidth reduction, modulation and reception techniques. In particular, studies of MUSE and HD-MAC in Japan and Europe respectively have led to the technology required for the complete studio-receiver chain. Systems have been developed and demonstrated. Cost reduction considerations in view of developing consumer equipment have already been included in the process; thus standardization of the studio production and emission formats is urgently needed. For broadcasting at frequencies up to 23 GHz, satellite technology should not be a limiting factor on the choice of an emission standard, and also will not as a consequence affect choice of the studio standard.

The CCIR considers it necessary to continue to study radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV satellite broadcasting. Further study is required to determine:

i) system parameters for wide RF-band analogue and digital high definition television transmissions by satellite;

ii) propagation characteristics for bands suitable for wide RF-band high definition television transmissions;

iii) inter- and intra-service sharing and interference, interregional sharing.

The progress of these studies is expected to allow definitive results before the end of the next CCIR study period.

2. Terrestrial emission of HDTV including cable distribution

2.1 Introduction

The majority of the world's consumers of television broadcasting receives television via terrestrial broadcast. Widespread adoption of higher definition television will depend, for many administrations, on ready consumer access to terrestrial broadcasts.

The task of recommending HDTV emission standards is rendered difficult by the diversity of strategies in different parts of the world where satellite transmission, terrestrial emission and cable distribution have different requirements and priorities. Basic statements for HDTV emission standards are:

- the numbers of emission standards should be limited;
- AM-VSB is one of the preferable modulation types with respect to the bandwidth saving;
- it would be preferable for the HDTV standard for terrestrial and cable transmission to be similar;
- existing networks should not be adversely affected by introduction of HDTV;
- each type of receiver compatibility, channel compatibility or baseband compatibility is advantageous;
- the whole studio-satellite/transmitter-cable-receiver chain should be taken into account when proposing the HDTV signal standard.

2.2 HDTV approaches in an NTSC environment

In the United States, the television industry has the objective of preserving the public's investment in current television equipment during a transition period for HDTV. A further goal is to preserve the diversity of television distribution media.

The feasibility of broadcasting HDTV terrestrially has been demonstrated by an experiment conducted over a three week period in Washington D.C., in January 1987. The experiment is part of a continuing project by segments of the United States broadcast industry to develop a system for terrestrial HDTV broadcasting. It was shown that such programmes could be delivered to viewers using two contiguous 6 MHz UHF television channels, employing conventional VSB-AM.

Additionally, terrestrial HDTV was also demonstrated using FM modulation in the 13 GHz band during the same period. In this project, the MUSE system was used.

In Japan, for the existing 6 MHz NTSC system, 9 and 12 MHz channel compatible systems are being studied and experiments have been carried out using existing cable networks.

In Canada a joint industry/government committee named the Canadian Advanced Broadcast Systems Committee (CABSC) was formed in 1987 with the objective of providing a national forum to address the medium and long term technological developments which may effect broadcasting and other related services. The activities of the Committee to date have focused on consideration of standards development and implementation strategies for HDTV broadcasting, addressing in particular the delivery of HDTV via terrestrial broadcasting and cable. In particular these activities have included:

Characterization of off-air and cable channels for wideband signal delivery (12 MHz) by carrying out a measurement program on selected facilities.

Development of procedures for the subjective testing of proponent ATV systems in preparation of carrying out the testing and evaluation. Testing is scheduled to commence the second quarter 1990.

Performing spectrum studies concentrating on the VHF/UHF TV spectrum to determine if terrestrial broadcasting of ATV can be adequately accommodated in these bands and to evaluate the impact ATV may have on existing NTSC operations [CCIR, 1986-90v].

2.2.1 Current status of United States television distribution

Television programmes for entertainment and information are available to most United States viewers in their homes by all of the available distribution means. Currently there are approximately 89 million homes with over 160 million television receivers that receive television broadcasts supplied by 1,060 commercial television stations and 342 non-commercial stations. They are about equally distributed between the VHF and UHF bands, 668 VHF and 734 UHF stations.

2.2.2 Approaches to HDTV distribution to the viewer

In the United States, there is agreement [CCIR, 1986-90w] that the introduction of HDTV should not adversely affect the unique character of the television industry. To achieve this goal, terrestrial broadcasting must be given the opportunity to compete with the other methods of television programme distribution. This fundamental objective was affirmed in the 1 September 1988 Tentative Decision and Further Notice of Inquiry of the United States Federal Communications Commission (FCC) which contains the following tentative findings:

- providing for terrestrial broadcast use of ATV (advanced television) techniques would benefit the public;

- tentatively concludes that the benefits of this technology can be realized by the public most quickly if existing broadcasters are permitted to implement ATV;

- any spectrum capacity needed for terrestrial broadcasting of ATV must be obtained from the spectrum now allocated to terrestrial broadcast television (VHF and UHF);

- finds that existing service to viewers utilizing NTSC receivers must be continued irrespective of the actual manner in which ATV services are delivered, at least during a transition period. This can be accomplished either by transmitting ATV signals that can be received directly by NTSC receivers or by simulcasting NTSC and incompatible ATV signals on separate channels;

- systems requiring more than 6 MHz to broadcast a signal not compatible with NTSC receivers will not be authorized [CCIR, 1986-90x];

- finds it in the public interest not to retard the independent introduction of ATV in other services or on non-broadcast media, but (the FCC is) sensitive to the benefits of compatibility between equipment associated with the various video delivery methods.

2.2.3 Spectrum for ATV options

2.2.3.1 Studies in the United States

For terrestrial broadcasting in the United States the investigations are currently concentrating on four options:

A) the use of a single 6 MHz channel compatible with NTSC;

B) the use of a single 6 MHz channel compatible with NTSC and an additional 3 MHz augmentation channel not necessarily contiguous with the 6 MHz channel to carry information to augment the base channel information when generating the HDTV picture in HDTV receivers;

C) the same as option B, except the augmentation channel [CCIR, 1986-90w] is 6 MHz wide;

D) each terrestrial broadcaster would be provided with an additional 6 MHz frequency band for a simulcast non-compatible ATV signal.

The United States has done studies [CCIR, 1986-90y] to determine the availability of spectrum under different conditions.

The analyses were done using a specially developed computer program which permits the examination of channels under different conditions. The studies presumed that advances in the technology for delivering ATV service may allow the minimum distance separations for ATV stations to be less than those currently required. The UHF taboos have been ignored*. Only the separation distances required to reduce adjacent and co-channel interference were observed.

It should be recognized also that the studies are preliminary in nature. For example, no consideration was given to the effects of using alternative sites for broadcasting ATV signals or the use of terrain shielding, or power reduction as a means to implement ATV for 100% of the stations.

The computer analyses were carried out to determine the number of stations which could be assigned for the following situations:

a) where contiguous spectrum (both 6 MHz and 3 MHz) can be assigned;

b) where UHF or VHF stations can be assigned (VHF stations augmented in UHF and vice versa, no preference for contiguous);

c) same as b), but as much contiguous spectrum as possible;

d) as much contiguous spectrum as possible.

---

* The UHF taboos are: intermodulation, cross-modulation and half-IF (n ± 2, 3, and 4 channels), local oscillator (n ± 7 channels), IF beat (n ± 8 channels), sound image (n ± 14 channels), vision image (n ± 15 channels).

The best results were for b). They show that 100% (96%) of all existing stations can be provided with an additional 3 MHz (6 MHz) supplemental (non-contiguous) if the minimum co-channel separation distance for the ATV stations is reduced to 160 km. On the other hand, if the current separations are maintained (249 - 353 km), the percentages would be 77% for 3 MHz and 60% for 6 MHz. For providing the same service area, these results imply the need for a system requiring a significantly smaller protection ratio than NTSC.

[CCIR, 1986-90z] reports the most recent progress towards introduction of Advanced Television (ATV) services in the United States. The new studies ignored adjacent channel protection, as well as the UHF taboos. It was also determined that the best spectrum approach to accommodating ATV systems needing an additional 6 MHz has the following characteristics:

1) the additional spectrum is not necessarily contiguous;

2) HDTV systems for terrestrial broadcasting must be able to operate at closer than present spacings.

The preliminary indications are that 99.7% of all existing television stations can be accommodated at a minimum co-channel spacing of 160 km (100 miles). [CCIR, 1986-90z] also describes a number of approaches under investigation by the United States regarding the modification or elimination of the existing NTSC UHF taboos. These include:

1) changes in receiver design;

2) change in minimum taboo transmitter spacings;

3) changes in the transmission system.

An example of one proposed system accommodating the UHF taboos, the Spectrum Compatible HDTV System, is shown in Table VIII. It indicates the wanted-to-unwanted signal protection ratios for just perceptible interference for the case of an HDTV signal to an NTSC receiver.

TABLE VIII

Wanted-to-unwanted signal protection ratios

Co-channel	+14 to +6 dB
Adjacent channel (n ± 1)	-30 dB
Intermodulation (n ± 2, n ± 3, n - 4)	-40 dB
Half IF (n + 4)	-30 dB
IF beat (n ± 7, n ± 8)	-45 dB
Sound image (n + 14)	-45 dB
Vision image (n + 15)	-45 dB

Note 1 - Wanted signal level: -45 dBm.

Note 2 - Based on measurements of seven television receivers representative of existing receiver population.

This 6 MHz simulcast system [Rypkema, J. 1989] achieves its interference robustness in the NTSC environment by:

1) using transmission scanning parameters that are identical to NTSC, (thus allowing for full co-channel protection advantage from precision carrier offset);

2) transmission of the synchronizing signal, the audio channels, the average DC level and the low-frequency components of the luminance signal by digital techniques during the vertical blanking interval (thus vastly reducing the incidence and visibility of linear and non-linear interference);

3) temporal filtering in the encoder and decoder (thus reducing field-to-field redundancy and interference visibility);

4) non-linear companding of the luminance and chrominance components (thus improving the apparent signal-to-noise ratio of the ATV signal and reducing the visibility of interference into ATV reception); and

5) dispersion filtering of the analogue image components (thus spreading peak signals from edge transitions to reduce interference visibility) [CCIR, 1986-90aa].

2.2.3.2 ATV Spectrum Studies in Canada

Spectrum studies of a preliminary nature have been carried out in Canada considering ATV emission systems of type B (i.e. 6 MHz NTSC compatible + 3 MHz augmentation channel) and, to a lesser extent, systems of type D (i.e. 6 MHz, simulcast ATV systems). All the studies were carried out for locations in Zone 1 defined as the corridor between Quebec City and Windsor and includes the Canada/US border. This Zone corresponds to the most spectrum congested area in Canada. The following summarizes the major assumptions made in the studies and the general results obtained [CCIR, 1986-90v].

Type B ATV System Assumptions

Several planning studies were done for this type of ATV system in order to try to assess the availability of additional spectrum capacity for augmentation channels. The main study was based on the following general assumptions:

- Co-channel protection ratios in terms of Wanted to Unwanted (W/U) field strength ratios between augmentation channels and NTSC channels of 14 dB, for non-precision off-set, and 7 dB, for precision off-set compared to a W/U of 18 dB (for non-precision off-set) used in the present domestic allotment plan.

- A reduced set of UHF taboos[1] for the 3 MHz augmentation channel were used. Assuming that the augmentation channel would not have a separate sound carrier and that a suppressed carrier AM modulation format would be used, only taboo channels 1, 4 and 15 were taken into consideration.

1 The UHF Taboo channels accounted for in the domestic allocation plan are channels ±1, ±2, ±3, ±4, ±7, ±14, and ±15 adjacent to the wanted channel.

Preliminary Results

With all existing assignments and allotments retained and protected in Canada and across the border in the USA, it would not be possible to provide a sufficient number of 3 MHz augmentation channels to satisfy all the Canadian assignments and allotments.

With all unused Canadian allotments in locations of zero growth (i.e. having no assignments to date) assumed deleted nearly all assignments (i.e. existing stations) could be accommodated with 3 MHz augmentation channels. However this comes at a sacrifice of future growth particularly in the larger areas where some or all of the unused allotments need to be used to provide augmentation channels for existing stations. In addition several unprotected Low Power Television stations would have to cease operation in areas where they are extensively used. These sacrifices might prove to be too heavy to be acceptable. Further studies are required in regions of the country where Low Power stations are heavily utilized to evaluate the impact that 3 MHz augmentation ATV systems would have on the existing service.

With the constraint that the 3 MHz augmentation channel must be adjacent to the target NTSC channel (i.e. contiguous), the results indicate that, in the majority of locations, it would not be possible to find a sufficient number of contiguous 3 MHz augmentation channels to accommodate even existing assignments.

Type D ATV System

A preliminary study was done to investigate the spectrum availability for ATV emission systems not compatible with NTSC receivers that occupy 6 MHz channels under the assumption that such systems could operate with co-channel spacings equal to existing (NTSC) first adjacent channel spacings and be non-interfering to NTSC. Furthermore it was assumed that all existing taboo channel constraints could be ignored.

Preliminary results indicate a good likelihood that 6 MHz ATV channels could be found to accommodate existing VHF and UHF assignments and allotments. However further study is required to verify this conclusion.

2.2.4 Proponent systems [CCIR, 1986-90y]

ATV systems proposed for consideration in the different categories are indicated in Table IX:

TABLE IX

VHF/UHF Spectrum Required	Technology	Comments	Number of Proponents
6 MHz	"NTSC-Compatible"	NTSC TV set displays ATV signal as NTSC signal. ATV set would display either ATV programmes or NTSC programmes.	7
9 MHz	Standard NTSC + 3 MHz Augmentation	NTSC TV set displays the standard NTSC portion of the signal. ATV set would display either ATV or NTSC programmes.	4
	"Non-Compatible" *	NTSC TV set requires converter for NTSC display of ATV programme. ATV set would display either ATV or NTSC programmes.	2
12 MHz	Standard NTSC + 6 MHz Augmentation	NTSC TV set displays only the standard NTSC portion of the signal. ATV set would display either ATV or NTSC programmes.	4
	"SIMULCAST" Standard NTSC + 6 MHz "Non-Compatible"	NTSC TV set displays only the NTSC programme. ATV set could receive ATV programmes and NTSC programmes.	3

* Not permitted for terrestrial broadcasting by FCC Tentative Decision.

Several systems have been proposed for terrestrial, cable and satellite broadcasting of HDTV in the United States. Some organizations have proposed more than one system. An article [Hopkins and Davies, 1989] gives information on these proposals and describes the activities of involved committees in North America. Table X is a summary of the systems presented to the FCC in November 1988.

TABLE X - Summary of systems proposed to FCC Advisory Committee

	AVE	BTA	DSRC		DEL	FAR	HRS	NHK			MIT		NYIT	NAP		OCS	PS	QTV	SA	ZEN
			ACTV I	ACTV II				MUSE 6	MUSE 9	NARROW MUSE	RC	CC		HD MAC	HD NTSC					
SPECTRUM CATEGORY	A	A	A	C	A	A	A	A	B	D	A	D	B/C	*	B	C	A	A	*	D
RF BANDWIDTH (MHZ)	6	6	6	12	6	6	6	6	9	12	6	12	9/12	*	9	12	6	6	*	12
H-RESOLUTION (TVL/PH)	660	NTSC	400	600	660	330	NTSC	422	422	568	300	675	750	495	495	?	?	NTSC	534	612
V-RESOLUTION (TVL/PH)	660	NTSC	480	800	650	400	NTSC	690	690	650	600	762	900	480	480	?	?	NTSC	480	720
FULL DIAGONAL RESOLUTION	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	?	?	NO	NO	NO
FULL TEMPORAL RESOLUTION	NO	YES	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	?	YES	YES	NO
WIDE SCREEN	YES	NO	YES	YES	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES
INTEGRATED SIDE PANELS	NO	N/A	NO	NO	YES	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	NO	N/A	YES	N/A	YES	YES
SEPARATE COLOR	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	YES	NO	NO	?	NO	YES	YES
FIELD STORE REQUIRED	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	OPT	OPT	YES	?	NO	YES	YES

N/A - NOT APPLICABLE ? - NOT SPECIFIED

ORGANIZATIONS PROPOSING SYSTEMS

AVE AVELEX
BTA BROADCASTING TECHNOLOGY ASSOCIATION
DSRC DAVID SARNOFF RESEARCH CENTER
DEL DEL REY GROUP
FAR FAROUDJA LABORATORIES
HRS HIGH RESOLUTION SCIENCES
NHK JAPAN BROADCASTING CORPORATION
MIT MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NYIT NEW YORK INSTITUTE OF TECHNOLOGY
NAP NORTH AMERICAN PHILIPS CORPORATION
OCS OSBORNE ASSOCIATES
PS PRODUCTION SERVICES
QTV QUANTICON
SA SCIENTIFIC ATLANTA
ZEN ZENITH ELECTRONICS CORPORATION

SPECTRUM CATEGORY OF PROPOSED SYSTEMS

A = 6 MHz NTSC COMPATIBLE
B = 6 MHz NTSC + 3 MHz AUGMENTATION SIGNAL
C = 6 MHz NTSC + 6 MHz AUGMENTATION SIGNAL
D = SIMULCAST (6 MHz NTSC IN ONE CHANNEL, 6 MHz NON-COMPATIBLE SELF-CONTAINED ATV SIGNAL IN SECOND CHANNEL)
* = SATELLITE DESIGN, REQUIRES ONE TRANSPONDER

November 1988

2.3. Approach using HDMAC system

The HDMAC system has been proposed for satellite as well as for cable and terrestrial distribution.

The possibility of delivering HDTV through terrestrial broadcasting has been studied by using HDMAC signals [CCIR, 1986-90ab]. The characteristics of the MAC signal allow the use of VHF and UHF channels with amplitude modulation offering the possibility of a development of a high-definition television service based on already available technologies. Moreover, if the high-definition television signal possesses characteristics at baseband such that the low frequencies of the spectrum are identical to those of the existing MAC signal, compatibility between the two types of service, D or D2-MAC/packet and high-definition television, will be possible. So far, the D or D2-MAC/packet standards offer an evolutionary path. The evolution is characterized as "compatible", since the first generation of D or D2-MAC/packet receivers will be able to interpret the lower part of the spectrum as that of a signal meeting the existing D or D2-MAC/packet standard. Due to the existence of an installed base of D or D2-MAC/packet decoders (equipped with baseband and BSS inputs) provided for satellite broadcasting at 12 GHz, this compatibility will make it possible, from the outset of the broadcasting of high-definition television programmes, to reach a large audience, thus permitting a gradual growth in receiver sales without compromising the economy of the system.

Based on previous experiments and simulations of an AM vestigial sideband channel in UHF with D2-MAC/packet signals, it is reported that an emission of HDTV (HDMAC) compatible with D or D2-MAC/packet decoders is made possible in a terrestrial AM vestigial sideband channel having a total width of 12 MHz to allow a Nyquist filtering of the baseband around 10.125 MHz either for digital assistance or video.

At the time of the IFA'89 in Berlin (West) an HD-MAC signal was injected into a cable network in a 12 MHz channel using AM/VSB modulation. This private cable network served the exibition premises. The signal was sent as analogue, base band signal to the cable head end by means of an optical fibre link. Furthermore the cable head end also received the transmitted HD-MAC signal from the TDF-1 and TVSAT-2 [CCIR, 1986-90u].

2.3.1 AM/VSB systems

The following parameters are the result of studies and first transmission measurements on cable [CCIR, 1986-90ac].

2.3.1.1 Nyquist filtering of vision carrier at the transmitter

The system for HDMAC signals is compatible with 625-line D2/DMAC system.

Channel width:	12 MHz		
Modulation type:	Vestigial sideband amplitude modulation (AM/VSB)		
Nyquist filtering:	Vision carrier ±500 kHz at transmitter		
Modulation polarity:	Identical to existing D2/DMAC system		
Modulation levels		Negative	Positive
Video signal -	white level	10%	100%
	black level	100%	10%
	clamp level	55%	55%
Data signal	"1"		19%
	"1"		91%
	"0"		55%
Receiver detection:	Synchronous		
Phase characteristic:	Transmitter and receiver linear		

An improvement of up to 5 dB of the S/N and signal-to-interference ratio can be reached when the Nyquist filtering is moved from the receiver to the transmitter site.

The system with a transmitter Nyquist filter was tested successfully for cable distribution.

2.3.1.2 Nyquist filtering of video carrier at the receiver

Same parameters as in § 2.3.1.1 except

Nyquist filtering: Video carrier ±750 kHz at the receiver

2.3.2 FM/VSB systems

Under consideration.

2.4 Other systems under development

[CCIR, 1986-90ad] entitled "HDTV transmission system" describes a single-channel transmission system with an intermediate (down) conversion of a number of lines and with a reflected modulation, which has been proposed and is under study in the USSR.

2.5. Protection ratios

Since it is understood that existing networks should not be affected by the introduction of new HDTV systems, protection ratios must not exceed those currently in use (Recommendation 655). It can be expected that the required protection ratios for most HDTV systems will not be greater because of the envisaged structure of HDTV signals, e.g. absence of normal synchronizing pulses.

Protection ratio figures for HDTV systems affected by HDTV on conventional TV systems are not available today. For conventional TV systems affected by HDTV emission, only limited information is available. More measurements are needed. These measurements shall be made with "modern" receiver types. The term "modern receiver" depends on the life-time of TV receivers from the intróduction date of HDTV in the different countries. Cable transmission systems employing adjacent channel operation require stronger protection ratio figures than those given in Recommendation 655. For this special case we have to define a new type of continuous interference which is 100% of time. Most interference on cable is present 100% of the time.

When in cable systems adjacent channel operation is applied then interference is present for 100% of time. In such systems a signal level difference of approximately 3 dB is allowed between adjacent channels and 6 dB between image channels. The interference should be limited to a certain impairment grade.

3. Multi-media distribution environment

When conventional television was standardized and implemented many decades ago, terrestrial broadcasting was the only medium that could be used to deliver the service to the homes. Consequently, the emission formats were optimized for such a medium and television receivers were dedicated to off-air reception.

Today, many broadcasting/distribution media can be used in parallel with conventional terrestrial broadcasting to deliver television to the home.

Consider the variety of broadcasting/distribution media that will co-exist and will be used to deliver television to the home. They include:

- terrestrial broadcasting;
- satellite broadcasting;
- cable distribution ("CATV");
- multipoint, multi-channel distribution (MMDS);
- optical fibre distribution (analogue and digital);
- pre-recorded distribution (VCR + cassette tapes, video discs).

Most of the broadcasting/distribution media may eventually be used to distribute HDTV to the home.

This diversity of media will undoubtedly continue and increase. For one thing, the present systems of terrestrial television broadcasting will need to be maintained for a significant time. Moreover, existing and future higher definition television systems will also need to co-exist for a period. This diversity will result in the existence of many interfaces between the media, as shown in Figure 13.

Such diversity could result in difficulties of converting from a studio/production HDTV standard, and in converting from one delivery format to another. The inevitable consequence would be higher system and receiver cost and complexity, or a degradation of picture quality, or a combination of both.

But the development of these new standards for HDTV broadcasting/distribution needs to take into account not only this multi-media environment, but the characteristics and capabilities of each of the several media in choosing formats, that are not only easily convertible between media but which make most efficient use of each delivery medium and lead to receiver implementation of minimum complexity.

Since different delivery media have different spectrum capacity and different transmission channel impairments, different types of modulation will be used and the optimum use of the transmission channel will imply that the signal quality and service capacity (e.g. number of audio channels) delivered on some media will be greater than on others. This should lead to the establishment of a hierarchy of related formats optimized for the different media they will be carried on.

This hierarchy would ensure that easy conversion can be made between these different transmission standards and that a common baseband signal representation can be generated and thus common baseband processing can be used in the receiver. An example of the use of a common baseband format is HD-MAC developed by the European Eureka 95 programme. The same baseband signal can be used for satellite broadcasting, terrestrial broadcasting, cable and fibre optic systems as well as home recorders and communication systems. As indicated in Fig. 13 (interface F.1), the common baseband representation would allow for common use of complex circuitry such as picture processor, sound processor and control circuits irrespective of the medium on which the signal is received.

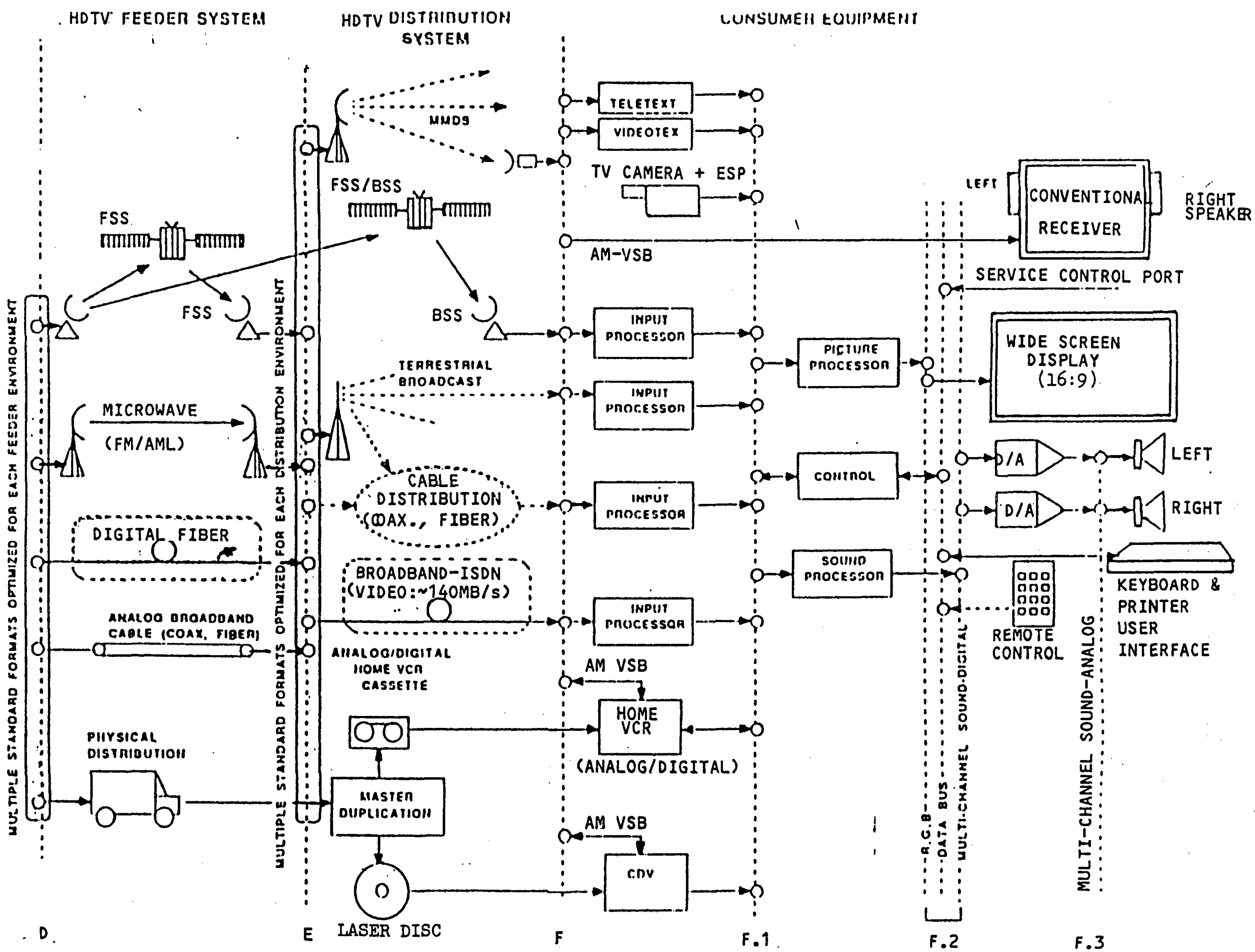

FIGURE 1 - High-definition television system architecture

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PART 8 - DATA BROADCASTING SERVICES IN THE HDTV ENVIRONMENT

In its studies on data broadcasting in HDTV, JIWP 10-11/5 recognized that improvements in the video picture should be harmonized with balanced improvements in the sound and data components [CCIR, 1986-90a]. These improvements should allow the evolution of present teletext services towards the use of more sophisticated presentation features (dynamically redefinable character sets (DRCS), geometric, photographic), new display formats (e.g. 80 characters/row, wide aspect ratio) accompanying sound, data for processing and new applications.

[CCIR, 1986-90b] points out the need to consider the capacity requirements of the programme sound and data broadcasting services at the same time as the HDTV emission format is developed and to adopt a digital multiplex structure allowing flexible reallocation of the capacity for either sound or data services [Chouinard, 1987]. The document also indicates the need to consider conditional access requirements for vision, sound and data.

The need to allocate adequate transmission capacity for data services and to adopt a flexible digital multiplex, as well as to provide for conditional access is also indicated in § 1.2.3 and 1.2.4 of Part 7 of this Report.

The consideration of a flexible digital multiplex carrying different data services would require the study of the features of an intelligent receiver which would allow interconnection to a personal computer, as indicated in [CCIR, 1986-90a,b], in order to achieve the best exploitation of the service resources.

[CCIR, 1986-90c] suggests an approach for the insertion of data broadcasting services in the HDMAC system whose basic characteristics are given in [CCIR, 1986-90d]. The opinion expressed in the above document is that the use of the field blanking interval of HDMAC signals for DATV data allows only two lines per field for data broadcasting services. This reduced capacity should be assigned to multilingual subtitling, while teletext should be conveyed through the digital sound/data packet multiplex, in both D and D2 versions. In order to ensure full service continuity in the evolution from D/D2-MAC/packet system [CCIR, 1988] to HDMAC, teletext services should be provided in the digital sound/data/multiplex from the beginning of MAC/packet transmission. Teletext decoders should therefore be developed with the capability of receiving data from both the field blanking interval and the digital packet multiplex.

A further document, [CCIR, 1986-90e] draws attention to some requirements for broadcasting of data in the context of HDMAC, namely, the need to ensure the largest flexibility in the management of the overall capacity (e.g. by sharing the capacity); the coexistence of various data services in every subframe (even at different bit rates, e.g. 10.125 Mbit/s and 20.25 Mbit/s); a proper operation of HDTV receivers by giving the highest priority to DATV data.

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[1986-90]: **a.** 11/353 (JIWP 10-11/5); **b.** 11/349 (Canada); **c.** JIWP 10-11/5-42 (Italy); **d.** 11/288 (Belgium *et al.*); **e.** JIWP 10-11/5-64 (France).

PART 9 - TRANSMISSION OF HDTV FOR INTERNATIONAL PROGRAMME EXCHANGE*

1. Introduction

This chapter deals with the transmission of HDTV. One part deals with the satellite transmission of HDTV and the other deals with the terrestrial transmission of HDTV. The future work in this area will need to be coordinated with the CMTT.

2. Satellite transmission of HDTV

Long distance HDTV transmissions, such as those made possible by satellites, are essential for the international exchange and distribution of programmes. There has already been demonstrations of such capability and it continues to be under study.

2.1 FM transmission

At the 1987 International Colloquium on HDTV held in Ottawa, Canada, the papers and workshops were supported by an extensive series of demonstrations, including broadcasts from live and tape material using the MUSE-E technique by satellite, CATV, cable, optical fibre and optical disc. The demonstrations also included inter-studio transmission of HDTV using the newly developed MUSE-T technique with a 54 MHz transponder on the Canadian Anik-C satellite. Following the Colloquium, the MUSE-E equipment and a 27 MHz ANIK-C satellite transponder were used for a period of two weeks for national and international HDTV broadcasts to the public for demonstrations and survey. Three sites in Canada and four sites in the United States were included, resulting in upwards of 100,000 people being introduced to HDTV [CCIR, 1986-90a].

HD-MAC was demonstrated during the IBC in 1988.

Signals from HDTV VTRs and from cameras were bandwidth reduced and transmitted via a satellite channel or millimetre wave link as HD-MAC. The signals were decoded and displayed as HDTV pictures.

In addition, the HD-MAC signals were displayed on D2-MAC receivers showing the compatible picture. HD-MAC VCR and compact disc video were both demonstrated during the presentation.

Implementation of HD-MAC in cable systems is being investigated.

Long distance HDTV transmission circuits are essential to an operational broadcasting system for the exchange and distribution of programmes.

During the IFA'89 in Berlin (West) a complete HD-MAC chain cascading several transmission ports including satellites was operating (see Fig. 1). More detailed information is to be found in Part 7, section 1.5.2 [CCIR, 1986-90b].

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* International exchange on video tape is considered in Recommendation 714 and Report 1231 .

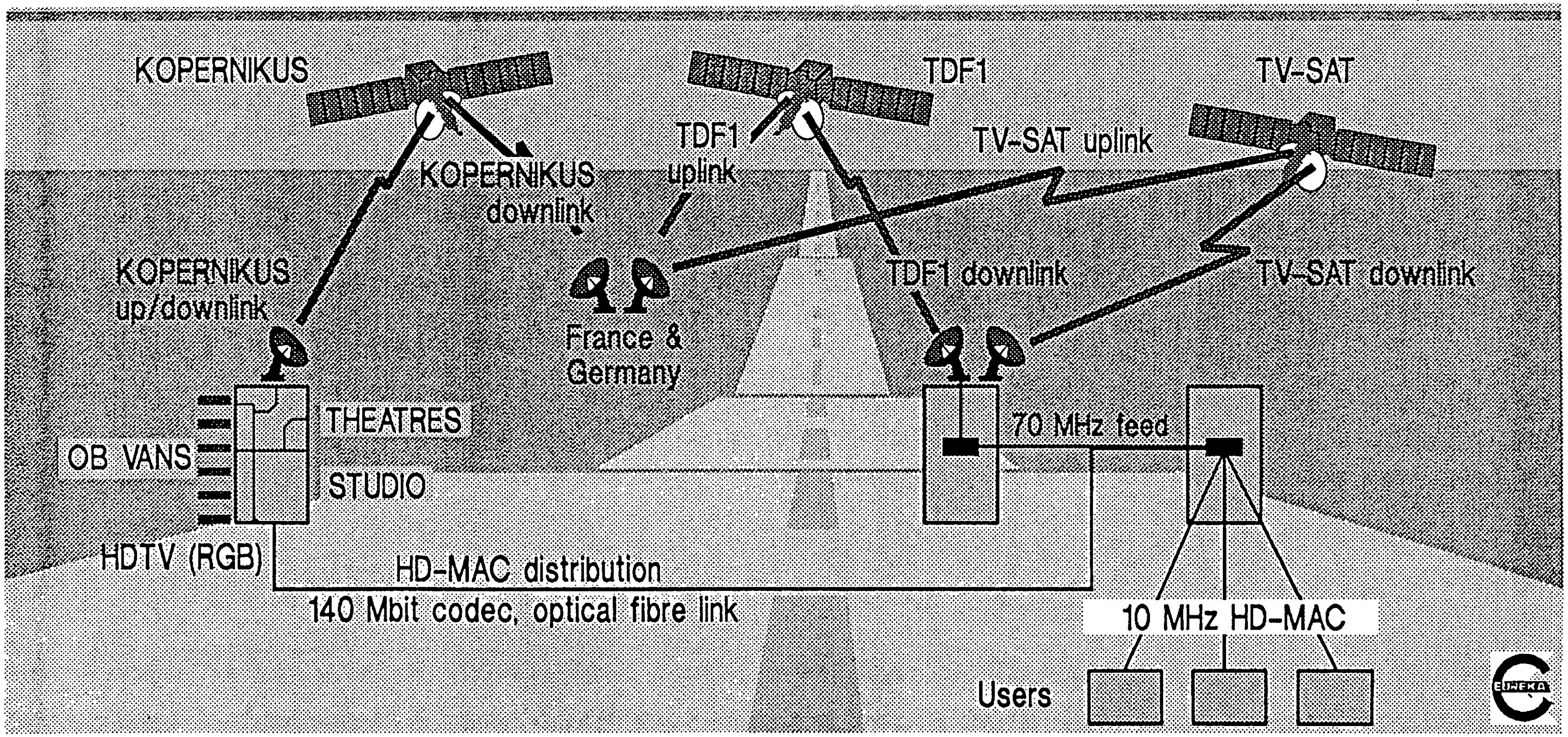

FIGURE 1

Illustration of the complete HD-MAC transmission and emission chain as implemented during the IFA'89 in Berlin (West)

Along with emission experiments on broadcasting satellites, transmission experiments on communication satellites and other media have also been carried out in Japan since 1987. Based on the results obtained through these experiments, international transmission from Japan to Australia using three satellite links, and from Korea to Japan using two satellite links was carried out in 1988. Although the RF-bandwidth of the satellite repeaters were different, frequency modulated MUSE signals with 27 MHz bandwidth were transmitted from end-to-end with interfaces at IF between the different segments of this multi-media, multi-hop transmission to eliminate degradation caused by the modulation and demodulation process.

Special precautions concerning waveform distortion were taken to correct both IF and baseband characteristics. Accumulated IF amplitude and group delay distortion were equalized at the receiving end, and the baseband equalization was performed with an equalizer in the MUSE encoder. The tap coefficients calculated from the test pulse signal in the vertical blanking interval measured at the receiving end were sent back through the telephone circuit. In addition to this equalization, a final equalization was performed by an automatic equalizer in the decoder.

In July 1988, a multi-hop experimental transmission was carried out between Japan and Australia using first the CS-2b (6/4 GHz) in Japan, then INTELSAT-V (F-1, 6/4 GHz), to Australia, followed by a final satellite hop over AUSSAT K2 (14/12 GHz), and finally by two terrestrial radio links in the 42 GHz band (see Fig. 2). The measured C/N for the overall modulation/demodulation section was 17.6 dB which was almost identical to the calculated value of 17.3 dB. The overall IF frequency characteristics measured after equalization were 0.5 dB p-p amplitude variation and 10 ns p-p group delay. No degradation was measured on the DCPM encoded audio signal in the vertical blanking interval because the overall C/N was high (17.6 dB). Satisfactory waveform transmission characteristics were obtained due to the IF and baseband equalization.

Major programmes of the Seoul Olympic Games held in September 1988 were transmitted in the form of HDTV from Korea (Rep. of) to Japan. HDTV programmes were encoded to MUSE and frequency modulated at the International Broadcasting Center, then transmitted using coaxial cable to the earth station, using INTELSAT-V (F-1, 14/11 GHz) to the NHK Broadcasting Center, Yoyogi, Tokyo, Japan, or the KDD Yamaguchi earth station for site diversity. Received IF signals were fed to the feeder-link transmitter for the BS-2 to distribute 81 receiving points within Japan (see Fig. 3). Other HDTV signals from a VTR in the Broadcasting Center were encoded to MUSE, modulated and fed to the NTT earth station and transmitted through CS-3 (30/20 GHz) to seven NTT earth stations and thence by transportable microwave link (11 GHz) to HDTV demonstration sites.

The measured overall C/N after two-tandem transmissions between Korea and Japan measured at the satellite broadcasting receiver with 75 cm diameter antenna was 17.9 dB compared with the calculated value of 18.3 dB. The overall IF frequency characteristics after equalization were 0.5 dB p-p amplitude variation and 5 ns p-p group delay. Satisfactory waveform transmission characteristics were also obtained after equalization.

These experiments confirmed the applicability of long distance and mixed-media transmission of HDTV signals to domestic and international connections.

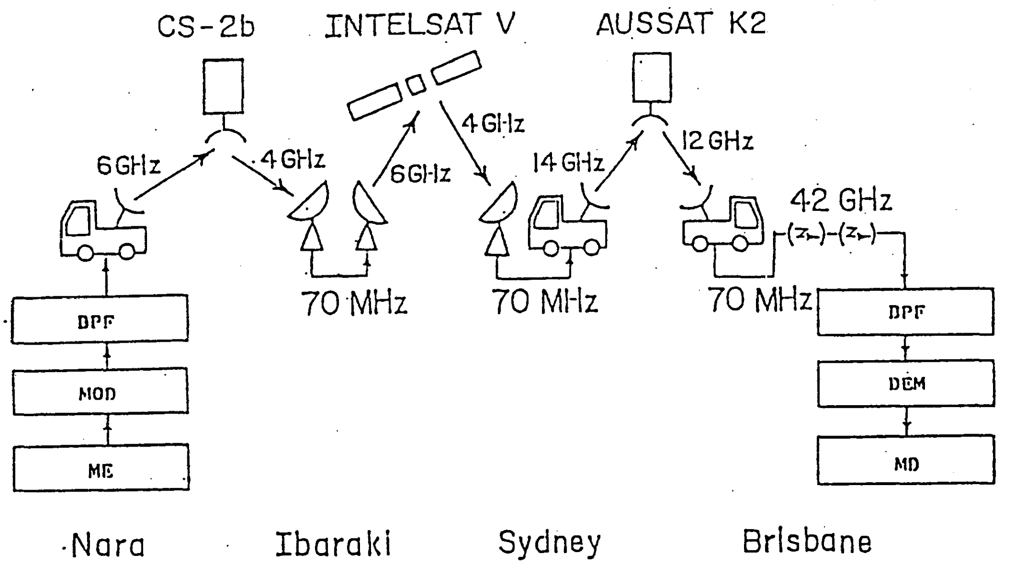

FIGURE 2 – System configuration for the transmission from Japan to Australia

ME : MUSE encoder
MOD : FM modulator
BPF : 27 MHz band-pass filter
DEM : FM demodulator
MD : MUSE decoder

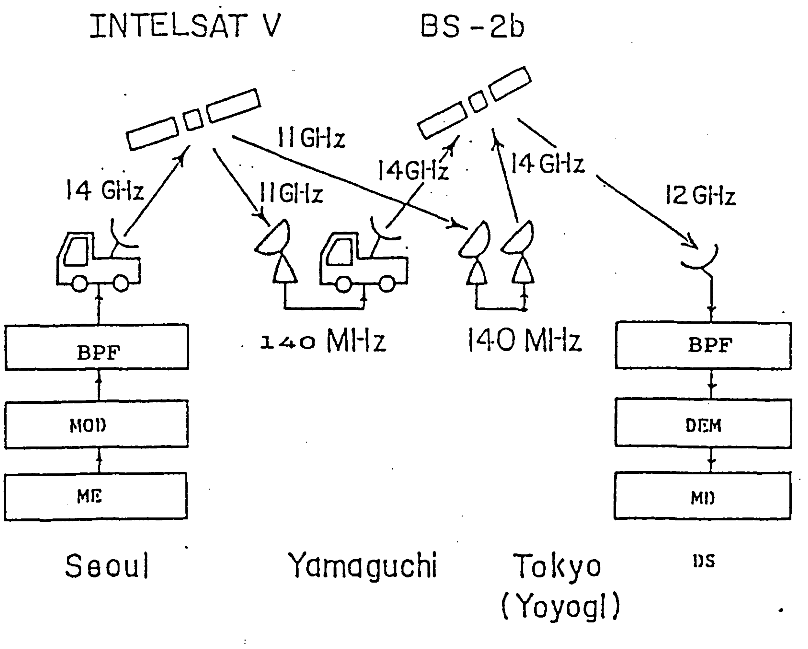

FIGURE 3 – System configuration for the transmission from Korea to Japan

ME : MUSE encoder
MOD : FM modulator
BPF : 27 MHz band-pass filter
DEM : FM demodulator
MD : MUSE decoder
DS : 81 demonstration sites

2.2 Digital transmission

IWP 11/7 reports in [CCIR, 1986-90c] studies which suggest that bit rate reduction techniques (DPCM, DCT) currently used for conventional television may well be suitable for HDTV, and a 140 Mbit/s system has been developed based on a 1125/60/2:1 source. A 140 Mbit/s codec for HDMAC signals has also been developed. The different requirements of contribution and distribution networks are discussed.

Furthermore, it is outlined in [CCIR, 1986-90d] that the investigations performed in the IWP 11/7 made evident the existence of various bit rate reduction techniques which will enable digital HDTV transmission to be effected at about 140 Mbit/s. Practical work currently in progress on codecs for the 4:2:2 level of Recommendation 601 should yield further relevant information. Final decisions as to standard methods can be expected to depend on the digital parameters chosen for the studio and for the international exchange of HDTV programmes.

A new sub-section 3.1 "Bit rate reduction methods for HDTV signals" in Report 1089 has been proposed based on contributions received by the IWP 11/7 [CCIR, 1986-90e].

The HDMAC bandwidth reduction coding principles are described in [CCIR, 1986-90f]. By these HDMAC is optimized to allow for introduction of HDTV services on WARC 77-BS channels. DATV and multibranch coding is used. The selection of the system was based on the result of subjective assessments.

[CCIR, 1986-90g] describes different systems of digital MUSE transmission with either PCM or DPCM coding and bit rates of 135 Mbit/s and 100 Mbit/s, respectively.

The digital transmission of the MUSE signal on distribution links is advantageous where MUSE is the destination system, in contrast to the contribution links which may be otherwise optimized.

A bit-rate reduction codec for HDTV was developed. This can transmit 1125 line/60 Hz HDTV signals at 97.728 Mbit/s, which is the 4th level bit-rate in the Japanese digital hierarchy. This codec is also applicable to the H4 channel rate (about 135 Mbit/s) coding for broadband ISDN. This CODEC employs adaptive prefiltering for noise reduction, extrapolative/interpolative coding with adaptive intrafield/interframe prediction and variable word length coding [Yashima and Sawada, 1987; Sawada and Yashima, 1988; Yashima and Sawada, 1989; CCIR, 1986-90h].

97.728 Mbit/s HDTV transmission was demonstrated using a prototype of this bit-rate reduction codec and actual optical fibre transmission lines. The HDTV baseband signals used are component signals of Y, P_R and P_B with bandwidths of 20 MHz, 7 MHz and 7 MHz, respectively [Yashima and Sawada, 1989; CCIR, 1986-90h].

[CCIR, 1986-90i] outlines 120/140 Mbit/s HDTV coding systems, implemented in hardware for practical applications. This system is designed for the purpose of transmitting HDTV signals through the 72 MHz bandwidth transponders of the INTELSAT satellite or the HD hierarchy of an optical fibre cable. The main bit rate reduction techniques employed are:

- removal of blanking intervals and line-alternate processing for two-colour components;

- a 1/2 sub-Nyquist sampling with a line offset structure; and

- intra-field DPCM with an adaptive noise shaping filter and an adaptive quantizer.

Although the MUSE system has been developed for the purpose of an analogue transmission, most of the signal processings in the system are carried out in digital form, and fit easily to the digital transmission. In the MUSE system, a technique of sub-sampling in the time domain is already used, but the compression of amplitude information is not yet performed, and may be applicable for further processings in the digital transmission.

2.3 Transmission interface considerations

In many cases links of several different media will be used in the chain from programme originator to the final viewer. For example, a national television network may receive a programme over coaxial or optical fibre networks, or by systems in the fixed service and fixed-satellite service, and then distribute it to their affiliated TV stations by the same or even different cable, fixed service or fixed-satellite system, which then broadcast the programming terrestrially.

Even broadcasting-satellite systems may receive their programming material from the multiplicity of sources mentioned above, and in the case of the community reception mode, distribute it beyond the BSS earth station in a variety of ways.

Such connections give rise to interface situations, that is, to places where formats may have to be connected. To permit conversion, the characteristics of the formats must be known. To make those conversions easily, and with minimal degradation in picture quality, the formats should be developed as part of a unified set of formats.

A specific example can be cited of interfaces that will arise involving satellite emission. In 1990 it is planned to inaugurate HDTV using the GS-3 satellite of Japan.

During these operations it may be necessary to provide a studio-transmitter link involving transmission links from a local station originating a programme to the BS-3 earth station. Such links might use MUSE, the HDTV format for the BS-3 emissions, but they might also use different formats.

Two PCM and one DPCM formats have been considered for MUSE transmission.

One PCM method encodes video, sound and control signals in the MUSE format. With 8 bits/sample for luminance and colour difference signals, it requires a net bit rate of about 117 Mbit/s. A second PCM format, simpler but less efficient, is also based on 8 bits/sample and requires a new bit rate around 130 Mbit/s. A DPCM format based on 6 bits/sample/sample would require only around 88 Mbit/s.

All these formats could be accommodated in the ISDN H4 level (132 Mbit/s minimum) with varying amounts left over for error correction.

A bit rate reduction codec for HDMAC signals which fits the H4 transmission level near 140 Mbit/sec has been developed [CCIR, 1986-90j].

In summary, the continuation and expansion of a domestic, regional and international system of television programme delivery through diverse media calls for defining interfaces between the media. It also dictates the need for a hierarchical set of transmission and emission formats that can take best advantage of the different characteristics of each media and can also be converted from one format to the other with minimal degradation and at reasonable cost.

2.4 Satellite news gathering

The technique of satellite news gathering (SNG) is a means for the international exchange of programme material, and an increasing amount of television transmissions are provided by these capabilities, particularly of such international events as the Olympic Games. The CCIR is carrying out studies in this area in JIWP CMTT-4-10-11/1.

The work of this JIWP has been focused on preparation of a Report and Recommendation. The Report has been prepared, taking into account the characteristics of television systems in operation today. These systems use the capabilities of existing 4/6 and 11/12/14 GHz band communication satellites which are in the geostationary orbit, and have very well known characteristics. They have been used as the basis for preparing a Report containing the technical and operational requirements of SNG which generally encompass the use of rapidly deployable, portable uplinks for events lasting from a few hours to several days.

SNG has been using fixed-satellite spectrum allocations. In examining the material in the draft report of JIWP 10-11/3 to the Extraordinary Meeting as it might apply to SNG, the following subjects appear to require some re-evaluation and subsequent modification if and when SNG is to use HDTV. Some areas which may require study are:

2.4.1 Link budget

HDTV requires more energy density. Link budget considerations range from larger up-link e.i.r.p., larger C/N, and thus more power/larger antenna gain from the satellites and earth stations.

2.4.2 Spectrum

Depending on what type of transmission format is chosen for HDTV, and the quality, it may be necessary to increase the amount of bandwidth required for a SNG/HDTV transmission, compared to that required today.

2.4.3 Orbit spacing

The impact of increased power density, it may not be possible to transmit HDTV signals on satellites which are closely spaced in the geostationary orbit.

2.4.4 Off-axis e.i.r.p. density

It may not be possible to retain the emission limits suggested for today's SNG up-link transmissions.

2.5 Conclusions

One or more closely related transmission/emission formats, optimized for use in diverse programme delivery media, may also be derived from the studio standard.

Definition of that studio standard should precede the definition of any subsidiary standards if signal degradation and the costs of conversion are to be minimized.

The continuation and expansion of a domestic, regional and international system of television programme delivery through diverse media calls for defining interfaces between the media. It also dictates the need for a hierarchical set of transmission and emission formats that can take best advantage of the different characteristics of each medium and can also be converted from one format to the other with minimal degradation and at reasonable cost.

Easy convertibility between any such formats should also be required to reduce the cost and complexity of home receivers intended to receive programmes from the different delivery media.

3. Terrestrial transmission of HDTV

3.1 Introduction

There is great progress being made in the terrestrial transmission of HDTV. This is illustrated through the experiments and development of various signal formats which have been reported.

3.2 Experimental signal formats for HDTV transmission

In a frequency division multiplexed composite signal, called HLO-PAL (Half-Line Offset PAL), the colour-difference sub-carrier signal corresponding to the narrow-band colour-difference signal (C_n) is located adjacent to the luminance signal (Y); while another signal corresponding to the wide-band colour-difference (C_u) is located around the same sub-carrier, and its lower sideband is partly interleaved with the luminance signal with a half-line offset. This signal has been used widely for distribution and transmission tests of the HDTV signals [CCIR, 1982-86a].

In a time division multiplexed signal, called TCM (time compression multiplexing) signal, the colour-difference signals are compressed, and the luminance signal and one of the colour-difference signals are multiplexed. Thus, colour-difference signals are transmitted line-sequentially. The proposed TCM signal bandwidth for a 1125-line system is 20 MHz [Tsuboi et al. 1985].

In another time division multiplexing signal, called TCI (Time Compressed Integration) signal, there are several versions depending on the simultaneous or sequential arrangement of colour-difference signals and on the difference compression ratios [Fujio and Kubota, 1982].

A scan conversion system for HDTV with motion-adaptive techniques, called FCFE (Frame Conversion Fineness Enhance), has also been developed. It converts 2:1 interlaced scanning to progressive scanning at the receiver. This is considered to be useful for the reduction of bandwidth required for HDTV transmission [CCIR, 1982-86a, b and c].

A bandwidth reduction system, called MUSE (Multiple Sub-sampling Encoding) system, has been developed to transmit HDTV signals via satellite using a single channel in the 12 GHz band. The baseband signal bandwidth is 8.1 Mhz. It uses 4:1 dot-interlaced sub-sampling which employs inter-field and inter-frame offsets. More general description can be found in Report 1075.

It is reported that non-linear pre- and de-emphasis has been used very effectively in FM transmission of HDTV signals [Fujio and Kubota, 1982].

Digital transmission has been discussed [Phillips and Harvey, 1978; CCIR, 1978-82], and it could become competitive with analogue FM transmission in the future, with regard to the required bandwidth and transmitter power.

3.3 Bit rate reduction methods for HDTV

3.3.1 Introduction

In accordance with Decision 60, IWP 11/7 is studying aspects of the digital transmission of high definition television signals, for which bit rate reduction is an essential process. This work is able to build upon the results of the studies into methods for the 4:2:2 level of Recommendation 601 reported in Report 1089 ——— and on the related work in hand at present on standard algorithms and codec specifications for 34, 45 and 140 Mbit/s transmission.

Studies are being aimed at both contribution and distribution networks, and take account of Decision 18-6. A distinction between these applications is not always easy to make. Broadly speaking, contribution applications are those for inter-studio traffic requiring signals of such fidelity that they can withstand studio post-processing and passage through more than one digital coding/decoding operation. In distribution between broadcasters, component video signals from a source centre are coded for transmission. In distribution to viewers, coding is applied to signals which have already been coded into analogue or digital formats, and it forms the final method of delivery to the home. Often the choice of distribution to viewers will be influenced by the economics of a low-cost decoder in the home.

At this time, some of the transmission techniques used for distribution of programmes to broadcasters are still under study with respect to adequacy of quality.

3.3.2 Distribution between broadcasters

[CCIR, 1986-90i] describes the outline of a 120/140 Mbit/s HDTV coding system, which has already been implemented by a compact hardware for practical appreciations. More information may be found in the satellite transmission section "Digital Transmission" (§ 2.2 of Part 9).

[CCIR, 1986-90k] describes some preliminary results obtained using the DCT algorithm. It is concerned with HDTV signals with parameter values as proposed in [CCIR, 1986-90l] employing progressive scanning and resulting in a bit rate of 2304 Mbit/s. It refers to the intensive work carried out during the present Study Period aimed at the specification of a contribution 34/45 Mbit/s codec for conventional digital signals conforming to Recommendation 601. It states that the promising results obtained have lead several organizations to apply such bit rate reduction techniques to HDTV signals, the target being HDTV contribution codecs at 140 Mbit/s. It points out that simple extrapolation of these results may not be appropriate since (a) a higher compression ratio is required, (b) progressive scanning yields a richer information content and (c), because of the high data rate, specific algorithm restraints must be taken into account in order to make the algorithms implementable in compact hardware.

The extra studies required to adapt the conventional codecs to HDTV are being presently addressed by some European cooperative projects. Simulations are being performed based on the DCT coding algorithm proposed by a DCT Expert Group. Whilst some further work has to be carried out, it states that extension of the algorithm has yielded promising results for both interlaced and progressive scan HDTV formats. Its conclusion is that 140 Mbit/s can be considered a possible channel for the transmission of HDTV in both formats, enabling all the benefits of progressive scanning to be retained in transmission.

[CCIR, 1986-90m] gives a summary on NI-DPCM sound decoding systems, which could find application in studio facilities too. A 48 kHz, 16-to-11 bit NI-DPCM and a 32 kHz, 15-to-8 NI-DPCM are reported to be capable of reproducing about the same quality as 48 kHz, 16 bits linear PCM and 32 kHz, 14-to-10 NI-PCM used in Japanese satellite broadcasting, respectively.

3.3.3 Distribution to viewers

A bit rate reduction codec for HD-MAC signals has been developed within the European Eureka-95 project and is described in [CCIR, 1986-90j]. The technique employs a hybrid of 8-bit PCM and 5-bit DPCM with a reflected quantizer, to reduce the bit rate of an HD-MAC multiplex to the H4 transmission level of about 140 Mbit/s. The method has a simple implementation, is rugged in the presence of transmission errors and can convey HD-MAC signals while still in their scrambled form. Such a codec was demonstrated at IBC 88 in Brighton, UK, where digitised HD-MAC was transmitted over 2 kms of optical fibre.

[CCIR, 1986-90n] contains an overview of digital transmission of the MUSE signal (see Report 1075, Annex II, for details of the MUSE signal). The digital transmission system described is considered to be an advantageous one especially when the destination requires a MUSE-encoded signal only. The document states that the digital transmission of the MUSE signal is possible with a bit rate of around 135 Mbit/s by the MUSE-DPCM scheme. Further refinement and implementation are under way.

A MUSE DPCM system has been developed, some tests were conducted and demonstrations performed with actual hardware inplementation.

Based on the results of the tests, it can be concluded that a DPCM at a rate of 6 bits/sample is applicable for the transmission of 1125/60 MUSE signals without visible degradation. This requires a bitrate of 100 Mbit/second, and may be suitable for a broadband transmission channel to be equipped with a Japanese broadcasting satellite, BS-3.

Further reduction of the bit rate is necessary in order to use it in conjunction with transponders having a bandwidth of 36 MHz. For this purpose, a 60 Mbit/s transmission without visible degradation is a goal to be achieved [CCIR, 1986-90o].

In [CCIR, 1986-90p] different subjective effects of the bit errors depending on three different coding schemes for HDTV still picture transmission are reported. For linear PCM component signals, for a sub-sampled PCM signal and for a sub-sampled DPCM signal, relative values of bit error rates, at which the subjective impairments are judged to be equal, were found to be 1, 1/6 and 1/10 respectively, in terms of the just perceptible limit of the impairment.

3.4 Short-distance transmissions

3.4.1 Fibre-optic transmission

At the International Broadcast Fair, 1987, Berlin, a transmission of 1125/60/2:1 HDTV signals over a 1.152 Gbit/s fibre-optic link was demonstrated. The total video signal bit rate was 864 Mbit/s (sampling frequency for the luminance signal 54 MHz, for the colour difference signals 27 MHz each). The remaining channel capacity was partly used for stereo sound and error protection [CCIR, 1986-90a].

[CCIR, 1986-90q] describes a digital HDTV signal transmission system on monomode optical fibre. This transmission system offers the possibility of conveying, in a serial form, a digital data stream at 144 Mbit/s rate issued from either a 1250/50/2 HDTV colour source (HDI standard) or from a diagonally prefiltered HDTV 1250/50/1:1 colour source HDQ standard). The serial line data rate is 1.296 Gbit/s. The document claims that in the near future an extension of the system towards a transmission system which can convey two digital data streams at a 144 Mbit/s rate will be performed. This extension would permit carrying the HDTV picture delivered by a 1250/50/1:1 HDTV source (HDP). It would lead to a 2.592 Gbit/s serial data rate.

An optical fibre transmission is used to transmit HDTV component signals from Seoul Main Stadium to International Broadcasting Centre. The actual distance of the cable was 34 km. The baseband signal used to this section was a component video signal of the luminance signal (Y) and the colour-difference signals (Pb and Pr).

Frequency modulated component video signals and PCM audio signals of HDTV were frequency-division multiplexed and then modulated a laser diode. An optical repeater was placed in the middle of the path. The unweighted signal-to-noise ratios obtained with the video signals were better than 55 dB.

MUSE signals were transmitted through an optical fibre from the Broadcasting Centre to some demonstration sites in downtown Tokyo during 1988 Seoul Olympic Games. In the system, a SWFM-IM (square wave frequency modulation - intensity modulation) was employed.

3.4.2 CATV distribution

CATV networks are also an important distribution medium of HDTV programmes to the general public. For this purpose, several methods have been proposed, and some experimental results have been reported.

The choice of an HDTV transmission system for the CATV network depends on various criteria such as the required RF signal bandwidth, the necessary guard band to avoid adjacent channel interference, the required C/N before demodulation, and the complexity of the subscriber's receiver, etc. Taking these criteria into account, an FM transmission system and an AM-VSB system were examined and experiments were carried out using both.

In addition terrestrial broadcasting, satellite, and Cable TV Networks all have important roles to play and are interconnected with one another. Document 11/279 (Rev 1), the Report of IWP 11/6, states that terrestrial emission standards should consider:

a) the need for compatibility with existing terrestrial infrastructures,

b) the costs associated with achieving compatibility between terrestrial higher definition television broadcast standards and the standards for other delivery media [CCIR, 1986-90r].

Large scale HDTV distribution experiments were carried out by the CATV Hi-Vision Promoting Association of Japan from 28 October to 3 November 1988. The HDTV signal was encoded to MUSE, frequency modulated on a 400 MHz carrier and combined with the conventional CATV signals being fed into the network. The modulated MUSE signal was also sent to another head/end through a two-hop microwave link in the 23 GHz band and the received signal was further relayed through an optical fibre link about 21 km long to another trunk route of the CATV network. HDTV signals were monitored at eight major check points, all of which observed excellent quality signals. The unweighted S/N was over 50 dB at the farthest point in the CATV facilities after a two-hop microwave link, one optical fibre link and nine trunk amplifiers.

The required RF-bandwidth of an AM-VSB system is 12 MHz and no guard bands are necessary. However, a higher C/N value is needed, which increases the load on the trunk amplifiers. In the case of distributing the MUSE signal received from the broadcasting satellite, a mode converter which includes recovery from the non-linear emphasis may be necessary. This system was also demonstrated at the Annual Convention of the NCTA (National Cable Television Association) in the United States, using existing CATV facilities. This demonstration confirmed that there was no mutual interference between a MUSE signal and conventional TV signals.

The above results indicate that, in practice, either method can be used depending on the situation encountered.

As described in Part 7, the United States is examining terrestrial over-the-air systems requiring 6 MHz, 6 plus 3 MHz, and 6 plus 6 MHz of channel bandwidth. No decision has yet been made on which approach to follow. This is due largely to the need to carry out required tests on proponent systems and to formulate the necessary spectrum management framework. The United States Cable Television Laboratories, Inc., plans to carry out tests of proposed ATV systems over cable facilities to determine the suitability of each for Cable TV Network use.

Parameters to be tested which represent the key technical and operating constraints for cable TV networks are:

a) Discrete Frequency Interference
b) Minimum Carrier-to-Noise Ratio (C/N)
c) Micro-reflections
d) High-Level Sweep
e) Cross-Modulation Distortion
f) Intermodulation Distortion
g) Hum and Low-Frequency Noise
h) Peak-Power Distortion
i) Incidental Carrier Phase Modulation
j) Gain Control Compatibility

[CCIR, 1986-90r].

[CCIR, 1986-90f] describes HDMAC bandwidth reduction coding principles for the emission of HDTV pictures derived from the proposed 1250/50/1 standard and is a status report on the studies in the Eureka-95 project. It states that HDMAC is optimized to allow the introduction of HDTV services on WARC 77-BS channels while preserving compatibility with the MAC/packet system. The methods of bandwidth reduction employed are discussed including the DATV (digitally-assisted television) concept and multi-branch coding. Some design trade-offs are highlighted, and reference is made to the subjective assessments which have led to the system being adopted by the Eureka project. It proposes that Report AZ/11 should be modified to take account of the document.

In [CCIR, 1986-90s], it is reported that AM/VSB and FM/VSB have been proposed for HDMAC cable distribution. AM/VSB is applied to the time multiplex baseband signal. The use of a channel spacing of 12 MHz has been demonstrated and is recommended as a common standard. The VSB Nyquist filtering is in the range of ≈ 500 kHz around the carrier and for compatible reception shall be the same as for MAC/packet distribution. The HD-Nyquist roll-off factor and the sharing between transmitter and receiver is under study. FM/VSB has also been demonstrated. It requires the use of a channel spacing of 16 MHz. Modulation parameters are under study.

Although demonstrations have been presented, results of the tests listed below must be known for all bandwidth combinations of ATV systems, including HDTV, before making any recommendations. Before transmission standards for cable TV networks can be established, the results of the tests listed above will be needed. The same should apply when considering any transmission system for use on cable TV networks [CCIR, 1986-90r].

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PART 10 - CONSUMER EQUIPMENT FOR HDTV

1. Introduction

This Part of the Report deals with domestic equipment for HDTV.

[CCIR, 1986-90a] stresses, in § 6.1, the need for considering the characteristics of all the potential delivery media for HDTV to the viewer's home in parallel in order to minimize receiver complexity through maximum circuit commonality such as picture processor, sound processor and control circuits leading to a minimum cost of the equipment.

2. Consumer-use display

A large screen high-resolution display is necessary for an HDTV reception system. This is also a key factor for determining the speed at which HDTV becomes popular. Direct-view displays using large-size cathode-ray tubes (CRTs) have been developed with an aspect ratio of about 16:9. For example, recently developed 51 to 104 cm CRT displays have sufficient brightness (90 to 230 cd/m^2) and resolution for home use.

Projection displays using CRTs have also been developed with diagonals of over 100 cm. For rear projection displays, almost sufficient brightness and resolution have been obtained with 127-178 cm diagonals at a brightness of about 400 cd/m^2.

To solve the problem of large-area flicker for 50 Hz field systems, especially for large screens, field rate up-conversion was investigated and several up-converters and displays were demonstrated in September 1988 (IBC 88, Brighton, United Kingdom).

Both direct view and projection displays for the converted signal on the display standard of 1250/100/2:1 with 62.5 kHz line frequency and a video bandwidth of about 60 MHz were built and demonstrated.

Another front projector designed to give a large screen made use of an automatic deflection circuit, ranging from 16 kHz to 62 kHz line rate and from 50 Hz to 100 Hz field rate, and enabled the display of both 1250/50/2:1 and 1250/100/2:1 scanning.

The simplest method of achieving field rate up-conversion is to repeat the fields producing two consecutive odd fields followed by two consecutive even fields. However, to remove problems such as interline twitter, reduction of resolution and judder, sophisticated techniques such as interpolation, picture reception and usage of DATV control signals may have to be applied.

3. Consumer-use receivers

3.1 General

Receiving equipment is an important sub-system in the HDTV broadcasting system, since it comprises the major part of the system's expense, and it determines system acceptability.

Receiving equipment of the HDTV broadcasting system, as well as the conventional system, basically consists of front-end units including an antenna, down converter, IF and demodulation stage, and a display. The front-end units are generally similar to those of conventional television receivers and are dependent on each broadcasting media. In the case of the narrow RF-band satellite broadcasting using the MUSE system, existing front-end units can be used commonly, or with some modification. This is verified through a number of receivers and field tests.

In Japan, HDTV experimental satellite broadcasting with the MUSE system has been in operation every day at a scheduled time for one hour by BS-2b since 3 June 1989. For the reception of this experimental HDTV satellite broadcasting, the same receiving antenna and the outdoor unit as those used for existing satellite broadcasting with digital subcarrier/NTSC system are being used.

The indoor unit is configured so as to be able to receive both digital subcarrier/NTSC and MUSE systems.

When receiving the MUSE signal, the FM detected MUSE signal is supplied to the MUSE decoder, where the dispersal signal is removed and de-emphasis is performed. The keyed AFC clamp pulse is supplied from the MUSE decoder to the indoor unit. For this purpose connecting terminals for detected signal output and for clamp pulse input are provided with the indoor unit.

The efficiency of the receiving antenna and the noise figure of outdoor unit which are available in current consumer market, are 68% on average and 1.8 dB on average, respectively [CCIR, 1986-90b].

Three manufacturers announced on 20 September 1989 developments of prototypes of MUSE receiver for consumer-use. They utilize a series of custom VLSIs. These VLSIs themselves are reported in section 3.2 of Part 10.

The announced receivers are of 32-inch CRT type and 50-inch rear-projection type. They are so designed as to receive those signals of the conventional VHF/UHF television, of Clear Vision (an enhanced quality television in Japan), and of Hi-Vision (HDTV in Japan) with a single equipment.

Most of them are capable of reproducing the 3-1 Surround Sound (described in Report 1072) accompanied by the HDTV picture. Connections with VCRs and VDPs have also been taken into their design in some cases.

Such achievement can be taken as an initial phase of the development, and further efforts will be made toward the second phase in which such consumer-use receivers will be made available in a large quantity [CCIR, 1986-90c].

Special consideration is given to other receiving equipment, and is described in the following sections.

3.2 HDTV decoders

3.2.1 General considerations

Most HDTV systems use digital processing, employing frame stores in order to achieve large-scale bandwidth compression. The required number of logic gates would be several tens of thousands and the necessary capacity of the store would be of the order of 10 Mbit.

Since the reduction of receiver cost depends on how efficiently large-scale integrated circuitry (LSI) can be introduced to signal processing, development of LSI for the MUSE decoder and related technologies is rapidly progressing. Recent trends towards larger capacity of the stores, from 1 Mbit to more than 4 Mbit, and towards digitization of conventional television receivers are expected to expedite the development of LSI circuitry for HDTV receivers.

3.2.2 MUSE decoder

As for the MUSE decoder, internal clock frequencies range from 16.2 MHz to 48.6 MHz, and the amount of memory capacity is about 20 Mbit for use in such functions as interpolation and motion detection. Experimental decoders using discrete parts, including medium-scale ICs, are produced by many different manufacturers. They have been constructed in a reasonably small size and are light-weight (e.g. volume $0.084m^3$, weight 50 kg) to serve as portable models.

Recently, a total of 26 kinds of custom VLSIs have been developed for the MUSE decoder. Employing these VLSIs, the decoder can be built with 46 pieces of custom VLSIs. The size and the power consumption of the decoder became approximately 1/30th that of the prototype made with conventional ICs. Such a development of the VLSIs made a significant step forward to realize low cost MUSE receivers for home-use [CCIR, 1986-90d].

HDTV receiving equipment also plays an important role in the development of other consumer equipment. For example, the MUSE receiver has a built-in memory with a capacity of about 20 Mbit. Attempts are being made to connect it to personal computers and other image processing equipment.

Successful interfacing with other devices will make the MUSE receiver multi-functional, enabling it to serve as a total information terminal in the home.

3.2.3 HDMAC decoder

The HDMAC decoder digitizes the input signal with a clock-frequency of 20.25 MHz, since the Nyquist frequency point is situated at 10.125 MHz. The output sampling frequency is 54 MHz for luminance in the 1250/50/2 display standard.

The HDMAC receiver includes an HDMAC bandwidth reduction decoder (BRD) with an optional upconverter to a field rate of 100 Hz. The BRD gives as output an Y, U, V signal on the 1250/50/2 standard with an aspect ratio of 16:9. The upconverter will output an 1250/100/2 signal.

The BRD contains five field memories for luminance and chrominance, each with 288 lines and each active line with 698 luminance and 349 chrominance samples of 8 bit, totalling some 12 Mbit. Furthermore line memories and non-linear interpolators are integrated.

Several events are planned to be broadcast "live" throughout Europe, using the HD-MAC/packet system. Therefore the European manufacturers for consumer electronics in the Federal Republic of Germany, Finland, France, Netherlands, Sweden and the United Kingdom have started to develop HD-MAC receivers with a high degree of circuit integration.

The development of the HD-MAC receivers is based on the experimental decoders that were made for and demonstrated at the Internationale Funk-Ausstellung 1989 (IFA) in Berlin (West) [CCIR, 1986-90e].

Most of the receivers will have a projection type of display, which is regarded as the best method today for displays with a diagonal size of over 1 meter.

All receivers will be able to display conventional PAL/SECAM signals as well as MAC signals in both 4:3 and 16:9 aspect ratio.

The DATV concept allows all the intelligent decision circuitry to be placed in the encoder. Consequently, the decoder complexity is much less and benefits from future improvement in the coding process [CCIR, 1986-90f and g].

4. Consumer-use converters

MUSE to 525-line standards converter

Considering compatibility with the existing receiver and displays, a MUSE to 525-line standards converter, intended for use with consumer receivers was developed and demonstrated. This is of small size (made up of four 20 cm by 30 cm circuit boards).

The resultant 525-line picture from this converter has, on average, higher quality than the normal picture originated with NTSC standard, although it has some flicker at the edge, with less interference than that caused by the NTSC cross-colour. It has a simple circuit construction and it will be made available at a lower price by using LSI technology. The development of this MUSE to 525-line standards converter gave some prospect to HDTV broadcasting in the 1125-line system which can be received utilizing conventional 525-line receivers.

After these studies [CCIR, 1986-90h], several VLSIs have been successfully developed. A simple version of such a converter has been realized on a single VLSI-chip for low-cost applications. Another version employs five separate VLSIs. This version enables the choice of the aspect-ratio conversion by discarding side panels or by the letter box format with blanks at the top and bottom of NTSC picture [CCIR, 1986-90i].

5. Consumer-use recorders

5.1 Video cassette recorders

[CCIR, 1986-90j and k] report the development in the Netherlands of a video cassette recorder using an improved VHS transport for recording and replaying an HD-MAC signal [Weissensteiner, 1988]. This recording was demonstrated at the International Broadcasting Convention in September 1988. It achieves a signal bandwidth of 10.125 MHz (-6 dB) and an unweighted video signal-to-noise ratio of 42 dB by using four heads, two frequency-modulated recording channels and digital video and audio processing, with a residual timing error of < 15 ns. It was able to record 80 min of HD-MAC (or MAC) signal on one 1/2-inch metal particle tape and included drop-out compensation.

The HD-MAC recorder is also capable of recording and replaying the 625 lines, 50 Hz television signals (D2MAC, PAL, SECAM). With some adaptations other types of television signals can also be recorded, like 1050 lines, 59.94 Hz. More information about this recorder is given in Report 1233.

A MUSE VCR for consumer use has already been developed [Ninomiya et al., 1987].

5.2 Disc systems

Disc systems that record and play back a MUSE signal have also been developed and can accommodate 60 min of HDTV programming on both sides of a 30 cm CLV (constant linear velocity) disc. The disc player can be used in combination with MUSE decoders in receivers and is expected to find a variety of applications in many fields as a long time playing medium of HDTV. Discs with customer's video materials can also be made.

[CCIR, 1986-1990j and l] report the development of an HD-MAC video disk player which was demonstrated at the International Broadcasting Convention in September 1988. This HD-MAC video disk player was developed in the Netherlands, based on existing optical laser and disk techniques [Horstman, 1988]. Its bandwidth is about 12 MHz with an unweighted signal-to-noise ratio of 32 dB and a residual timing error of -6 ns. The playing time is 20 min per side for a 30 cm (12 inch) diameter disk.

This HD-MAC video disk player is capable of reproducing next to the complete D2-HD-MAC signal, with the full data/sound possibilities of the D2-MAC a Compact Disk (CD) signal. This CD signal is recorded in the lower band of the FM spectrum. More information about this video disk player is given in Report 1233.

5.3 Still-picture disc player

A digital MUSE video disc for still pictures, called CD-HV, has been developed. A 12 cm disc in conformity with the CD-ROM standard is used. Thus, about 640 still pictures with digital stereo sounds can be accommodated in a single disc. It can be played back either in sequential playback mode with 60 min of playing time for one disc, or random access mode with an average access time of 4.5 s [CCIR, 1986-90m].

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REPORT 1217

FUTURE DEVELOPMENT OF HDTV

(Question 27/11)

(1990)

1. Introduction

The Extraordinary Meeting of Study Group 11, May 1989, identified studies that need to be undertaken as expeditiously as possible in order to further build on the agreements already achieved. This report outlines:

- approaches to a single world-wide HDTV studio standard;
- preliminary studies;
- further activities to be undertaken.

2. Approaches to a single world-wide HDTV studio standard

2.1 Concepts for approaches to a single world-wide digital HDTV studio standard

The long-term future of HDTV lies in the digital domain, and equally the long-term future of HDTV standards should lie with unique world-wide standards. In order to achieve this, a number of alternative routes were identified at the 1987 CCIR Interim Meeting. They were essentially defined in digital terms, with any required analogue definitions derived from the digital ones. The routes proposed were as follows:

a) The concept of a "virtual studio standard"

In this concept, there is a unique format for a digital data bus which is used to transport and record HDTV signals. The source and destination could communicate using the unified standard by means of gateways, which perform the appropriate standards conversion.

A "virtual studio standard" [Miceli, 1986; Fierro and Miceli, 1987], may be considered as a common standard for the purpose of exchanging programmes. Consequently, its characteristics should be chosen in order to allow the minimum of artifacts resulting from possible double conversions.

Some general characteristics of the virtual studio standard would include:

a) it should be digital, because of the greater flexibility and the most powerful processing capability allowed;

b) it should be independent of the physical studio equipment and therefore from the current technology;

c) it should allow enough headroom for production, the standards conversion process and for accommodating future needs;

d) it should lead to manageable bit rates.

The overall system performance between source and destination at any time, will be dependent on the characteristics of the actual equipment in the video chain at that time. Therefore, the system performance can be further improved, without affecting the coding structure, by simply improving the local characteristics of the weakest devices along the video path.

Examples of this concept are found in discussions of the common image format and common data rate approaches below.

b) <u>The concept of a totally unique parameter set from the outset</u> (adoption of an existing proposal in digital form)

In this scenario there would be, from the outset, a direct and universal adoption of a single studio standard. This could arguably be based on 50 Hz, 60 Hz, or even some other value. Factors which could affect the choice include motion portrayal, existing practices and display technology.

Examples of possible values can be found in Part 5 of Report 801.

c) <u>The concept of a two-step approach</u>

This scenario relies on the widespread introduction of switchable (50 Hz-based/60 Hz-based) HDTV studio equipment. This would not dispense with the need for standards conversion in HDTV programme exchange between countries using different standards, but it would lead to the possibility of the universal use of one or other systems in the course of time.

d) <u>The concept of a convergent approach</u>

This scenario relies on the adoption of common spatial characteristics of the active picture area for applications using current picture rates initially with ultimate convergence on a single picture rate in the course of time.

2.2 <u>Possible approaches to the development of a single world-wide HDTV standard</u>

This section examines some approaches to a unified world-wide HDTV standard from the viewpoint of digital technology and outlines approaches that could be considered as routes towards a single world-wide standard.

[CCIR, 1986-90a] from IWP 11/7 also discussed related studies for digital formats. Three approaches to achieve ultimately a "unique world-wide standard" for studio production and international programme exchange on the basis of the single picture rate are:

- the adoption of a single "unique" standard meeting the goals of Decision 58;

- the adoption of standards based on the "common image format" approach leading to the future adoption of a single standard;

- the adoption of standards based on the "common data rate" approach leading to the future adoption of a single standard.

Contributions have been received from a number of administrations further developing these concepts and the following explanations have been proposed to characterize and to distinguish between the "common image format" and "common data rate" concepts:

Common Image Format
The common image format (CIF) concept implies a commonality of spatial characteristics for the active picture area between implementations or applications with differing picture rates. These common characteristics include the picture aspect ratio, the number of samples per active line and the number of active lines, as exemplified in current proposals for HDTV. Other system characteristics may also be common whilst sampling frequency and data-rate may vary according to the picture rate.

Common Data-Rate
The common data-rate (CDR) concept implies a commonality of sampling frequency and data-rate (total and active) between implementations with differing picture rates. The picture aspect ratio and the number of samples per active line are also common, as exemplified in current proposals for HDTV. Other system characteristics may also be common whilst the number of active lines may vary according to the picture rate.
Proposals have also been made combining the features of a common image format approach with a common total data-rate.

Also the following definitions [CCIR, 1986-90b] are intended only for use in clarifying CCIR texts concerning HDTV.

A Sample, is the value of an image at a defined point in horizontal, vertical and temporal space.

A square sample distribution results when the sampling points are equispaced on an orthogonal horizontal-vertical lattice on a time-discrete image plane, assumed to be vertical for the purpose of this definition.

Pixel is the abbreviation of "picture element". It is the smallest area of the optical image that can be faithfully reproduced.

A square pixel has equal size in the horizontal and vertical directions.

With respect to the resolution actually achievable, the relation between samples and pixels is not necessarily identical in either or both the horizontal and vertical directions

2.2.1 A unique standard

All administrations have stated their preference for a single world-wide studio standard for HDTV. In [CCIR, 1986-90c] are summarized the essential reasons for the need for a world-wide unique studio standard for high definition television.

In [CCIR, 1986-90d] EBU states that it remains convinced of the value of a totally unique standard, but is studying other approaches against the possibility that it cannot be achieved.

Based on analysis [CCIR, 1986-90e] and the information contained in Part 5 of Report 801-3 the United States concluded that a single world standard should be based on 1125/60 [CCIR, 1986-90f]. The United States now believes [CCIR, 1986-90g] that it is apparent that unanimous agreement on a complete set of parameter values for a single world-wide HDTV studio standard is not possible during the 1986-1990 study period. Therefore, the United States proposed that the adoption of a single world-wide HDTV studio standard be extended to the 1990-1994 study period.

In Document [CCIR, 1986-90h] the United States reaffirms its support for the adoption of a single world-wide HDTV standard for the studio and for international programme exchange as a very important CCIR goal.

A proposed draft Recommendation supported by 11 administrations for parameter values for a single world-wide programme standard (1250/50/1:1) is given in [CCIR, 1986-90i].

Document [CCIR, 1986-90j] states that these European Administrations report that the administrations of the European Community fully supports the goal of a unique studio standard and considers that the 1250/50/1:1 system best meets this target. However, following agreement within the CCIR to study a two-step approach based on either a common image format or a common data rate, studies have been carried out into the relative merits of the two approaches and the results are analysed in the document.

Documents [CCIR, 1986-90k and l] argue that an HDTV standard that meets the needs expressed in CCIR documentation can most efficiently be implemented in the long-term with an image format of 1920 samples per line by 1080 active lines and a common frame rate.

2.2.2 A common image format approach

This approach, described by some administrations as a "unified" approach to a single standard is based on the fact that the development of a single standard is presently constrained by the desire for compatibility with the frame rates of existing television systems but that such constraint will likely be removed, in time, by developments in technology leading to the setting of a standard based on a higher frame rate for better motion rendition and easier conversion to all current frame rates. Initial studies [CCIR, 1986-90m] have indicated that frame rates higher than the ones presently in use will be needed in HDTV production if unimpaired motion portrayal is required. The common image format approach leads, in the interim, to a partial standard including only parameters for which single values are adopted on a world-wide basis. Adoption of common values for the basic parameters should lead to convergence towards a single world standard and avoid re-opening discussion on already agreed parameters during the later steps of the process. The partial standard will allow different system implementations meeting the common agreed parameters and harmonized with the current television systems. The larger the number of parameters adopted at the beginning, the better it is to maximize homogeneity between the different system implementations, and the easier it will be to convert programmes produced through interim system implementations to the ultimate single standard.

In order to secure the convergence process toward a single standard, a number of basic parameters need to be identified for which single values have to be agreed upon early in the process. The multi-step "unified" approach is based on the concept of "common image format" to define the first step by allowing early agreement on image parameters leaving the frame rate, the scanning method and the related parameters for later discussions and agreement.

The concept of the Common Image Format is based on a broad view of image reproduction techniques including aspects from the fields of television, film, computer display and publishing. It consists of using common values for the parameters defining the active picture area in different HDTV system implementations. An image is a bounded, two-dimensional representation of a three-dimensional space which is defined by its spatial characteristics and its luminance and colour transfer functions. The image format is the specification of a virtual image defining the active picture area of the television frame. Figure 1 gives a pictorial representation of the concept of a common image format along with a possible set of parameter values.

The concept of a common image format applied in the context of the "unified" approach to a single HDTV standard implies a world-wide agreement on the following basic parameters of the active image area:

- aspect ratio of the image;
- aspect ratio of the picture element (pixel);
- number of samples in the horizontal direction;
- number of samples in the vertical direction (i.e. number of lines);
- sample arrangement;
- colorimetry - reference primaries, reference white;
- opto-electronic transfer characteristic at the camera; and
- electro-optic transfer characteristic at the display.

These correspond to the parameters in sections 1, 2 and 4 of the table in Recommendation 709. The definition of the common image format is exclusively confined to the samples and spatial domains of the active picture area and relates to its digital representation. The way this image is scanned for transmission, its repetition rate to reproduce motion, and its rendering on a physical display include temporal and subjective aspects that are beyond the definition of the image format. The concept leaves complete freedom as to the choice of scanning method, the frame rate and the size of the blanking intervals needed for synchronization and other purposes in the implementation of different HDTV distribution systems formats (see Fig.2) [CCIR, 1986-901].

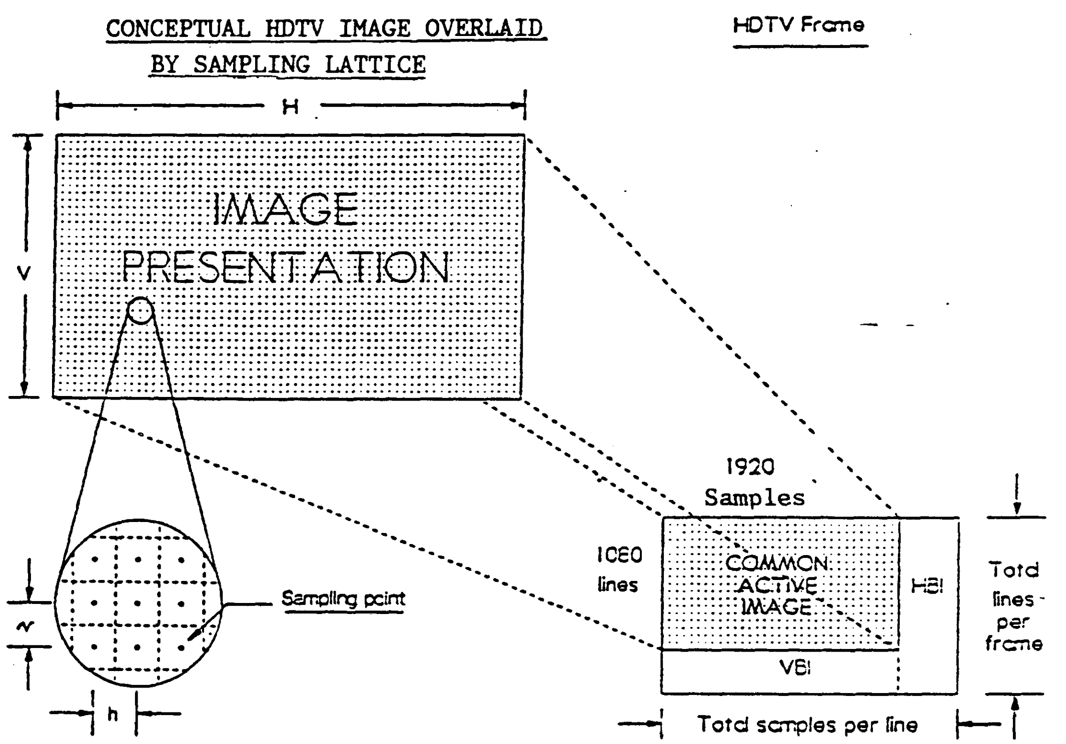


Image aspect ratio : H/V = 16/9

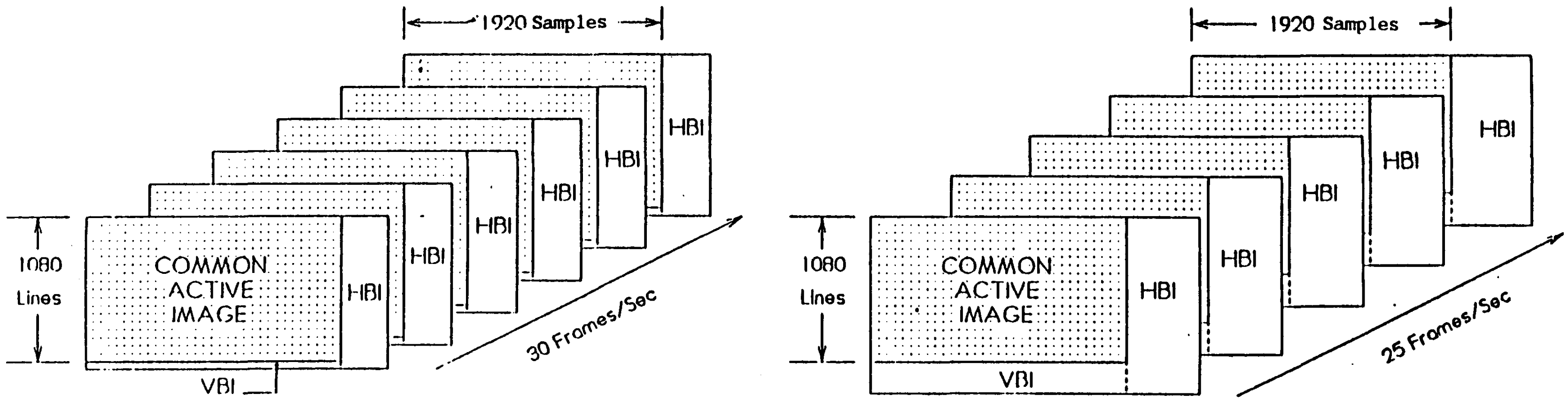
Pixel aspect ratio : h/v = 1/1

HBI = Horizontal blanking interval

VBI = Vertical blanking interval

FIGURE 1

Common image format using a possible set of parameters



HBI: Horizontal blanking interval
VBI: Vertical blanking interval

FIGURE 2

<u>Implementations of common image format at 30 and 25 frames per second using a possible set of parameters</u>

[CCIR, 1986-90n] suggests that an image frame with 2 250 000 samples will simplify the task of ensuring compatibility with Recommendation 601 and proposes a common image format based on 1080 active scanning lines per frame. This number of scanning lines is derived from a pixel aspect ratio of 1:1. No three parameters can be chosen without automatically defining the fourth as illustrated below. Active horizontal pixels, aspect ratio, active vertical pixels and pixel aspect ratio are interrelated by the formula:

$$\frac{\text{active horizontal pixels}}{\text{active vertical pixels}} = \frac{\text{aspect ratio}^*}{\text{pixel aspect ratio}^*}$$

[CCIR, 1986-90o] points to advantages for electronic image processing and for a wide variety of non-broadcast applications.

[CCIR, 1986-90p] claims that a common image approach to the HDTV standard is at once economical, logical and technically sound, being based on the natural unit of TV and film production, the time-discrete image sample, the "frame". It is believed that the common image approach is the only one, short of immediate adoption of a "unique" standard, that will lead to the eventual adoption of the desired single world-wide standard.

The common image format can be seen as an electronic equivalent of a 35 mm film image and so it allows flexibility in the choice of picture rate. The actual rate will depend on the application, but all picture rates employed in current image display systems could be accommodated [CCIR, 1986-90o].

[CCIR, 1986-90q] outlines two examples of common image format systems. The first uses 1152 active lines and 1200 total lines, and both interlaced and sequential scanning are considered. The second uses 1080 active lines and 1125 total lines, both with interlaced scanning. The EBU is currently investigating common image formats which also have a common data rate.

In [CCIR, 1986-90g] the United States expressed its belief that the concept of a "common image format" should be explored as an interim step in the development of a future single world-wide HDTV studio standard. The United States has continued its studies [CCIR, 1986-90h] of the concept of common image format and common data rate and has concluded that the common image format, as an interim step, is the approach which is most likely to lead to the future single world-wide HDTV standard for the studio and for international programme exchange. The United States supports the common image format approach and could support the concept of common data rate if the principle of common image format is fully incorporated within it.

The ABU points out [CCIR, 1986-90r] that "all possible efforts should be made for the development of all parameter values which remain undefined in Recommendation 709 in the conclusions of the Extraordinary Meeting of Study Group 11. Should such objective not be achievable within the current study period, the ABU will support in this period the adoption of a common image format with 1920 x 1080 for the studio standard as a unified CCIR Recommendation, provided that there is a common agreement within the CCIR".

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* Picture and pixel aspect ratio are defined by width ÷ height.

[CCIR, 1986-90s] points out that while the common image format concept implies that the horizontal and vertical active portions of the image are the same for all members of the family, the blanking periods, total line period, and total number of lines can be varied between members of the family to provide compatibility with existing picture rates, provide for vertical anti-aliasing, and ease selection of a sampling rate that is an integer multiple of 2.25 MHz.

It is shown in [CCIR, 1986-90t] that it is possible to have both a common image structure and overall common data rate by enclosing the proposed common active image structure within the appropriate full frame structures of current proposals through the use of different but quite realistic values for horizontal and vertical blanking.

2.2.3 A common data rate approach

In the first step of this approach, it is assumed that HDTV standards based on 50 Hz and 59.94 Hz field rates related to current emission standards would be adopted, but having a maximum of commonality in other parameters such as line frequency and sampling frequency, based on the principles of Recommendation 601, leading to a common data rate.

Central to any approach which commences with more than one picture rate is the need for high quality conversion as a gateway between the different HDTV standards during the first phase. Document [CCIR, 1986-90u] reports confidence in the likely availability of high quality converters demonstrating the viability of a common data rate approach as the first step towards a single HDTV standard.

In addition, Document [CCIR, 1986-90v] suggests that the advantages to manufacturers of having a single product which can be sold world-wide are significant, as are the advantages to the broadcaster who may at times wish to use his equipment on the alternative standard. The manufacturers' advantages of commonality can be easily eroded if significant changes need to occur within such equipments when switching between standards. Commonality advantages to the broadcaster can also diminish if changing standard means also changing an equipment's operating environment, perhaps because of different interfacing requirements. In this regard it is instructive to examine the commonalities which were considered important in the choice of parameters for Recommendation 601. Of great consequence however for HDTV sampling specification is also the ease of conversion to and from the parameters of Recommendation 601 itself. A simple relationship in terms of picture rate and line number between HDTV and current scanning standards is fundamental to the concept of practical compatible emission. This issue is being addressed in both 625- and 525-line countries.

Similarly there is a real practical need for the inclusion of picture material originated at 525/59.94 and 625/50 into HDTV productions and vice versa; Document [CCIR, 1986-90w] concludes that a similar simple relationship between each HDTV system and its respective present definition television system, as provided by CDR, should make these conversions more straightforward.

As a first step, the common data rate approach therefore chooses to retain, between two 16:9 ratio HDTV standards, the same features in common as the Recommendation 601 pair and a simple conversion to and from the respective member of the Recommendation 601 pair.

Figure 3 shows the concept of the HDTV future delivery environment in step 1. All items of studio equipment are switchable between 59.94 and 50 Hz field rates. The 59.94 and 50 Hz studios exchange programme material through a high quality HDTV-HDTV standards converter. For HDTV distribution in the local environment no field-rate or line-rate conversion is required. The converters required for 525- or 625-line distribution or enhanced 525- or 625-line broadcasting are relatively simple line-rate converters. Similarly the arrangements for 525- or 625-line contributions to the HDTV production centre are simple and of high quality.

Advances in digital technology should enable the second step to be taken where one of the two standards is adopted as the single production standard. For the other standard the consequence will be more complex standards conversion for distribution and enhance emission or for contributions from normal definition television standards. The timing of the second step will be determined by technology and by economic factors.

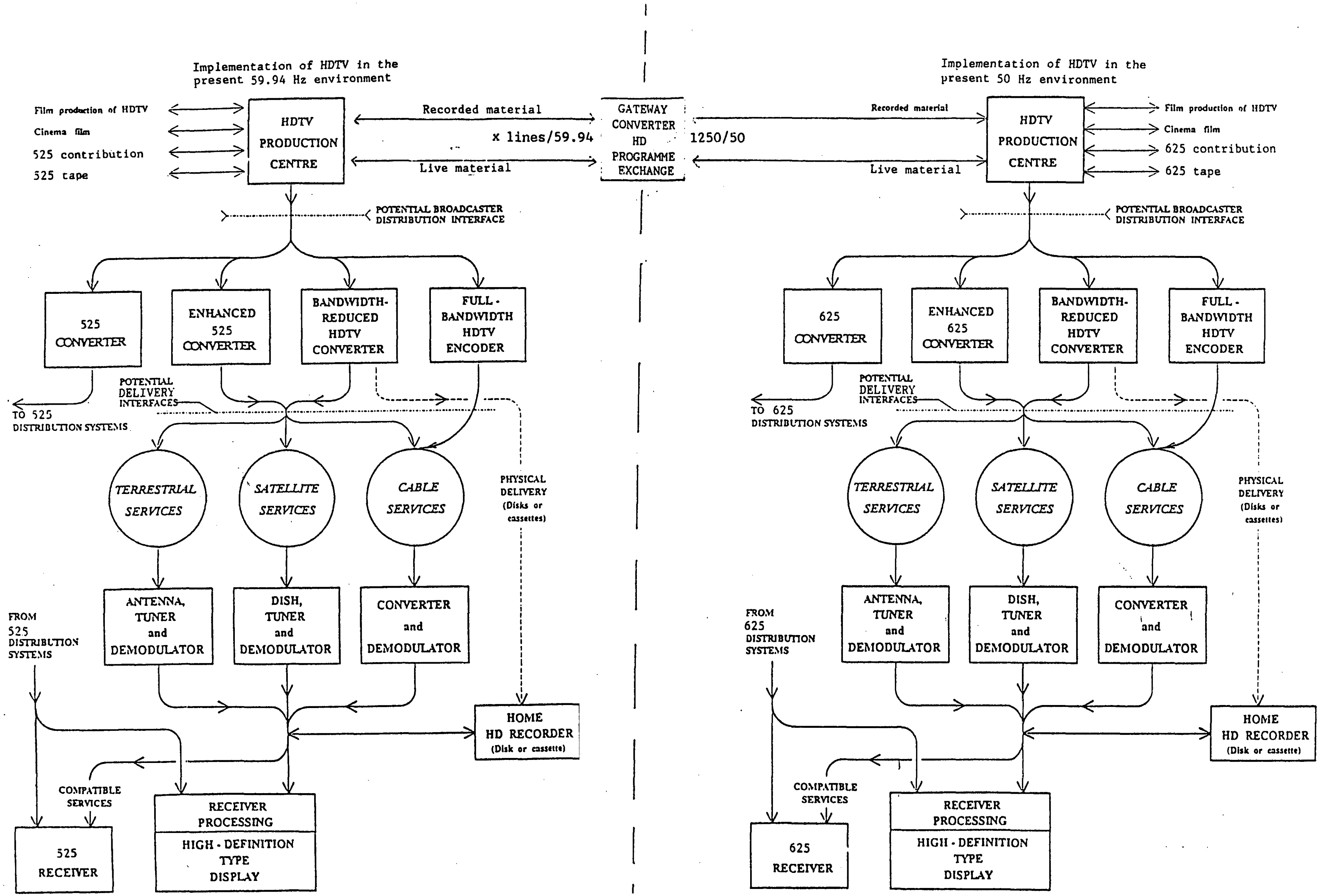

FIGURE 3

An example of the first step of the common data rate approach

In [CCIR, 1986-90x] the criteria and advantages of an appropriately chosen dual-mode HDTV studio standard are examined taking into account the importance of commonality and the significance of a natural relationship with Recommendation 601. It is shown that then a particular set of parameters arise in a natural way that preserves the same common features, those of sampling rate and active horizontal sampling sites, while exhibiting ease of conversion to the 4:2:2 signal by applying a relation factor of 2 in both horizontal and vertical dimensions: this pair of HDTV standards is 1250/50/1:1 - 1050/59.94/1:1. It is proposed to use the high definition progressive quincunx signal representation for this pair. Progressive scan and quincunx sampling allow, while limiting the data rate, to preserve all benefits of progressive scanning. This is particularly important from the point of view of vertical resolution and motion portrayal, and leads to significant improvement of the standards conversion performance. Moreover, this interface format is identical to that resulting from interlaced scanning; this last could be used in the short-term introductory phase of HDTV on the basis of existing equipment.

[CCIR, 1986-90v] provides a discussion of approaches for a dual-mode HDTV studio standard based upon Recommendation 601. It argues that the main considerations in Recommendation 601 are those of a) common sampling structure, b) common sample mode and c) common number of samples per active line, and goes on to discuss four examples of possible dual standard parameter sets [1250/50 and 1050/59.94, 1250/50 and 1125/60; 1375/50 and 1125/60; 1200/50 and 1001/59.94 and 1000/60]. It concludes that the most logical set is that of 1250/50 and 1050/59.94 implemented either in a common orthogonal or a quincunx sampling structure.

[CCIR, 1986-90q] gives three examples of common data rate systems. The first is a (horizontally and vertically) scaled-up version of CCIR Recommendation 601. The second achieves the same overall bit rate, but uses sequential scanning and quincunx sampling. The third is a system, proposed for study by the OIRT, based on the 1125/60/2:1 system with a 1375/50/2:1 partner.

[CCIR, 1986-90y] provides a discussion of two examples based upon a common sampling frequency of 74.25 MHz which enable 1125/60 duality with two variants of a 50 Hz field rate system. The first variant uses 1250 lines and provides both countries with a very simple relationship to Recommendation 601 based emission standards. The second variant was 1375 lines which provides higher vertical resolution and offers the feasibility of matrix picture screens consisting of 15 x 10 blocks of 128 x 128 picture elements.

[CCIR, 1986-90z] provides some technical details of the 1375/50/2:1 system described as version 2 in Document [CCIR, 1986-90ag], and also includes some theoretical considerations concerning its interfacing to the 625/50/2:1 system.

[CCIR, 1986-90aa] gives an example of a common data rate system involving 1375/50 and 1155/59.94 partners. The number of active lines are respectively 1280 and 1080.

3. Preliminary studies

Preliminary studies of the relative merits of the common image format and common data rate approaches have not been conclusive. There are differences in the operational, technical and economic assumptions on which different administrations have based their tentative assessments. Further studies are necessary, however there is already a substantial amount of relevant documentation which is listed under the subject headings below.

3.1 Sources

CCIR 1986-90j, k, l, p, ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am.

3.2 Recording

CCIR 1986-90j, k, l, ad, ae, ah, al, an, ao, ap, aq, ar.

3.3 Displays

CCIR 1986-90j, l, ac, ah, al, am, as.

3.4 Production and post production

CCIR 1986-90j, l, ah, al, am, as.

3.5 Standards conversion

CCIR 1986-90j, k, l, u, w, z, al, am, at, au, av.

3.6 Transmission networks

CCIR 1986-90j, l, al.

3.7 Emission

CCIR 1986-90j, l, v, an, av, aw.

3.8 Other considerations

CCIR 1986-90j, k, p, v, ag, ai, aj, al, aq, ax, ay, az, ba, bb, bc.

4. Future activities to be undertaken

The CCIR considers it necessary to continue studies in the following areas:

i) the operational, technical and economic implications of the common image format and the common data rate approaches to the ultimate achievement of a single world-wide HDTV standard.

In making comparisons between both approaches, basic factors that may influence conclusions should be clearly stated. They should include:

- the assumptions made regarding the balance between equipment cost/complexity and the related operational benefits to the broadcasting or production organisations;

- the degree of commonality of components and subsystems between professional and consumer equipment;

- the strategy proposed to accommodate multiple frame rates. Studies should include both switchable and dedicated systems or equipment;

- the strategy to ensure the proposed scenarios are followed;

- the level of development maturity achieved;

ii) HDTV quality assessments and methods of measurement in the following areas:

- the subjective and objective effects of noise in HDTV pictures. Studies are to include both progressive and interlaced systems and comparisons between them;
- the quality of images after conversions between systems having different field rates;
- the quality of images after any conversion to emission systems.

iii) further compatible enhancements of the HDTV studio standard by the wider colour garment, improved luminance coding, and greater contrast ratio;

iv) temporal parameters of HDTV to achieve adequate motion portrayal, and to ease conversion to current television systems and interim HDTV implementations;

v) outstanding and additional parameters for inclusion in Recommendation 709;

vi) an analogue HDTV video tape studio recording format for programme exchange must be specified in the form of a Recommendation;

vii) similar work must also be done for a digital HDTV video tape recording format including studies on the implications of the possible use of bit rate reduction techniques;

viii) identification of appropriate locations and specifications of interfaces for different segments of the HDTV broadcast system;

ix) in consideration of the importance of multimedia release for HDTV productions, harmonization of HDTV standards; operating practices and interfaces for professional, non-broadcast and consumer applications must be pursued in cooperation with the IEC, ISO, CMTT AND CCITT;

The CCIR also considers it necessary to continue to study radio frequency and emission technical parameters including modulation, channel coding and multiplexing of HDTV satellite broadcasting. Further study is required to determine:

a) system parameters for wide RF-band analogue and digital high definition television transmissions by satellite;

b) propagation characteristics for bands suitable for wide RF-band high definition television transmissions;

c) inter- and intra-service sharing and interference, interregional sharing.

Additional studies are needed on terrestrial broadcast of HDTV. In particular it is necessary to study the relevant technical parameters including modulation, channel coding, spectrum utilization and protection ratios. Further, more measurements are required to determine the appropriate protection ratio between terrestrial and satellite HDTV systems.

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REPORT 1224 *

HDTV STANDARDS HARMONIZATION

(1990)

HDTV techniques have been developed first to improve the quality of todays television, and in the long term replace completely the equipment presently in use. Standardization has been discussed in the light of broadcast usages for production, transmission, broadcasting and reception.

It becomes more and more clear that applications of HDTV will exist in many other areas for professional or commercial purposes. It is possible to quote some of them: medical industry, printing industry, publicity, teleconference, etc, and it is impossible to make an exhaustive list since HDTV will probably penetrate domains we have not yet addressed. It is also impossible to predict at what speed these different applications will occur and which will dominate in the years to come. They will probably interact and each will take advantage of the progress made in the others.

It would be wise to anticipate the likely difficulties which could result from these uncontrolled cross influences by trying to harmonize the HDTV standards early enough to avoid that too many de facto standards and practices appear in neighbouring areas which should logically take advantage of a common basic approach.

In addition to CCIR, there are three main bodies directly concerned with this dramatic technological trend: IEC, ISO and CCITT.

1. HDTV related activity in IEC

1.1 Introduction

The IEC, the International Electrotechnical Commission, provides world standards for the electrical and electronic industries. IEC standards are used as the basis of national rules and standards in more than 100 countries. The final results of deliberations by IEC Committees are International Standards, which the National Committees of the IEC are encouraged to use in preparing their national standards. They represent consensus on the technical content as represented by the members of the IEC.

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* This report should be brought to the attention of the ISO, the IEC and the CCITT.

The Technical Committees dealing with subjects closely related to the work of the CCIR in the field of HDTV are:

TC 12, Radiocommunications
TC 60, Recording
TC 84, Equipment and systems in the field of audio, video and audiovisual engineering

and their subcommittees. These committees all deal with both professional and consumer equipment. Full detail of the work of these committees can be found in the current IEC Yearbook.

1.2 IEC activities (current and foreseen) concerning HDTV

The priority areas appear to be:

1) A studio recording standard - SC 60B is waiting for contributions. The CCIR documentation consists of reports which describe the state of the art, but are not really at a stage to constitute a full standard. The same is true for discs.

2) Up-links to satellites - SC 12E will shortly be starting work on this subject on a Japanese initiative. They will deal with measurement methods only. It is expected that this work will include necessary references to HDTV. The transmission of programmes using the fixed services, both terrestrial and satellite could probably also taken into account by appropriate additions to existing publications.

3) Cabled distribution systems - SC 12G is following developments on HDTV, and has in its work programme delivery of MAC packet family signals. It is anticipated that delivery of HDTV will shortly also figure in the work programme.

4) DBS receivers - SC 12A has the first draft standards out for final voting (Six Months' Rule). Again, though these are not yet specific to HDTV, it is to be expected that extensions to cover HDTV can be prepared. In particular, measurements for MAC packet family receivers are being developed.

5) Display units - SC 12A will probably start work in this area, but this is likely to be difficult and rather long-term. However, work on receivers in general will almost certainly take place. Also to be included will be work on data broadcasting (teletext) in as much as it is affected by HDTV.

6) Consumer video recorders - SC 60B will also have to deal with this matter but this is still not a mature subject.

7) There is a need for electrical interface standards at all these levels (studio, transmitters, consumer receivers and recorders). This subject will be covered by IEC TC 84. These standards will have to cover video, audio and control signals, and will have to also deal with the problem of connectors.

It should be noted that there are a number of existing IEC standards relating to the interconnection of audio and video (television) systems. These standards cover both component and composite video interfaces, as well as dual-channel audio and digital audio. Further standards relating to the control of audio and video equipment (D2B) are also at an advanced stage of preparation.

2. HDTV related activity in ISO

The work in ISO most immediately relevant to HDTV concerns film, either still pictures or slides, covered by ISO/TC 42 "Photography", or motion picture film, covered by ISO/TC 36 "Cinematography". This latter committee already has one standard project relating to HDTV aspect ratios for 35 mm cameras, whilst its Working Group 5 "Film/electronic interface technology" has developed, and is developing, a number of standards relative to the use of motion picture films in television and it seems likely that these standards will need to be reviewed in the light of HDTV technology.

A major trend at the present time is the growing merger of image, voice, telecommunications and information technologies and this question is currently being addressed in the joint ISO/IEC technical committee for information technology, ISO/IEC JTC 1. There are a number of activities within this committee with which work on HDTV should be coordinated, in particular:

- work on encoding of audio information and picture encoding, including motion pictures, in JTC 1/SC 2 "Character sets and information coding";
- work in JTC 1/SC 6 "Telecommunications and information exchange between systems", especially that concerning access to ISDN networks;
- work on electronic supports/media, in JTC 1/SC 11 "Flexible magnetic media for digital data interchange" and in JTC 1/SC 23 "Optical digital data disk", the latter also being responsible for the standard on CD-ROM disks;
- work on colorimetry in JTC 1/SC 18 "Text and office systems";
- work on graphics in JTC 1/SC 24 "Computer graphics".

Also under review in JTC 1 is a proposal to undertake work on the representation and protocols for the exchange of audiovisual interactive applications.

3. HDTV related activity in CCITT: broadband ISDN

3.1 Several CCITT Study Groups are or will be involved with studies on broadband ISDN and will therefore also consider the HDTV aspects. These are inter alia:

- Study Group I (Services)
- Study Group II (Network operation)
- Study Group IV (Maintenance)
- Study Group XI (Switching signalling)
- Study Group XV (Transmission systems and equipment)
- Study Group XVIII (ISDN)

Study Group XVIII has performed a coordinating role on these studies since the period 1984-1988.

3.2 As a result of these studies the IXth CCITT Plenary Assembly (Melbourne, November 1988) has approved Recommendation I.121 which establishes the basic principles for broadband ISDN, with the objective to have developed detailed Recommendations during the present study period.

3.3 The main feature of the ISDN concept is the support of a wide range of services, including audio, video and data applications in the same network. A key element of service integration for an ISDN is the provision of a range of services using a limited set of connection types and multipurpose user-network interfaces (UNI).

B-ISDN supports both switched and non switched connections. Connections in B-ISDN support both circuit-mode and packet-mode services. A layered structure should be used for the specification of the access protocol to a B-ISDN.

3.4 Asynchronous Transfer Mode (ATM) is the target transfer mode solution for implementing a B-ISDN. It will influence the standardization of digital hierarchies and multiplexing structures, switching and interfaces for broadband signals. ATM as used in I.121 concerns a specific packet-oriented transfer mode using the asynchronous time division multiplexing technique: the multiplexed information flow being organized in fixed size blocks (cells). A cell consisting of a user information field and a header to identify cells belonging to the same virtual channel on an asynchronous time division multiplex. ATM will offer a flexible access and transfer capabilities common to all services.

It is recognized that in the early stages of evolution of B-ISDN, some interim user-network arrangements(e.g. combination of asynchronous transfer mode and ATM techniques) may need to be adopted.

3.5 In this respect, it is worthwhile to mention that the IXth CCITT Plenary Assembly has also endorsed a set of Recommendations for the newly developed synchronous digital hierarchy. These are:

- Recommendations G.707 (Synchronous Digital hierarchy bit rates),
- G.708 (Network mode interface for the synchronous digital hierarchy)
- G.709 (Synchronous multiplexing structure)

Study Group XV is currently developing corresponding equipment and line system recommendations.

CCITT has already established liaison with several CCIR Study Groups (such as CCIR Study Groups 4,8,9 and CMTT). In particular, Study Groups XV and XVIII have established liaison with CMTT regarding the transmission of sound and television programme signals, including the broadband ISDN. Considerable liaison information has been exchanged with CCIR Study Groups in the past and were taken into account in the development of CCITT Recommendations. Similar working procedures could be envisaged for liaison with CCIR Study Group 11, as necessary, possibly in concert with CMTT.

It is recalled that the recommended levels in G.707 are STM-1 (155520 kbit/s) and STM-4 (622080 kbit/s), other levels are likely to be endorsed during the present study period.

3.6 Recommendation I.121 also gives the considered broadband channel rates and the characteristics of user-network interface (UNI) and other network considerations. Recommendation I.121 also classifies services into interactive and distribution services, including HDTV.

3.7 At its first meeting (Geneva, June 1989) Study Group XVIII has charged Working Party XVIII/8 (General B-ISDN aspects) with the continuation of broadband studies, by assigning to it the preliminary study of Questions 2/XVIII (Asynchronous transfer mode), 13/XVIII (Network capabilities for the support of broadband services in ISDNs) and 22/XVIII (Broadband ISDN influence on principles for video encoding). Annexed to all broadband questions is the status report on broadband aspects of ISDN adopted at the end of the past study period.

3.8 Study Group XVIII at its June 1989 meeting, confirmed the intention to continue to develop CCITT Recommendations for B-ISDN towards unique, world-wide standards for the asynchronous transfer mode (ATM) parameters and user-network interfaces (UNI). It was in particular agreed that the UNI bit rates at the T reference point is 155 520 kbit/s with an interface transfer capacity equivalent to 149 760 kbit/s. This capacity (149.7 Mbit/s) is the peak bit rate available for the user. Higher capacity for the UNI is under consideration.

3.9 As an objective for 1990, Study Group XVIII intends to update Recommendation I.121 (in particular the principles for the evolution of B-ISDN), Recommendation I.113 (Vocabulary for B-ISDN) and to draft new Recommendations, as follows:

- I.150 (Basic characteristics and description of ATM)
- I.2xx (Broadband services)
- I.3xx (B-ISDN architectural principles)
- I.413 (UNI for ISDN with broadband capability)
- O.6xx (B-ISDN operation and maintenance)
- G.7xx (NNI for B-ISDN)
- G.xxx (B-ISDN network performances)

Some of these Recommendations may need to be completed by the end of the study period.

3.10 In due time, Working Party XVIII/8 will involve in its studies other Working Parties of Study Group XVIII and relevant Study Groups as appropriate.

4. HDTV related activity in CCIR

The CCIR, and in particular Study Groups 10 and 11 being responsible for sound and television broadcasting respectively, considers HDTV to be the major development in broadcasting which will take place over the next decade. Consequently the CCIR has been studying the development of HDTV in a number of specific areas:

a) Television studio production draft Recommendations (Decision 58-4)

b) Terrestrial and satellite baseband characteristics (Decisions 58-4 and 51-5)

c) Emission standards (terrestrial and satellite) (Decisions 42-3, 43-6, 58-4 and 51-5)

d) Subjective assessment (sound and television) (Decision 95)

e) Digital standards (Decision 60-3)

f) Sound systems for HDTV (Decision 94)

g) Data accompanying HDTV signals (Decision 72-2)

h) Harmonization of HDTV standards for broadcast and non-broadcast applications (Decision 91)

i) HDTV recording (Decision 59-3)

j) Protection ratios and r.f. receiver characteristics (Decision 42-3)

Interim Working Party 11/9 with terms of reference given in Decision 91 is specifically charged with providing an interface between the CCIR and other organizations active in the HDTV field, e.g. ISO, IEC, CCITT. It will consequently be holding a meeting in September 1990 with the objective of ensuring that close liaison is maintained with the above-mentioned organizations.

5. Conclusion

It is clear that with the resources presently available it is in the interest of all standard organizations to avoid proliferation of studies and duplication of efforts. To enable that, appropriate liaisons must be established to keep bodies working in areas of mutual interest fully informed of developments in each organization.

In this context a special coordination meeting is tentatively planned for spring 1990 when CCIR, CCITT and ISO and IEC technical committees working in the field of imagery will be able to exchange information on current activities and identify needs for liaison and collaboration. This meeting will also address standardization activities supporting HDTV.

More generally, this Report gives a comprehensive list of HDTV related activities of IEC, ISO, CCITT, which should be taken into account by CCIR and used as a basis for an actual harmonization programme.

REPORT 312-5

CONSTITUTION OF A SYSTEM OF STEREOSCOPIC TELEVISION

(Study Programme 1C/11)

(1963-1966-1970-1978-1982-1990)

1. Methods of providing stereoscopic television have long been the subject of study. Projects carried out in various countries have led to production of industrial systems. However, many of the methods thus developed utilize professional equipment in closed-circuit and are not practical for public three-dimensional television. Most methods propose that the reproduced stereoscopic images be overlapped and channelled separately so each reaches the proper eye of the viewer.

The first method, based on the optical stereoscope, reproduces two small spacially separated images, one for each eye. Larger image separations require prismatic viewing devices or prismatic spectacles to produce visual registration of the two images. The prism spectacles cause annoying eye fatigue when the viewer looks away from the television images. A second method consists of two overlapping images, each produced in a different colour; and the use of similarly coloured filters to separate the two images, sometimes mounted in spectacles. Colour filtered glasses may cause psychological and physiological viewing problems and do not produce a full colour picture. A third method provides two overlapping images, polarized in different orthogonal planes, together with the use of spectacles with similarly polarized filters to separate the two images.

Several methods of separating the stereo images without the use of spectacles or viewing devices have been designed. These make use of gratings, or Fresnel or lenticular screens in association with cathode-ray receiver displays. When two stereo images are used these methods have more serious limitations as to permissible viewing positions than do methods employing spectacles. Recently, methods have been developed using multiple stereo images with lenticular-type screens which provide expanded viewing positions. Holographic three-dimensional television requires excessive bandwidth and its perfection is not expected in the immediate future.

2. The transmission of a stereoscopic television picture requires the simultaneous or successive transmission of several separate signals. Methods have been suggested for reducing the bandwidth required. This question has many aspects in common with the development and techniques used in colour television. Various solutions for reproducing the stereoscopic television picture have been envisioned. Presently, electronic image tubes are used to pick up the picture, and direct view or projection cathode-ray tubes are used to display the picture. In the near future charge-coupled matrix devices will be employed for pick-up and display. The flat matrix devices provide very accurate positioning of each picture element.

3. A practical stereoscopic television system requires:

– Orthoscopic three-dimensional display (the depth of the scene should appear natural and without viewer discomfort);
– group viewing (almost any location in the room should provide good stereoscopic viewing);
– compatibility (three-dimensional colour receivers should display a stereoscopic transmission in full depth and a two-dimensional transmission monoscopically; present two-dimensional receivers should display a stereoscopic transmission monoscopically);
– non-degraded picture (the colorimetry and resolution of a three-dimensional colour television picture should be comparable to a present two-dimensional colour picture);

- minimal modification of video standards (the industry and government specifications should not require extensive revision); and
- moderate price (the cost and complexity of converting studio and station television equipment and the cost of the stereoscopic television receiver should not be significantly greater than the conversion from monochrome to colour).

4. Three examples of proposed stereoscopic television systems, which meet some or all of the above requirements, are given below:

- stereo-pair system without spectacles using a charge-coupled matrix pick-up and a flat screen matrix display with a lenticular screen accurately positioned in accord with picture elements [CCIR, 1978-82a];
- stereo-pair system with polarized spectacles using a stereoscopic colour television camera to pick-up two images, transmission of images on two channels or with bandwidth reduction means on one channel, and display with special polarized direct view cathode-ray tube or by projection [CCIR, 1978-82b];
- multiple stereo-image system without glasses using special stereoscopic colour television camera to pick-up a panoramic sequence or continuum of stereo images, transmission of multiple images on several channels or with bandwidth reduction means on one channel, and panoramic display in a special direct view lenticular-type cathode-ray tube or by projection on a lenticular-type screen [CCIR, 1978-82b].

5. The limitation to merely two images commonly applying to stereoscopic systems (as compared to the infinite number of images perceived in normal viewing and - adapted from it - in holographic pictures) means a severe restriction in sensation which may cause irritation and/or eye fatigue if certain rules are violated in shooting stereoscopic pictures. [CCIR, 1986-90] reports results of the quality assessment of a half-hour stereoscopic television production. The system used two PAL signals recorded on magnetic tape with a system of two colour projectors. The display screen was viewed through polarizing glasses. The evaluation of the subjective assessments identifies items of concern which, if not taken into account or avoided in the composition of stereoscopic pictures, cause impaired performance. Although a variety of negative effects were encountered in the stereoscopic image composition, the overall effect is a significant enhancement to the impression of natural vision.

6. [CCIR, 1958; 1962a and b; 1963-66a and b; 1966-69; 1974-78; and 1978-82a and b] and their bibliographies, contain information on the question of stereoscopic television.

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SECTION 11B: ANCILLARY TELEVISION SERVICES

REPORT 802-3 *

ADDITIONAL SERVICES USING BROADCASTING CHANNELS

(Question 29/11, Study Programmes 29A/11, 29C/11 and 29H/11)

(1978-1982-1986-1990)

1. Introduction

Many countries are now broadcasting information and other services in a television channel, in addition to normal television services. Most of these use digital data broadcasting, and probably the most widely-known at the present time are the teletext systems described in Annex I to Recommendation 653. Systems which use analogue techniques, or a combination of digital and analogue techniques, are also within the scope of this report.

A classification of additional services is given in Table I, which, for completeness, also includes services using sound-broadcasting channels.

The sections of this report are as follows:

- section 2 deals with multiplexing and organizational methods for data broadcasting;
- section 3 deals with the services which use data broadcasting systems;
- section 4 deals with systems to provide conditional access to services;
- section 5 is concerned with still-picture television broadcasting (SPTV).

2. Digital data broadcasting systems

2.1 Multiplexing methods within the television channel

Recent work on defining methods for broadcasting television, sound and data signals in one satellite channel, has led to the description of new multiplexing systems and the adaption of one of these to terrestrial broadcasting has been reported [CCIR, 1986-90a]. For ease of reference, and association with other CCIR reports, the various methods are referred to under the application for which they were first developed.

* This Report should be brought to the attention of the CCITT.

2.1.1 Methods for terrestrial broadcasting

a) Time division multiplexing (TDM)

At present, most systems use this method, inserting the data signals into television lines in the field blanking time, (data lines), or into the line blanking time of the video signal. The teletext systems described in Annex I to Recommendation 653 use data lines which, in the absence of television picture signals, may extend throughout the active field time as well as the field blanking time; though the television line and field synchronizing signals are preserved.

Some possibilities for incorporating the sound information in the video signal in terrestrial broadcasting are given in Report 958. An estimated capacity corresponding to four high-quality sound channels could be obtained in 625-line systems. Such a technique may provide an opportunity for broadcasting data.

The influence of the data signal on television protection ratios is under study and some results are available in Recommendation 653 for 625-line B or G/PAL television. Some recent results concerning the protection of a data broadcasting service for televison system L are quoted in [CCIR 1982-86a].

b) Frequency division multiplexing (FDM)

Several European administrations have selected the NICAM 728 system [CCIR, 1986-90b, and c; BBC/IBA, 1987] which is recommended for television systems B, G, H and I in Recommendation 707 for use when multi-channel sound transmission for terrestrial television services is introduced. This system uses an extra digitally modulated carrier to provide two high-quality digital sound channels and a small amount of additional data capacity. The two sound channels may be used to transmit a single stereophonic signal or two independent monophonic signals. Alternatively, one or both sound channels may be used for transparent transmission of data (see Report 795).

2.1.2 *Methods of multiplexing for satellite broadcasting*

Information on this topic is available from other CCIR Reports as follows:

– Report 632: "Broadcasting-satellite service (sound and television) – *Technically suitable methods of modulation*"

  Although the main topic of this Report is *modulation* methods, some information is given on multiplexing.

– Report 954: "Multiplexing methods for the emission of several digital audio signals and also data signals in broadcasting"

  This describes two multiplexing methods known as "system A" or "continuous" which is an FDM system and "system B" or "interrupted" which is a TDM system.

– Report 1073: "Television standards for the broadcasting-satellite service"

  This describes several well-developed systems providing for data broadcasting and known as C-MAC/packet, D2-MAC/packet, B-MAC and digital sub-carrier/NTSC.

These systems provide for sharing of the entire WARC-BS-77 channel capacity among the different services. Means for assisting users to access the different services possible within one WARC channel, and the different WARC channels, are provided. Further information on this aspect is given in § 3.2.2 below.

TABLE I – *A classification of identified additional services which may be provided by data broadcasting systems*

Additional services (1)	Television broadcasting channel multiplex		(2) Sound broadcasting channel multiplex
	Time division multiplex (TDM)	Frequency division multiplex (FDM)	AM or FM channel
1. Teletext	Reports 802 (§ 3.1), 956; Recommendations 653, 655		
2. Sub-titling	Reports 802 (§ 3.2.1), 1080; Recommendation 653		
3. Service and programme identification	Reports 802 (§ 3.2.2), 1073; Recommendation 653		Report 463 (3) (4)
4. Programme delivery control	Reports 802 (§ 3.2.3), 1073 Recommendation 653 Report 1226		Report 463 (4)
5. Speech-quality sound	Report 802 (§ 3.2.4.1) Report 958 Report 954, Report 632 Report 1073	Report 795 (2) (3) Report 954 Report 632 (3)	Report 632 (3)
6. Synthesized sound	Report 802 (§ 3.2.4.2); Recommendation 653		
7. Broadcast audiography	Report 802 (§ 3.2.5)		Report 463 (3) (4)
8. Data for processing (includes "telesoftware")	Report 802 (§ 3.2.6)		Report 1061
9. Broadcasting of time and date in coded form	Reports 802 (§ 3.2.6.1), 1073 and 1078; Recommendation 653		
10. Independent data services	Reports 802 (§ 3.2.7) and 1073; Recommendation 653	Report 1073	Report 463 (4)
11. Broadcast facsimile	Report 802 (§ 3.2.8)	Report 795 (2) (3)	Report 463 (4)
12. Still picture television	Report 802 (§ 4) (3)		Report 463 (3) (4)

Note. – The modulation is assumed to be digital, unless otherwise stated.

(1) Conditional-access techniques may be used with television and sound and any of the additional services 1-12 (see § 3.3 of this Report, Reports 1073, 1079 and Recommendation 653).

(2) The systems for these services are being studied by Study Group 10.

(3) Service may partly be provided using analogue modulation.

(4) Report 463 while not referring to "teletext" does deal with the transmission of supplementary information including text using FM sound broadcasting.

a) *Time division multiplexing (TDM)*

Report 1073 describes several TDM systems:

C-MAC/packet : A radio-frequency multiplexing system: available bit rate approximately 3 Mbit/s.

D-MAC/packet: A baseband multiplex using duobinary coding: available bit rate approximately 3 Mbit/s.

D2-MAC/packet : A baseband multiplex using duobinary coding: available bit rate approximately 1.5 Mbit/s.

B-MAC : A baseband multiplex system using quaternary coding with an available bit rate of approximately 1.6 Mbit/s.

Baseband representation of member of the MAC/packet family (D, D2, HD) may be distributed over digital links. Where these links make use of data compression techniques it is important that channel coding schemes are transparent to all TDM structures including field interval and full field data. One proposal [CCIR, 1986-90c] has been made for channel coding in the 140 Mbit/s hierarchical level.

While it is expected that satellite data broadcasting services will progressively make use of a digital sound/data multiplex, during a transitional period, present data standards may be adapted to the transmission in the field blanking interval of any television signal. This may be desirable for the provision of certain multilingual subtitling services at the outset but rapid adoption of teletext transmitted in the sound/data multiplex as proposed [CCIR, 1986-90a] will facilitate the compatible introduction of HD-MAC.

In Germany (Federal Republic of) data broadcasting transmission tests were carried out with a 20.48 Mbit/s system originally intended for sound-only broadcasting via satellite channels in the 12 GHz band. With this system (see Report 215-6, Annex II) 16 stereophonic or 32 monophonic high-quality sound channels may be conveyed. One or more of these channels can be used for data broadcasting purposes. Each monophonic channel offers one 352 kbit/s highly protected capacity (for C/N = 12 dB the BER is $8.1 \cdot 10^{-3}$) together with 96 kbit/s of unprotected data capacity. Under typical receiving conditions the BER is negligible [Assmus, U., 1989].

b) *Frequency division multiplexing (FDM)*

Report 1073 describes a system known as digital sub-carrier/NTSC which uses a digitally-rmodulated sub-carrier giving an available bit rate of approximately 2.0 Mbit/s.

2.2 *Organization of the multiplex*

The organization of the data multiplex is defined by a certain number of characteristics and parameters concerning the available resource and sharing mode:

- available resource;
- method of multiplexing data from different sources;
- identification of a data channel;
- number of available data channels;
- specification of a data channel.

General descriptions of the data broadcasting systems that have been used primarily for the teletext service are given in Annex I to Recommendation 653. The use of a packet transmission technique for broadcasting data is described on the basis of the lowest four layers of the ISO reference model for open system interconnection.

Similarly, the sound/data multiplex of the MAC/packet direct satellite broadcasting systems described in Report 1073 uses a packet multiplexing structure to allocate the available digital resource to the various sound and data sources.

2.3 Digital interfaces and protocols for transmission and reception

In general, it is necessary to provide interfaces to permit the transmission of digital data from a number of different sources. Since broadcasting is a unidirectional transmission medium, it is not possible to adapt the characteristics of the transmission to comply with the requirements of the receiving equipment in each case. It is therefore necessary to adapt the transmission speed of each source to the available bit rate, taking into account the relative priority of each source. For example, sound may have the highest priority, and sub-titles a higher priority than teletext. Such an interface has been defined in [Blineau *et al.*, 1980], the regulation of the bit rate being achieved by the use of a "hand-shaking" procedure at the sending end.

Furthermore, the interface, and compatibility, with other data networks must often be considered. For example, the interfacing of an SPTV system with several telephone data channels is described in [CCIR, 1982-86 a].

It has been shown that by defining the General Purpose Data (GPD) type of MAC/packet component [CCIR, 1986-90e] only at OSI layers II and III, interworking with other types of telecommunications networks may be facilitated by the use of end-to-end protocols [BSB, 1989]. The uni-directional nature of broadcasting makes existing "connectionless" end-to-end protocols appropriate.

3. Additional broadcasting services using the capacity within a television channel

3.1 *The teletext service*

The definition of the teletext service is as follows:

A digital data broadcasting service which may be transmitted either within the structure of an analogue television signal or by using digital modulation systems. The service is primarily intended to display text or pictorial material in two-dimensional form reconstructed from coded data on the screens of suitably equipped television receivers.

Four teletext systems are recommended for international adoption in Recommendation 653. They are described in Annex I to Recommendation 653 where they are referred to as systems A, B, C and D, viz:

System A : the system proposed by France

System B : the system proposed by the United Kingdom

System C : the system proposed by Canada

System D : the system proposed by Japan

There is now extensive literature describing the development of these systems and an overview is given in [Cominetti, 1985]. Many further references are given in the Bibliography. The results of field trials and theoretical studies, in particular, are given in Report 956. (Volume XI - Part 1, XVIth Plenary Assembly, Dubrovnik 1986).

Exchange between and combination of pages from different teletext data sources may be required when a programme of a particular content or structure is to be composed, for example a regional programme which is to include parts of a nationwide teletext programme. Besides the use of different data lines in the field blanking interval of the television signal for different teletext programmes or the interconnection of two or more teletext computers through data links, a "teletext combiner" device might be used to combine pages from several input cycles, exchange predefined pages and suppress unwanted pages. The combiner also allows for an uncomplicated insertion of "on-tape" sub-titles in an existing programme cycle [CCIR, 1982-86b].

3.2 *Systems for other new services*

The services listed below also rely upon data broadcasting. The number of these services is increasing. Some may also be provided by use of teletext systems.

3.2.1 *Sub-titling (closed-captions)*

Sub-titling services associated with teletext services or the dedicated "line-21" system [Lentz et al., 1978] have been in operation for several years. Improved operational methods and equipment have been developed [Holmberg et al., 1981; Lambourne, 1983; Baker et al., 1984]. Sub-titling provided through data broadcasting can be multi-language and multi-level [CCIR, 1978-82a; Sechet 1980a, and b]. In France, multilingual sub-titling equipment, with independent language management has been produced and presented [Renoullin and Pinon, 1985]. This possibility is particulary important with the advent of broadcasting satellites.

The number of languages that can be provided simultaneously is limited in practice only by the transmission resource, but a reasonable maximum corresponds to about 10 to 20 languages or levels in normal operating conditions.

The transfer of sub-title data for transmission may either be rapid and directly in the form in which it is immediately to be transmitted, or at a lower data rate. In the latter case, a minimum serial data rate of 130 bytes/s is required for the transfer – or recording – of sub-titles in one language concurrently with the main programme material [CCIR, 1982-86c].If a small increase in the minimum inter-sub-title time could be accepted, then the transfer – or recording – could employ the "user bits" of the EBU time code [EBU, 1982] for a single sub-title channel (i.e. 100 bytes/s).

Some statistics relating to sub-title services by means of teletext systems A and B are also presented in [CCIR, 1982-86c].

The international exchange of television programmes containing sub-titling data is dealt with in [CCIR, 1982-86d].

3.2.2 *Service and programme identification*

Where many broadcast transmissions can be received, especially when an RF channel might carry several services, programmes or independent information items, the need arises for the broadcasting of data that will help the user by:

- facilitating access to the desired RF channel;
- defining actual organization of the different signal components within the RF channel (if this is varied from time to time);
- facilitating access to a desired service which is one of several services within an RF channel. (A service may have several components of different types.)

In direct satellite broadcasting, a large number of transmissions are likely to be receivable at each point. For each transmission, several services are likely to be available. It is therefore desirable to adopt a common and comprehensive identification system within the geographical area which is served in accordance with a regional plan, such as that established by the WARC-BS-77.

As an example, the EBU service identification system within the MAC/packet family of systems is based on the use of a dedicated data channel within the digital sound/data multiplex, together with the sending of RF channel and TDM control data in line 625. The processing of the RF channel and TDM configuration data allows the receiver to separate the analogue part of the TDM multiplex, that is to say, the picture, from its digital part, which is the packet multiplex. The processing of the information conveyed by the dedicated channel gives access to the various services and to the various components of each service, and to programme items within each service. Such a system could also be the basis for a service and programme identification system for terrestrial broadcasting.

3.2.3 Programme delivery control

The programme delivery control system facilitates the recording of programming by video recorders. The service should comprise information enabling the preselection by the viewer of programmes for recording, and information for the video recorder which identifies when the programmes are actually broadcast.

The EBU has harmonized work undertaken in Germany (Federal Republic of) on the system known as VPS (Video Programming System) which uses 2.5 Mbit/s bi-phase coded data [CCIR, 1982-86e] and similar functions included in the specification of teletext system B which operates at a rate of approximately 7 Mbit/s but includes additional means of error protection. The operational principles of the EBU system and its specification [CCIR, 1986-90f] are summarized in CCIR Report 1226.

3.2.4 *Sound*

3.2.4.1 *Speech-quality sound*

An experimental system has been developed in Italy [Ardito *et al.*, 1980; CCIR, 1978-82b] to provide a commentary channel to a teletext programme, or auxiliary speech channels to a television programme for multilingual purposes.

The sound commentary is time-multiplexed with the teletext programme and makes use of the same structure of the data signal. In the proposed system, speech pauses are exploited in order to reduce the average channel occupation.

3.2.4.2 *Synthesized sound*

This type of service may be provided, for example, by means of teletext systems B and D (see Annex I to Recommendation 653) and allows text and graphics to be accompanied by synthesized music if required. The addition of this facility to the other teletext systems (§ 3.1) is planned.

3.2.5 *Broadcast audiography*

A service called "audiography" [CCIR 1974-78a] is still the subject of studies in France but no operational service has yet been introduced. It is proposed that services should contain sound with associated graphics information, which enables a drawing in course of execution to be reconstituted (teledrawing or telewriting).

Possible applications could include the broadcasting of educational programmes (in the form of lecture) consisting of a lecturer's comments, diagrams, formulae, etc., drawn on a blackboard. The receiving system's television screen would thus act as a distant "electronic blackboard".

3.2.6 *Data for processing*

These services are rapidly growing in importance. They involve the broadcasting of data which is intended for machine processing but not primarily for the purpose of producing an image on the user's television screen. The best-known example of this type of service is "Telesoftware". In general, "Telesoftware" services provide computer programs for use with personal computers in the hands of the general public.

"Telesoftware" services, broadcast as part of a teletext service, were the subject of experiments several years ago [Vivian and Overington, 1978] and there are now public services in some countries [CCIR, 1982-86g].

A system for broadcasting computer programs and data files by FM sound channels at the rate of 4 800 baud, as an alternative to the main sound programme, has been introduced in Italy by the RAI [Amato et al. 1987; CCIR 1986-90g]. This system called Radiosoftware, now in operation on the third FM radio network is based on a communication protocol [CCIR, 1986-90h] structured according to the ISO-OSI model, whose flexibility allows the use of the system on other broadcasting media, such as digital sub-carriers associated with television or radio channels. These applications are under study.

The Radiosoftware system has also been tested on the two-carrier sound system for television in Italy [CCIR Report 795]. The results of laboratory tests [CCIR, 1986-90i] have shown that, during the transmission of monophonic sound accompanying television programmes, the second sound channel can be used to transmit data at 4.8 kbit/s without affecting the picture and sound quality on domestic television receivers.

Other services under the general heading of "data for processing" may be intended for the remote control of machines (but excluding programme delivery services). An example is the broadcasting of low data-rate signals, for remote-control switching (see Report 1061).

3.2.7 *Broadcasting of time and date in coded form*

Time and date is an important item of information in broadcasting. When broadcasting across time-zone boundaries, especially from broadcasting satellites, a common convention for broadcasting time and date in coded form is desirable. Recommendations 457 and 460 provide such a convention, and its use in broadcasting is proposed in [CCIR, 1982-86g]. Report 1078 deals further with this matter.

3.2.8 *Independent data services*

The independent data services make use of the data broadcasting systems to broadcast various types of data intended for suitable terminals connected to data receivers and commonly require conditional access facilities (see § 4.0). In this case, unlike that of the other services, the organization of the data is the responsibility of the user. Examples of services that have already been used operationally are the transmission of:

- news agency bulletins;
- lists of stolen credit cards;
- educational software for schools.

The system of data packet broadcasting which is in operation in France and known as DIDON [CCIR, 1974-78b; Noirel, 1975; Blineau *et al.*, 1980] is currently being used for such services.

The BBC has provided a service of data broadcasting in the United Kingdom since 1985 under the BBC Trade Mark 'DATACAST'. Although it can be used with any form of encipherment and conditional access capable of use over a one-way transparent data link, a particular system [Wright, 1987] has been developed for this application. Further information is given in Report 1079.

ORACLE-AIRCALL has provided a data broadcasting service in the United Kingdom since 1985, associated with the teletext service using Teletext System B, broadcast on the IBA transmitter network of the United Kingdom. From the wide range of applicable techniques, this service has selected a particular form of data scrambling and access control. Both page organized and independent data is carried by the service. Further information is given in Report 1079.

At the inception of BSS operations in the United Kingdom the distribution of general data to open or closed user groups will use the General Purpose Data (GPD) type MAC/packet service component [CCIR, 1986-90e].

A service for the transmission of data with a high degree of reliability in the analogue TV signal for various users is described in [CCIR, 1986-90j].

3.2.9 *Broadcast facsimile*

A broadcasting facsimile system in which the signal is multiplexed with a television sound channel using the second sub-carrier, has been developed in Japan. In this system, both analogue and digital facsimile signals can be transmitted to the receiver [CCIR, 1986-90k, see Report 795].

4. Systems to provide conditional access to services

The conditional access facility may be applied to all services, including the television services. Methods for controlling access required the use of encryption techniques in conjunction with scrambling. A conditional access television service was introduced in France in November 1984. It is operated over a national terrestrial broadcasting network using bands I and III for the main transmitters. The scrambling techniques are pseudo-random delay of the wanted line part for video and spectrum reversal for sound [Marti and Mauduit, 1975]. Access entitlement control and management operations are effected simultaneously by providing a personal code to each subscriber and introducing the code in the decoder by means of a keyboard.

France is implementing BSS operations, and in particular on the TDF 1 satellite, using the D2-MAC/packet system and the Eurocrypt conditional access system [CCIR, 1986-90 l]. A general description of this system is given in Report 1079, Annex II.

In the United Kingdom, British Satellite Broadcasting is implementing BSS operations using the D-MAC/packet system and the Eurocypher conditional access system [CCIR, 1986-90m].

The Eurocrypt and Eurocypher systems can be used with all members of the MAC/packet family of systems to provide access to television, teletext, sound, and data services.

5. Still-picture television (SPTV) broadcasting systems using a television or narrow-band channel

Still picture broadcasting systems are being studied in a number of countries. These studies include both digital and analogue systems for transmission over television or narrow band channels. The analogue systems are further subdivided into full field and line multiplex types.

5.1 Studies in the USSR

Studies have been conducted in the USSR [CCIR, 1978-82c] into the transmission of digital SPTV signals over narrow-band channels.

A possible application of the system is the broadcasting of signals from a public information centre to a large number of users.

Other applications (e.g. conference communications, subscriber video services etc.), are envisaged which are being studied by the CCITT. Broadcasting of the information is based on the use both of time and frequency multiplexing techniques in television and/or sound-broadcasting channels.

Investigations of various technical parameters have been carried out with particular reference to the number of picture elements per line, number of bits per picture element, change-over time and bit rate and their influence on the service quality [Minashin *et al.*, 1979]. Concerning transmission aspects, it has been shown that to reduce the effect of errors, particularly when methods of reducing redundancy are used, codes must be employed to correct both single and multiple errors [Braude-Zolotarev *et al.*, 1979].

Experiments conducted in the USSR on still-picture transmission using non-switched connection lines of urban telephone networks have shown that effective correction of errors of various structures can be assured by the use of convolutional auto-orthogonal codes and an optimized threshold decoding algorithm. This technique makes it possible to transmit still-picture digital signals virtually error-free on channels having an error probability of as much as 5×10^{-3} [Braude-Zolotarev and Krasnoselsky, 1982; CCIR, 1982-86h].

5.2 Studies in Japan

The full-field multiplex type can transmit many programmes using a frequency band allocated to one TV channel. The signal consists of a one-frame composite video signal and a digitally encoded sound signal which are transmitted by TDM [CCIR, 1974-78c; Yamane et al., 1980]. The transmission tests using the broadcasting satellite were carried out [CCIR, 1978-82d; Hasegawa et al., 1980]. On-air experiments with UHF TV were carried out at Beijing in cooperation between Japan and China [Kang et al., 1987].

The line multiplex type can transmit a few programmes keeping compatibility with a normal TV. The video signal is multiplexed on the field blanking interval of a main TV signal line by line and accompanying sound signal is multiplexed by the additional carrier [CCIR, 1974-78d; Harada, 1976].

A digitally coded multiplex type still picture system using a data channel of satellite broadcasting TV [CCIR, 1986-90j] has been developed. A service by digitally coded still pictures of HDTV and high quality PCM sound is being studied [CCIR, 1986-90n].

5.3 Further studies

Particular attention must also be paid to the protection of the control and still-picture synchronizing signals. Detailed information is given in [CCIR, 1978-82e] Further studies are required on more efficient methods of coding both of SPTV signals and the accompanying sound signal. Further study is also required of means to enhance noise immunity.

The results of these studies must be drawn to the attention of CCITT Study Groups XV and XVIII concerning coding and compatibility with the integrated services digital networks (ISDN).

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[1986-90]: a. 11/14 (France); b. 11/44 (Sweden); c. JIWP 10-11/5-41 (UK); d. JIWP 10-11/5-36 (EBU); e. JIWP 10-11/3-115 (UKIBA); f. JIWP 10-11/5-66 (EBU); g. 10/74 (Italy); h. 10/75 (Italy); i. 11/470 (Italy); j. 11/420 (Japan); k. 11/423 (Japan); l. JIWP 10-11/3-116 (France); m. JIWP 10-11/3-117 (UKIBA); n. 11/576 (Japan)

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REPORT 958-1 *

POSSIBILITIES FOR INCORPORATING THE SOUND INFORMATION IN THE VIDEO SIGNAL IN TERRESTRIAL TELEVISION

(Question 1/11, Study Programme 1H/11)

(1982-1986)

1. Introduction

At some time in the future it may be possible to implement a new system in terrestrial television in which the sound information is incorporated in the video signal. The implementation of such a system while at the same time maintaining compatibility with existing television broadcasting systems, poses many problems which must still be resolved. The present Report is a first response to § 1 of Study Programme 1H/11.

2. Compatibility requirements

The EBU [CCIR, 1978-82a] has taken into consideration the various items mentioned in Study Programme 1H/11 and has come to the conclusion that in terrestrial television the following requirements must be fulfilled to ensure compatibility with existing systems:

- the inserted digital sound signal should not cause any unacceptable interference with the performance of existing receivers;
- the new system should at least allow for the use of either two independent high quality channels, or stereophony, or four to six independent speech channels, and switching to those various modes should be made automatic;
- the reception quality of a transmitter should be limited by the degradation of the picture and *not* by that of the sound signals.

The last requirement seems to be fulfilled if the new system will allow for a sound quality definitely better than the corresponding vision quality, in all reception conditions where the vision quality is at least grade 1.5 (in a 5-grade scale) [CCIR, 1982-86].

It is felt desirable that the new technology be developed with a view to achieving a single overall system suitable for satellite as well as for terrestrial broadcasting applications and that this be done in such a way that the configuration for terrestrial television forms a compatible sub-system of the overall system [CCIR, 1978-82b].

3. Compatibility tests with existing receivers

In order to study the feasibility of integrating sound information into the video signal, preliminary tests with system M have been carried out in Japan [CCIR, 1978-82c], to investigate the compatibility with existing television receivers in the case of pulse signals inserted into the line blanking interval and of line synchronizing signals modified as shown in Fig. 1.

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* This Report is also of interest to Study Group 10 and the CMTT.

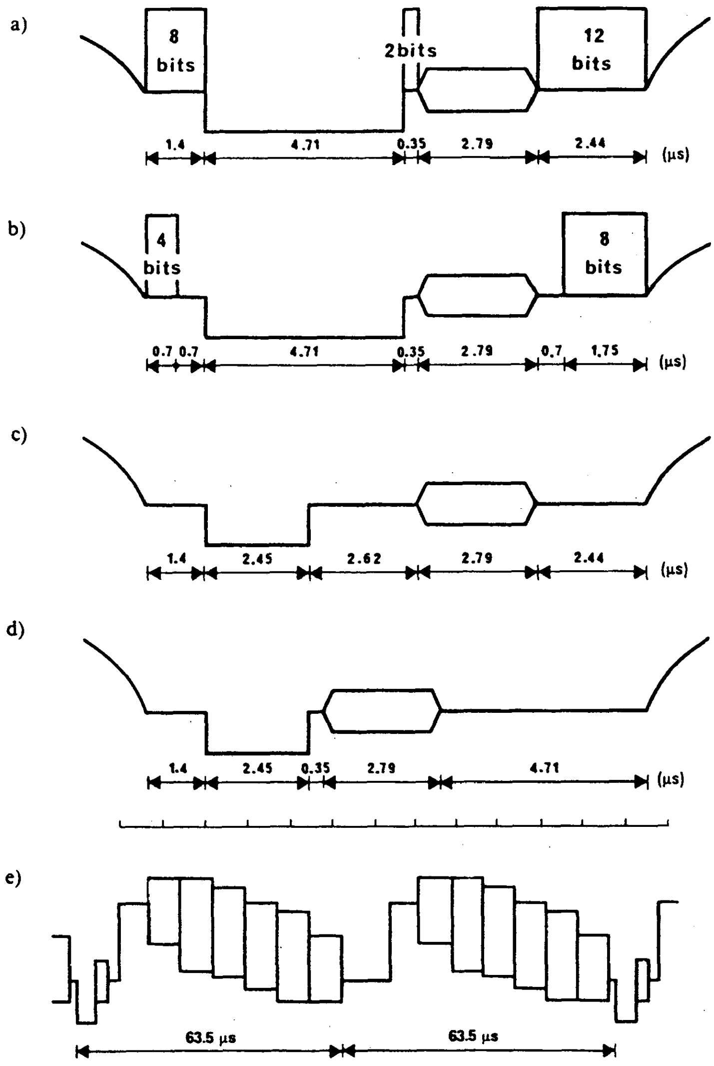

FIGURE 1 – *Waveform of signals for tests with system M*

The results showed that the signals tested were incompatible with receivers currently on the market. However, it seems possible that compatible receivers might be developed by improving their signal processing circuits since several receivers tested were not impaired by the test signals.

Preliminary compatibility tests with existing modern receivers for systems PAL/B have been carried out in Sweden [CCIR, 1978-82d], in which the whole horizontal blanking interval on every other line was used for a 8.86 Mbit/s digital signal; alternatively, two successive such lines were followed by two original lines (Fig. 2). The results showed that the signals caused more or less serious picture or synchronization impairments and that no real compatibility was obtained.

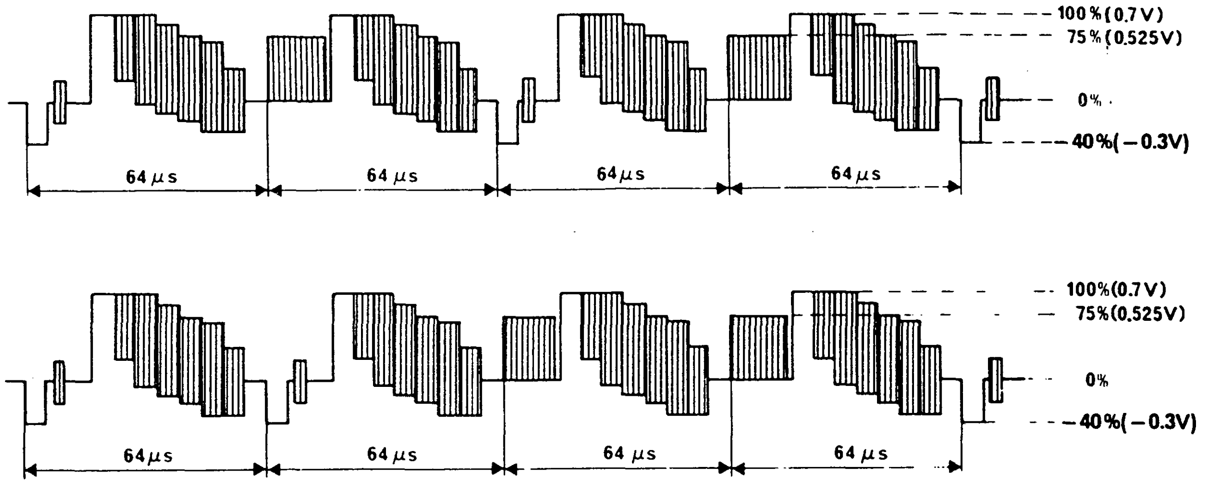

FIGURE 2 – *Waveform of test signals for system PAL*

4. Introduction of a digital system

The EBU has considered various practical aspects of implementing a new transmission standard whereby digital signals are included in the line-blanking interval and has come to the following conclusions for a 625-line PAL signal. Further work is required to determine whether these conclusions apply also to other systems, in particular the SECAM system.

– Experiments with conventional receivers have shown that any new system with digital signals in the line blanking interval is not likely to be compatible with existing receivers. This is true even if only alternate line blanking intervals (or similar schemes for partial use) are used.
– In order to achieve the greatest sound capacity viz. four high-quality sound channels (see Report 632), it is necessary to introduce digital signals within the entire blanking interval of every line.
– Because of the problem of incompatibility and the desirability of introducing any new system within the shortest possible transition period (about 15 years corresponding to one generation of receivers), it would be necessary to adopt a new generation of receivers within that period. This situation cannot be avoided by adopting the partial use of blanking periods either on a temporary or permanent basis.
– Such receivers should have circuits which can function with the standard waveform during the transition period and with the digital signals once the new transmission system is introduced. This circuitry could be contained entirely within the receiver or else could be included in a device external to the receiver, to be connected via standardized external plugs*. The latter solution would probably offer the greatest receiver flexibility.
– Special services such as cable or pay television could probably implement digital sound in the video waveform during the transition period.
– A possible disadvantage of the digital system in terrestrial broadcasting is the somewhat increased sensitivity of the picture to impairments arising from multipath propagation. This occurs when the delayed digital signal appears in the active picture period and arises from its greater visibility as compared with a normal waveform in the line blanking period.
– Further work is required on the quality of sound achieved under certain unfavourable propagation conditions.

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* The Director, CCIR, is invited to draw the attention of the IEC to the necessity for the standardization of such interface plugs and sockets. CENELEC Technical Committee TC 103 have drafted such a standard (see CENELEC Doc. pr. GN 50 049).

REPORT 1078*

THE BROADCASTING OF TIME AND DATE INFORMATION IN CODED FORM

(Question 29/11)

(1986)

Time and date information is already included in broadcast programmes in various ways. Direct methods, such as the audible time signal with a spoken announcement or the display of a calendar and clock-face in a television picture, provide the information in a form easily recognizable by listeners and viewers. Indirect methods make use of auxiliary data transmission channels, such as are provided by teletext, radio-data and the audio/data multiplex of satellite broadcasting, to convey this information in a coded form particularly suitable for controlling the operation of machines.

In the case of broadcasting within a geographically small country, a transmission carrying the time and date information that is correct at the point of origin also provides time and date information that is valid at the point of reception. However, even with domestic terrestrial broadcasting and cable services, in some cases the points of transmission and reception are situated in different time zones, corresponding to a time difference which is almost everywhere an integral multiple of 30 min. In some instances these differences themselves change during the year, due to the practice of implementing "daylight-saving" time in some countries.

Already there are cases, notably in HF broadcasting, where a transmission is received over a large geographical area containing many time zones, and, conversely, signals from most parts of the world can be received at any one point. In these cases, there would be a particular advantage in adopting a common standard time reference to permit the relative timings of programmes from different sources, and their local times at the point of reception, to be determined without the need for detailed current information on world time zones and various calendar conventions.

A similar situation will arise with the advent of satellite broadcasting, and in this particular case, it is expected that the accompanying data multiplex will include coded time and date information as part of programme and service identification (see Report 1073). This information may then be used directly to control automatically the reception of several programmes in sequence, in accordance with the predetermined instructions of the user.

Suitable common world-wide time and date conventions have already been defined in Recommendations 460 and 457. These refer to the use of Coordinated Universal Time (UTC), and the Modified Julian Date (MJD), a five-digit decimal day count incremented at midnight UTC. This information is sufficient to determine relative timings of programmes. Knowledge of the local offset from UTC at the point of reception would allow the local time and date to be inferred from time and date codes regardless of their origin. If the local offset at the point of origination was added as supplementary information to the coded signal, it would allow the time and date at the source to be calculated where required.

In order to avoid ambiguity when data broadcast from various sources are processed at various points, not all of which may be within the same time zone, and to allow calculations of time intervals to be made independent of time zones and "daylight-saving" time discontinuities, it is proposed** that all coded broadcast time and date signals should be expressed only in UTC and MJD, in accordance with Recommendations 457 and 460. A coded local offset, expressed in multiples of half an hour with range -12 to $+15$ h, may be appended when required to indicate the difference between this time and that currently applicable locally within a particular time zone [CCIR, 1982-86a].

A more complete account of the conventions for the expression of standard time and date, and a method for conversion between date conventions [CCIR, 1982-86b] are given in Annex I.

The conventions are being followed in teletext transmissions in the United Kingdom [CCIR, 1982-86c].

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* This Report should be brought to the attention of Study Group 7.

** Administrations are invited to submit additional contributions to this Report, possibly leading to a new Recommendation.

ANNEX I

A NOTE ON STANDARD TIME AND DATE CONVENTIONS

1. Introduction

There are already international standards concerning the distribution of time and date information. This Annex indicates how these standards relate to each other, and to the needs of broadcasting.

Time and date information is used to label the actual or nominal point of origin of material (a document, a television or radio programme) or the actual or anticipated point of receipt. The difference represents the propagation delay. There is also a requirement for indicating local clock-time and date in their own right, or for use together with such labels for assisting decisions or controlling processes associated with broadcasting.

The broadcasting and telecommunications environment provides the possibility of sending signals world-wide within 1 s of time. It is therefore necessary to accommodate the variations in local time (and date) in any method of coding intended to be consistent world-wide. There are also known discontinuities in local time (the duplicated hour at the end of "summer time", and the "leap second") to be taken into account.

2. Standard time

The standard unit of time is the second, obtained by defining the frequency of the caesium atomic transition as 9 192 631 770 Hz. For the purpose of creating a regular time scale these seconds are counted to give days, hours and minutes since 1 January 1958. This is known as International Atomic Time (TAI). This time scale, based on a physical property, drifts out of step with a time scale, such as Universal Time (UT) or Greenwich mean time (GMT), obtained from astronomical observation. Since the origin of TAI was set in agreement with UT at the beginning of 1958, TAI has advanced by about 21 s with respect to UT. In order to provide a time scale with seconds coincident to those of TAI, but within a close tolerance (± 0.8 s) of UT, a version of TAI offset by a whole number of seconds is maintained by the Bureau international de l'heure (BIH). This is known as Coordinated Universal Time (UTC). The tolerance is maintained by occasionally adding (or, in principle, deleting) a single second to make a 61 s (or 59 s) minute. The preferred occasions are at the end or middle of the year, with at least eight weeks' notice. For example, one of these "leap seconds" occurred at 0000 h UTC on 1 July 1982 when the UTC seconds marker sequence was:

30 June 1982	23 h 59 min 59 s
	23 h 59 min 60 s
1 July 1982	00 h 00 min 00 s

All of the standard time signals used by broadcasters world-wide are derived from the UTC time scale, and the times are often, wrongly, referred to in terms of Greenwich mean time (GMT) and an offset. For reasons given above, the UTC time signal known in the UK as "the Greenwich time signal", will sometimes differ from true GMT by more than half a second. This confusion of name is of little practical consequence in everyday life, but it is significant to astronomers, navigators and lawyers.

Recommendation 460 recommends "that all ... time signal emissions conform as closely as possible to Coordinated Universal Time (UTC) ... from 1 January 1975".

2.1 *Time offsets*

In practice all countries refer their national time or times to UTC with an offset. There are 38 different offsets currently in use. Except for Nepal (+5 h 40 min) all the offsets are multiples of half an hour and range from −11 h (Samoa) to +14 h (Anadyr, USSR, in summer time). Many countries advance their time by one hour during local summer (dependent on hemisphere); exceptionally Cook Islands advance by half an hour. There are various dates and times for summer time changes. Within some countries (Australia, Canada) there are some time zones differing by half an hour. There are some states (Queensland, Australia; Arizona and Indiana, USA) which, unlike their neighbours, do not adopt summer time.

It would probably be sufficient to provide a method of signalling a local time offset with a six-bit code giving half an hour steps in a range −12 to +15 h. In some applications, the local offset of the programme source or of the transmitter would be signalled: in other cases, the local offset applicable to the receiver site would be required.

3. Date

The change of date varies, of course, with local time, so a common broadcast standard for date would be referred to UTC and it would be corrected, if necessary, by the operation of the local offset.

There are several calendars in use world-wide but a simple common reference, the Modified Julian Date (MJD), has been defined for this purpose. This is a five-digit decimal number increasing by one at midnight UTC. The origin of the count is 17 November 1858, because at midday on that date the Julian Day (used by astronomers to give continuity from 4713 BC) reached the figure 2 400 000. A more convenient reference is 31 January, 1982 when the MJD was 45 000. It is a simple matter to calculate time intervals, even over many days, by use of MJD and UTC (provided the occasional leap second is known or can be neglected).

Recommendation 457 recommends that for modern timekeeping and dating requirements, a decimal day count should be used wherever necessary; the calendar day should be counted from 0000 h TAI, UTC or UT, and be specified by a number with five significant figures.

Although not defined in any standards, it is convenient to use the idea of a local day number which is advanced or delayed by the local time offset and which changes at local midnight.

3.1 *Week number*

For many commercial purposes, and for planning broadcast programme schedules, it is convenient to work in terms of day of the week, week number and year.

There is an international standard (ISO 2015) for the numbering of weeks. This can be summarized by saying that weeks begin on Mondays, and that week 1 of a year contains the first Thursday of January. The week number can be associated with a day of the week (conventionally, Monday = 1 to Sunday = 7) and a year to specify a particular date. Note that occasional years (about 5 in 28) have 53 weeks, and that the "week-year" of a date in the inclusive range 29 December to 3 January may differ from the "calendar" year. The relation between week number and MJD is given in § 4.

Although the ISO week numbering system is in general use world-wide, other week number systems remain within certain organizations. In some cases, the week number of Monday accords with ISO but the week is taken to run from Saturday to Friday for example. In other cases, even the years containing 53 weeks are different.

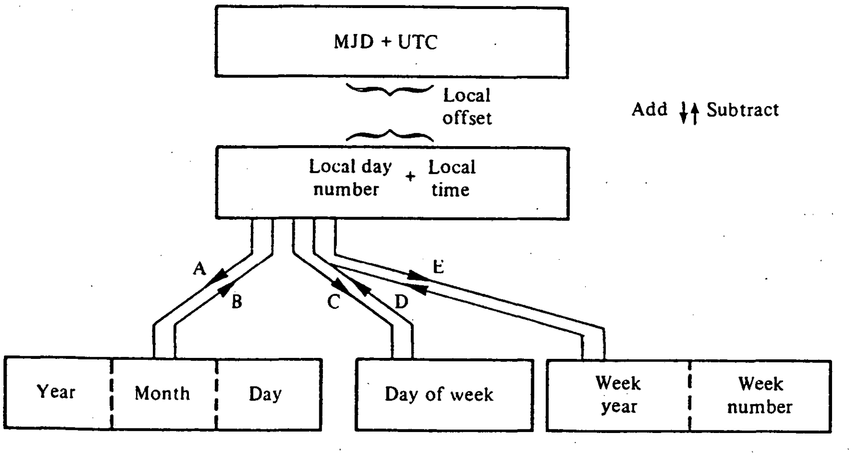
3.2 *Calendar date*

The various calendar systems in use are well-known and, in most cases, well defined. In these cases, it is possible to generate a formula for conversion between calendar systems, the convenient intermediate standard being the MJD. The information for conversion between MJD and the Gregorian calendar is given in § 4.

Certain calendar systems depend on a suitably qualified person witnessing an event (e.g. the first sighting of a crescent moon, or the sighting of a particular type of fish off a Pacific Island) and these can only be related to the MJD after the event.

4. Conversion between time and date conventions

The types of conversion which may be required are summarized in the diagram below.



The conversion between MJD + UTC and the local day number + local time is simply a matter of adding or subtracting the local offset. This process may of course involve a "carry" or "borrow" from the UTC affecting the MJD. The other five conversion routes shown in the diagram are as follows: –

Note. – These formulae are applicable from 1 March 1900 to 28 February 2100 inclusive.

Symbols used:

MJD:	Modified Julian Date
Y:	year from 1900 (e.g. for 2003, Y = 103)
M:	month from January = 1 to December = 12
D:	day of month from 1 to 31
WY:	"week number" year from 1900
WN:	week number according to ISO 2015
WD:	day of the week from Monday = 1 to Sunday = 7
K, L, M′, W, Y′:	intermediate variables
INT:	integer part, ignoring remainder
MOD 7:	remainder (0-6) after dividing integer by 7
*:	multiplication

A: To find Y, M, D from MJD:

Y′ = INT((MJD – 15 078.2)/365.25)
M′ = INT((MJD – 14 956.1 – INT(Y′*365.25))/30.6001)
D = MJD – 14 956 – INT(Y′*365.25) – INT(M′*30.6001)
If M′ = 14 or M′ = 15 then K = 1 else K = 0
Y = Y′ + K
M = M′ – 1 – K*12

B: To find MJD from Y, M, D:

If M = 1 or M = 2 then L = 1 else L = 0
MJD = 14 956 + D + INT((Y – L)*365.25) + INT((M + 1 + L*12)*30.6001)

C: To find WD from MJD:

WD = ((MJD + 2) MOD 7) + 1

D: To find MJD from WY, WN, WD:

MJD = 15 012 + WD + 7*(WN + INT((WY*1461/28) + 0.41))

E: To find WY, WN from MJD:

W = INT ((MJD/7) – 2144.64)
WY = INT ((W*28/1461) – 0.0079)
WN = W – INT((WY*1461/28) + 0.41)

Example:

MJD = 45218	W = 4315
Y = (19)82	WY = (19)82
M = 9 (September)	WN = 36
D = 6	WD = 1 (Monday)

REPORT 1207

REFERENCE MODEL FOR DATA BROADCASTING

(1990)

1. Introduction

The study and development of systems and services of data broadcasting are active in various areas such as the television and sound channels in terrestrial and satellite broadcasting.

In order to ease standardization of data broadcasting systems and to facilitate smooth evolution of data broadcasting services in the future, the development of a common reference model for data broadcasting is necessary.

In particular, the use of such a reference model would facilitate the description and introduction of integrated services digital broadcasting (ISDB) which could include teletext, still pictures, audio signals, high fidelity audio, facsimile, data and other type of information.

In the CCIR Reccomendation 653 the teletext systems are described having an alignment with the ISO layer model for open systems architecture. This layered model could also be the basis for the development of a common reference model for data broadcasting whereby the four lower layers describe the data broadcasting system and the three upper layers generally characterize the service.

2. Definition

Data Broadcasting: the broadcasting of coded information intended to be received by means of appropriate data processing equipment.

3. A layered Model for Data Broadcasting

A hierarchical organization of communication functions for data broadcasting is presented in Fig.1 where the functional items, listed at each hierarchical level, do not refer to specific implementation solutions, but to the overall logical features that are considered sufficient to characterize the service and performance of any typical system.

According to this functional model, services may be delivered by arranging the information into logical groupings, delivering them to lower layers for

proper form for use by the recipient.

In what follows, the names of the layers are those adopted by the ISO in ISO 7498 (1984) "Basic reference model for open systems interconnection".

LAYER 1: Physical

Within a given broadcast transmission system this layer relates to the electrical transmission of the data signal and includes such items as bit rate and pulse shaping.

LAYER 2: Data link

This layer includes logical functions related to the data transmission such as digital frame syncronization techniques and associated error control procedures, and data formatting.

LAYER 3: Network

This layer includes logical functions related to multiplexing, demultiplexing and error control of data packets belonging to different communication flows. Examples of such functions are data channel addressing and data packet sequencing.

LAYER 4: Transport

This layer provides the function of arranging the data in a way suitable for secure transfer from one point to another, by such means as scrambling where applicable and segmenting data into groups of information, delivering them to the lower layers for transmission to the distant point and there reconstituting the groups of information and arranging them in a proper sequence.

LAYER 5: Session

This layer includes data handling functions which are intended to assist the user to gain access to services.
Examples of such functions are access control and information selection.

LAYER 6: Presentation

This layer comprises the functions needed for the presentation of information relevant to each application which could include text, pictures, sound and other types of processable data.

LAYER 7: Application

This layer refers to practical use of the potential facilities provided by the lower layers for a given type of service.
Examples are captioning, telesoftware, cyclic teletext, stock market data, telemusic, etc..

ISO: Reference Model	Data broadcasting	
Layer	Principal function	Classification
7 Application	Use of information at application level	Service information protocol
6 Presentation	Conversion & presentation of information	
5 Session	Selection of and access to information	
4 Transport	Identification of group of data	Data broadcasting system
3 Network	Identification of logical channel	
2 Data Link	Linkage with logical transmission unit	
1 Physical	Physical transmission	

FIGURE 1 - Layer structure of data broadcasting

An example to illustrate the feasibility of the reference model in describing a broadcast software service using the FM radio channel, in operation in Italy, is given in the Annex.

ANNEX

RAI - Radiosoftware

outline of the communication protocol

A system for broadcasting software and data files in FM sound channels, called RAI - Radiosoftware, has been developed in Italy [Amato *et al.*, 1987 and CCIR, 1986-90a, b]. Its communication protocol, structured in seven hierarchycal levels according to the ISO - OSI structure, is outlined in the following.

1. PHYSICAL LAYER

Information unit: bit

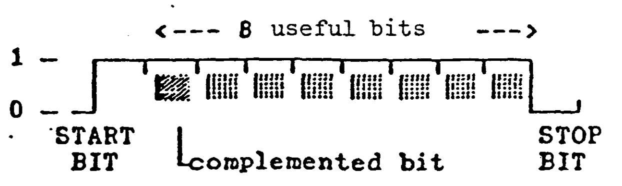
Physical and electrical characteristics of the signal:

- RS - 232 interface between the transmission computer and the base-band coder (CCITT V-21);
- base-band biphase differential coding (Manchester level code);
- bit rate: 4800 bit/s;
- FM modulation

2. DATA LINK LAYER

Information units:

- RS - 232 character (10 bits, 1 START bit, 8 useful data bits, 1 STOP bit).



- The Data Unit of 128 bytes is made up of 1 framing code byte followed by 127 data bytes.

<- 1 byte -><------ 127 bytes ---->

SYNC	DATA

Transmission procedures:

The sync byte (01111110) is used to allow framing synchronization in the receiver.

3. NETWORK LAYER

Information unit:

- Data Packet **(127 bytes), composed by:**

- Packet Prefix (Header)
- Data Block
- Packet Suffix (CRC)

The first byte of the prefix is the Packet Type (PT) which defines the packet structure according to 4 possible configuration For PT = 0 (default configuration) the Data Packet structure is the following:

<-- 9 bytes --><-- 116 bytes --><- 2 bytes ->

PACKET PREFIX	DATA BLOCK	SUFFIX

- The Packet Prefix (9 bytes) is composed as follows:

a) Packet Type PT; 1 byte; four possible configurations (with Hamming distance 5) [hexadecimal notation]: 00, E3, 1F, FC.

b) Packet Address (PA): identifiyng the data packets belonging to the same data file. It is composed of 2 interleaved (8,4) Hamming codes. It provides the identification of up to 2 = 256 distinct data channels.

Two values of PA are reserved for particular files:

PA=0 for the Menu File (see level 5)
PA=1 for the Comment File (see level 5)

c) Continuity Index (I): allows the reconstruction of the logical sequence of the transmitted file (I=0 is the first packet of the file, I=N-1 the last). It is composed of 3 interleaved (8,4) Hamming code blocks; 12 useful bits (I1 is the most significant half byte).

d) Packets Number (N): is the total number of packets in the file. It is composed of 3 interleaved (8,4) Hamming code blocks; 12 useful bits (N1 is the most significant half byte).

- Data Block : 116 bytes of useful data.

- Data Suffix (CRC): it is composed of the 2 bytes redundancy of a cyclic error detection code, with the generator polynomial of CCITT Rec. V41.

4. TRANSPORT LAYER

Information unit :

- Data File (116 bytes) transmitted in the Data Blocks of the packets.

The Data Blocks can assume two configurations:

- for I=0 (first packet of the data file) the Data Block is composed of the File Header (20 bytes) and of 96 Useful Data bytes:

<-- 20 bytes -->	<-- 96 bytes -->
FILE HEADER	USEFUL DATA

- for I ≠ 0 the Data Block is filled by 116 bytes Useful Data:

<-- 116 bytes -->
USEFUL DATA

A Data File is then transmitted in the Useful Data section of the packets.

The File Header (20 bytes) conveys information relevant to the data file, i.e:

- number of useful bytes in the last Data Block (I=N-1).
- type of coding of the Data File (see Lev.6).
- type of scrambling mask.
- encryption informations.
- number of future repetitions of the transmitted file.
- file name (8 ASCII characters (max) + . + 3 ASCII characters of extension, following the MS-DOS rules).

5. SESSION LAYER

The following data handling functions are provided:

- for cyclic transmission of several files:
  the Menu File giving the file names, as reported in the File Header of each data file and the computer family which can execute the transmitted programs and the Commentary File;
- for a single transmission of a file:
  construction of an Empty File (Data File composed of all 00) to ease synchronization recovery in the receiver.

The following procedures are carried out at the receiving end:

- information exchange with the user;
- Menu and Commentary Files acquisition;
- acquisition of the selected file;
- file storage on magnetic support.

6. PRESENTATION LAYER

Conversion and presentation of the processable data information.

7. APPLICATION LAYER

Practical use of the potential facilities provided by the lower layers for the RAI-Radiosoftware service.

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CCIR Documents

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REPORT 1080-1

INTERNATIONAL EXCHANGE OF TELEVISION PROGRAMMES WITH DATA-ENCODED CAPTIONS (SUB-TITLES)

(Question 29/11, Study Programme 29G/11)

(1986-1990)

1. Introduction

This Report considers the methods used in the international exchange of television programmes which contain data-encoded captions (sub-titles).

These considerations relate to the work of Study Group 11 but methods of international exchange include television magnetic tape recording, satellite and long-distance transmission links. It will therefore be necessary to inform the CMTT and Study Group 10 of this work and, where necessary, refer questions to them. Such questions may include the choice of line numbers in the field-blanking interval for captions.

Further information on captions and teletext services can be found in Report 802 and on teletext systems in Recommendation 653.

Usually, the caption data is according to one of the teletext systems although in North America a low-speed method, using Line 21, developed by the Public Broadcasting Service (PBS) [Lentz *et al.*, 1978] is also in widespread use.

These "closed" captions are displayed, at the viewer's choice, with the picture by means of a special decoder associated with the receiver. Captions are usually in the language of the programme and intended as a service to persons with impaired hearing. Captions may be provided in languages other than the programme sound, or in the case of special educational programmes, explanatory text or graphics may be used. The use of captions is expected to increase, especially multi-language captions in the case of direct satellite broadcasting.

Captions are an integral part of the programme. Caption data can be broadcast in the field-blanking interval, either confined to certain lines or included within part of a total teletext package which contains other material not related to the programme.

Methods of caption exchange include the use of several different types of computer floppy discs. The caption data on these discs is related to the programme videotape using the SMPTE or EBU time-and-control code, details of which are available in Reports 630 and 963.

2. Data requirements

It has been reported that for most alphabetic writing systems, the peak data rate needed reaches 130 characters per second, for an unconstrained use of captions in a single language. This allows for the worst-case (infrequent) occurrence of a very long caption immediately succeeding very short captions. A lower data rate would suffice for the majority of captions and would be sufficient for all captions if the inter-caption time could be constrained [CCIR, 1982-86a]. For captions in a single language, one data line per field is more than adequate for anv of the teletext systems.

3. Current exchange methods

3.1 *Field-blanking interval data formats*

These methods use a teletext or specific data format in the field-blanking interval of the video signal, which can allow the captions to accompany the programme and be exchanged using videotape or international connection circuits.

The various current uses of the lines in the field-blanking interval are detailed in Reports 314 and 823.

When recording on videotape, consideration should be given to repeating the caption data to reduce the effects of tape drop-out.

3.1.1 *Data using dedicated lines*

According to some current practices, caption data is confined to (a) nominated line(s) and has an exclusive magazine number. The only data on the(se) line(s) is from the caption source. The data can be separated by a line-number-triggered selector or by the magazine number. If there is more than one language, each is identified by its assigned page number.

Use of an exclusive data line for national and international exchange of captioned programmes between Australia and New Zealand has been reported [CCIR, 1982-86b,c] and is described in Annex I. The system is used for satellite, long-distance links and videotape programme exchange. A "captioned" programme can be received through a link or replayed from a videotape and be broadcast independently of any local teletext system.

3.1.2 *Data using a dedicated teletext channel*

An alternative way of specifically identifying captioned material is through the use of a dedicated teletext data channel, magazine number or page number. This approach makes efficient use of the field-blanking interval in that captioned material can be multiplexed with other teletext data on any available line.

3.2 *Longitudinal track data formats*

Results of tests carried out on the longitudinal track of a 19 mm (3/4 inch) U-format videotape recorder suggest that a single language could be carried in the user bits of the SMPTE or EBU time-and-control code which normally occupies a single longitudinal sound track. With a higher data rate, additional languages could be carried [CCIR, 1982-86a].

These methods are useful for the exchange of television recordings for programme evaluation (see Recommendation 602) because smaller format VTRs and VCRs will not record teletext type data in the field-blanking interval.

4. Data format standards conversion

Standards conversion may be necessary between the various data formats, often in conjunction with video standards conversion. Experimental conversion between the PBS 0.5 Mbit/s Line 21 system and system B teletext has been reported [Lambourne *et al.*, 1984].

5. The need for standardization

Signals are likely to be partially or completely deleted when carried in arbitrarily assigned lines in the field-blanking period by television recording and distribution equipment. Deletion at points of international connection may also occur. Further problems may arise when new system designs using digital techniques are employed.

Standardization is therefore required to ensure the integrity of the caption data. The designation of lines that would not be subject to deletion, to be used for caption data would avoid this problem.

In addition, it may be desirable to establish preferred operating practices for use with particular systems.

As an example, Annex I describes the practices adopted by Australia and New Zealand.

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LENTZ, *et al.*, [June, 1978] Television captioning for the deaf, signal and display specifications. Public Broadcasting Service Engineering Report No. 7709C.

CCIR Documents

[1982-86]: a. 11/330 (EBU); b. 11/366 (Australia); c. CMTT/209 (Australia).

ANNEX I

OPERATING PRACTICE FOR THE EXCHANGE OF CAPTIONED PROGRAMMES USING SYSTEM B TELETEXT BETWEEN AUSTRALIA AND NEW ZEALAND

The following information is provided to facilitate the international exchange of captioned programmes by a variety of methods including videotape and international transmission circuits.

1. Lines 21 and 334 in the television field-blanking interval should be used and other information on these lines should be avoided.

2. Appropriate operating practices should be exercised during editing and replay of videotape to ensure the data is not blanked, clipped or shifted to another line by time base correction or video processing.

3. To overcome corruption due to tape drop-out effects and for the improvement of marginal reception conditions, the data of each sub-title page should be repeated.

4. If data regeneration is used then the data should not be corrupted, line shifted or delayed by more than one TV frame.

5. The data and "control bits" should be set as follows:

5.1 The teletext caption signal is assigned to magazine 8, with page numbering [CCIR, 1986-90] as follows:

Page 800	reserved for an index of programmes and pages;
Page 801	sub-titles for adult deaf and hearing impaired at 120 words per minute;
Page 802-8xx	future allocations for alternate languages and other reading speeds and reading levels. These would be used for special applications such as ESL (English as a second language) and remedial reading. Page 888 is not specifically allocated at present.

5.2 Caption page is selected (C6 set to 1).

5.3 An update indicator is sent on each page (C8 set to 1).

5.4 Parallel magazine mode is selected (C11 set to 0). This should present few difficulties where national systems operate in serial mode as the caption data attached to the incoming/outgoing programme will necessarily need to be redirected into/out of the local teletext system where the mode aspect can be reset.

5.5 Care should be taken to overcome special operational problems such as "sticking captions" at the conclusion of a programme segment. A header row with an erase page command (C4 set to 1) sent about a second before the end of the programme would correct this problem. Additionally, as a clock would be irrelevant in the case of tape relay, the word "CAPTIONS" could be included in the last eight character positions of the header row for convenient user checking.

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CCIR Documents

[1986-90]: 11/109 (Australia).

REPORT 1208

TELESOFTWARE SERVICES

(1990)

1. INTRODUCTION

The name "telesoftware" was first used at the time of the pioneering transmissions in the UK from Independent Television in 1977 to describe transmissions of coded data and computer programs.

Telesoftware is now one of the data broadcasting services recognized by the CCIR (Report 802-2) and it complies with the definition of the broadcasting service as given in Article 36 of the Radio Regulation.

The activities described in this Report relate to the following definition of "telesoftware": the provision, via telecommunications or broadcast networks, of software and associated data files intended to be acquired and then executed or used by terminals subject, when appropriate, to certain conditions governing access and payment.

Section 2 of this Report presents a survey of existing operational or experimental telesoftware services within broadcasting organizations. Section 3 summarizes the technical aspects of telesoftware. More detailed information about these technical aspects is given in the Annex. Section 4 identifies potential areas of standardization in the telesoftware domain.

2. TELESOFTWARE SERVICES WITHIN BROADCASTING ORGANIZATIONS

2.1 Current situation and future projects in the UK

2.1.1 Broadcast software by teletext (BBC)

The BBC Telesoftware Service was launched as a regular public service on 22 September 1983. It enjoys the same status as radio, television and teletext, although with lower priority and smaller budgets and audience. Three years after the launch, there were about 12 000 teletext adaptors for the BBC microcomputer in use, the only generally available method of receiving telesoftware by teletext.

The BBC Telesoftware Service is a part of the teletext service (Ceefax) under the control of the Manager, teletext. The day-to-day editorial control of the telesoftware output is with the Telesoftware Editor, who is also responsible for the commissioning and control of software for transmission. Rigorous standards are applied to ensure that the software performs as expected even in the hands of the inexperienced user.

The BBC Telesoftware Service was initially part of the BBC Computer Literacy Project [BBC, 1983], and much of the first year's material has been based on educational and practical applications for schools, colleges and the home programmer. Software already broadcast, covers such diverse applications as creating a weather database and providing programming building blocks. As with teletext itself, there is strong, and generally favourable and constructive feedback from users of the service. The service is now commissioning a new generation of more sophisticated software of the type which depends on, and takes advantage of, regular updating of data by telesoftware or from the normal teletext pages.

As well as presenting software which stands alone, there are many instances of software directly intended to supplement broadcast programmes, particularly those of an educational, documentary or current affairs nature.

The BBC Telesoftware Service has initially been funded by hardware royalties and support from national educational bodies. It is currently provided free of charge once the necessary adaptor has been purchased.

The future offers the possibility of a greater data channel capacity, whether by full-field teletext, or cable or satellite, allowing faster access and larger databases. An encrypted conditional-access option within the telesoftware service would allow commercially valuable software to be broadcast to paying subscribers.

At present, almost the entire output of the BBC Telesoftware Service is intended for use on the BBC microcomputer, and the computer language and machine specific functions of that particular device are used. Undoubtedly, there will soon be a need to broadcast versions of programmes for other machines. This will entail extra cost and effort by the broadcaster and it will reduce the overall throughput of information as, in some way or other, the different versions will need to be time-shared on the same channel. Although different versions of the programmes will be needed, a common data transmission format to support all versions should be possible.

2.1.2 Broadcast software by teletext (UK Independent Broadcasting)

A recent development in the UK is the transmission of telesoftware on Independent Television's Channel 4 as part of the "4-tel" teletext service. The telesoftware is broadcast in connection with a television programme series "4-computer buffs". An interim protocol has been defined and has been published. A Channel 4 teletext adaptor is available and this facilitates the loading of the telesoftware into the user's personal computer. Initial transmissions are aimed at the Sinclair Spectrum personal computer, but it is hoped to broadcast telesoftware for other personal computers later.

2.1.3 Broadcast software by radio (BBC)

In January 1984, the BBC began to broadcast software by radio using the BASICODE standard [NOS, 1984] - see also Section 2.3.1 - as short inserts in a weekly computer programme called "The Chip Shop" together with separately-scheduled late evening transmissions of about 40 s duration on four nights each week, using the v.h.f. and l.f. UK Radio 4 network. The information pack and an audio cassette of interpretation programmes were distributed by Broadcasting Support Services, about 20,000 sets were delivered as a result of the ten-week first series of the radio programme.

Subsequently the BBC acquired the UK distribution rights for the BASICODE 2 information and interpretation programmes, and this standard was used during the second series of "The Chip Shop" later in 1984 when more than 4000 sets of an improved cassette and bookset were distributed. This time the software transmissions were scheduled for early morning, which was operationally more convenient and which also found favour with the audience. The m.f. Radio 1 network was used and there were many difficulties in making useful recordings of software. Because of this, all of the software was subsequently repeated as a single block lasting 20 minutes using a v.h.f. network late at night.

Comparatively little cost and effort is required by the user to be equipped for receiving BASICODE 2 transmissions, and it was made clear that a continuing service was not being offered by the BBC. Users are, of course, also able to receive BASICODE 2 transmissions from commercial and foreign broadcasters.

It is likely that future transmissions of software by radio will use BASICODE 2 and that they will be related to specific radio programmes. As the language is necessarily a "highest common factor" of the functions offered by a large number of different machines, it is in some respects very limited, in particular in terms of graphic display and input/output facilities. So the technique offers wide coverage at low cost to distribute rudimentary programmes. It is an ideal method of servicing a "club" of BASICODE 2 enthusiasts who wish to offer their own programmes for transmission, indeed there is considerable exchange of material in this standard on the Radio Amateur and Citizens Band channels already. But a radio software service is always competing with conventional radio programmes, and the shock caused to a casual listener when unexpectedly assailed by a high-level mid-band audio tone must not be overlooked.

2.1.4 Other transmission channels

Software is, of course, regularly marketed and distributed on audio cassettes and floppy discs, and in printed form as listings and bar-codes. The BBC already publishes software in these forms and a broadcast software service relates to these in much the same way as teletext relates to the printed words. The broadcast service provides immediate delivery with nation-wide coverage at very low cost, whereas the use of a physical transmission medium allows large quantities of information to be delivered to known recipients in return for payment. The BBC Telesoftware Service is regularly used to provide reviews and examples of commercially published software, and it can also be used to update and even to correct published software.

Software is also distributed by viewdata (videotex) systems in the UK. This offers the prospect of rapid delivery with a simple method of recovering payment, but the capital cost of establishing a source and the costs of the telephone connection and computer time have to be considered.

Alternative digital broadcasting channels may have capacity available for the transmission of software, such as the radio-data system [EBU, 1984], the proposed DBS sound/data packet multiplex system (Report 1073) and a proposed digital stereo sound system for television.

2.2 Current situation and future projects in France

Experimental chains for the production and coding, broadcast or point-to-point distribution, reception and execution of software have been built and tested. The different aspects are detailed below:

2.2.1 Production

In the case of existing software or data files, the problem of production does not arise and the telesoftware service is reduced to a transport service. Several applications of this type have been tried in television broadcast networks and they should lead to operational services in the near future:

- broadcast transmission of software to microcomputers used in the National Education Service
- broadcast transmission of "black lists" (for example, numbers of stolen credit cards).

In contrast, when the application is created specifically for the telesoftware service, it can be enriched by introducing into an existing language a range of additional primitives serving, for example, to allow access to the teletext display module or the data acquisition module. A project of this kind has been effected in PASCAL USCD (the transmitted code being P - code resulting from the compilation) and similar work is under way in BASIC.

2.2.2 Coding

The problem of coding arises when the software is transmitted within the services or infrastructure provided for videography. In other cases, and for data file transmission in particular, the network is transparent and no pre-coding is needed.

Where videography services are involved, the first coding technique to be used was to divide each byte into two hexadecimal-coded ASCII numbers. The technique used now is the "3 in 4" method defined by the CEPT.

2.2.3 Transport

a) On television broadcast networks:

When data files are transmitted the transport protocol used is DIDON 3 (involving data groups, error-detection and systematic repetition).

In the context of teletext (D2-A4 standard) the coded data described in the previous section are transported in sub-articles protected by a CRC 16. These sub-articles are grouped in articles with a dual liaison byte. Correction is achieved by exploiting the inherent repetition in cyclic transmission.

b) On telecommunications networks:

The videotex network provides a synchronous transport service for words of 7 bits + parity, with an error-correction procedure operating in block mode.

2.2.4 Reception

In videographic services (broadcast or interactive) reception is done by the circuits of the videography terminal. Additional error-correction processing is necessary in broadcast services.

For data file transmission services, use is made of special equipment called "DIDEM" (by analogy with "modem"). This equipment takes the form of an autonomous "black box" or a microcomputer card.

2.2.5 Utilisation

In data file services the execution is done by a terminal (microcomputer or specialized terminal) which takes data from the DIDEM.

When an extended language is used, the terminal must incorporate facilities for executing this language. A P - code interpreter has been written for a teletext terminal with extended memory.

Experiments with broadcast software have been done using A2-Antiope.

2.3 Situation in the Netherlands (NOS)

2.3.1 Broadcast software by radio

The Dutch domestic radio programme "Hobbyscoop" broadcast by NOS transmitted its first computer programme in 1978, and it soon became a regular feature of their weekly programme. The programme was heard throughout the Netherlands on FM (VHF) and medium wave, on the Hilversum 2 and 4 networks.

Four different computers were supported in turn, each having a monthly service. Subsequently a common language and transmission format were established under the name BASICODE, and an improved version known as BASICODE 2 [NOS, 1984] has been in regular on-air use since the start of 1983. Some computers require minor modification to accept the signals, and most require a programme to be loaded first in order to interpret BASICODE 2.

Since the medium-wave signal of Hilversum 2 was reaching outside the Dutch borders, letters came from computer enthusiasts in the UK, Germany, Belgium and Denmark asking for more information. Further international interest was obtained when the Dutch external service, Radio Netherlands, which broadcasts worldwide on short wave, took interest in BASICODE. For the time being, a 15-minute English language programme called "Media Network" is sent out to radio stations worldwide, which rebroadcast the programme for their local listening areas. It can be heard on stations in Australia, USA, Canada, Sweden, England, parts of Africa and Asia, and Islands in the Pacific Ocean.

The use of a system as BASICODE requires constant updating in order to cope with new computers.

2.3.2 Broadcast software by teletext

Up till now, no regular transmission of telesoftware via teletext has taken place. Only during an exhibition in September 1984, NOS gave a demonstration of downloading software for home computers, using teletext as a transmission channel.

2.4 Situation in Italy (RAI)

A pre-operational telesoftware service has started on the first and second television networks.

A unified system for broadcasting software on sound channels, called RAI-Radiosoftware, has been specified and is now in operation on the third FM radio network.

2.4.1 Broadcast software by radio

The first experiment carried out by the RAI dates back to May 1984: during the programme "Un certo discorso", of the Third Network, several programmes were broadcast for personal computers like Commodore 64, Spectrum 48K, Olivetti M10, Apple II.

The transmitting technique was very simple: the programmes were recorded on a cassette with the same language, format and modulation of the receiving computer, and transmitted on the FM radio channel in a pause of the main programme. The receiving computer could read the transmitted software directly from the headphone output of the FM radio set.

This way of transmitting is convenient because it does not require any interface between radio sets and home computers but the transmitted software must be dedicated to a single computer, the transmission speed is low and it is not possible to adequately protect the data file from errors.

In order to overcome the above constraints and to establish a standardization for broadcasting software by radio the RAI-Radiosoftware system has been developed for home and personal computers equipped with a standard RS-232 serial port.

This system is a versatile instrument for radio programmes having educational and financial purposes, which allows over-air delivery to the listener of software in the various computer languages (Basic, Pascal, Assembler, etc.), and of texts and graphics intended to be displayed on the terminal or stored on disk.

The system is mainly finalized to be used in audio band channels (15 kHz) but can be advantageously used even on other physical broadcasting supports, such as on an additional subcarrier in the radio channels.

The system bit-rate is of 4800 bit/s, significantly higher than bit-rate used in the previous radiosoftware emissions to home computers on the third FM RAI network.

The receiving system requires a simple and economic interface, containing only a few commercial integrated circuits (less than 10 LSI/MSI chips), wich can be installed in the expansion slot of the computer.

Decoding of the communication protocol is carried out entirely by the computer through an appropriate reception software, developed ad-hoc for the most common computer operative systems (e.g. MS-DOS, CP/M, etc.). This flexible approach enables to introduce, in the future and when necessary, other application modes simply by updating the reception software (supplied to the user on floppy disk or over-air) and without the need of modifying the hardware interface.

The communication protocol, organized according to the 7 layers ISO structure, allows three trasmission modes:

a) single transmission of a data file,

b) repeated transmission of a data file,

c) cyclic transmission of several data files.

In the latter case, a "menu file", automatically acquired when switching the computer on helps the user to choose between the transmitted files. In addition a "commentary file" gives information relevant to the file selected by the user (language, execution modalities, etc.).

Compatibility tests carried-out in the laboratory [CCIR, 1986-90a] have shown that the "Radiosoftware" system can also be adapted for use on the second sound channel of the two-sound carrier TV system [CCIR Report 795-2] adopted in Italy, during television programmes with monophonic sound, without affecting the picture and sound quality of domestic TV receivers.

2.4.2 Broadcast software by teletext

The RAI has started the pre-operational phase of its new service of telesoftware transmission that is based on the structure of CCIR teletext system B.

The system adopts the same transmission rate and data organization (40-character/row) as teletext system B and it allows the use of presently available integrated circuits (VIP 5230, EUROOCT) in the receiver. With respect to teletext it differs only in the higher levels of transmission protocol. Moreover, the system does not require the use of special linking mechanisms, such as ghost rows (e.g. data packet X/27). This information is carried out by a special "configuration" page and additional control codes transmitted on each page.

The telesoftware communication protocol [CCIR, 1986-90b] is structured in seven hierarchical layers in accordance with CCIR Recommendation 653. The Physical and Link layers are the same as in teletext system B. The Network layer adopts the same data packet format as in CCIR teletext system B and at this level the data packets are protected from reception errors by Hamming correcting codes and CRC error detection. In the Transport layer the data files are segmented into one or more chapters each consisting of a single telesoftware page or a set of rolling pages. The Session layer includes character coding, page coding, chapter linking, access control and dynamic protocol configuration. The Presentation and Application layers refer respectively to the conversion/presentation and utilization of the broadcast data and software.

Particular attention is paid to the protection strategy since telesoftware requires the absolute absence of errors in the received data files. To this extent a (40,34) interleaved Hamming code, associated with a CRC (Cyclic Redundancy Check) on each data row, has been adopted in the communication protocol. This allows the correction of any single error in a 40 bit block and detection of residual errors on each data row.

In order to improve the efficiency of the error correcting code the transmitted data are masked by a pseudo-random sequence; this avoids the occurrence of repetitive critical data patterns.

Results of laboratory tests and field trials have shown the efficiency and suitability of the adopted protection strategy to allow correct data reception even in critical receiving conditions [CCIR, 1986-90c and Cominetti et al, 1986].

2.5 Situation in Sweden (SR)

In Sweden, no telesoftware experiments by teletext have been carried out yet. The Educational Radio/TV Company (Utbildningsradio) is interested in such a service, mainly to be able to distribute computer programmes to schools.

One form of telesoftware that is being used is the weekly transmissions by a computer club over a local FM radio transmitter in Stockholm. Transmissions are by audio, using directly the tone-shift recordings from some popular home computers - different for each model, and thus for only one model at a time. There has also been a test series of three such transmissions over one of the national radio networks. "BASICODE" is being considered but has not yet been used.

2.6 Situation in Denmark (DR)

Only some small experiments with broadcast software by teletext have taken place and there are at present no plans to introduce a service for this application.

Concerning broadcast software by radio, the second DR radio programme is broadcasting software programmes as part of one of its radio programmes "Båndbixen". The software is intended for home computers like the BBC, Commodore, Sharp, etc.. and some of it is BASICODE. The programme is heard all over Denmark on FM, and it is also transmitted by long wave (Kalundborg 245 kHz). The transmission takes place between 0.15 - 0.45 local time on Sunday nights.

After some initial problems, the experiments have been good. The data signals are sent 9 dB below maximum level, and the FM stations use "Ball-empfang" to avoid difficulties with the normally used carrier network (Siemens MST 15). The Kalundborg transmitter is provided by a 7.5 kHz digital link.

2.7 Situation in Finland (YLE)

In 1983, the YLE began to broadcast a radio programme for "everyone in computer age" by name "Silikoni". At the beginning, it was a non-regular part of a school radio magazine but from August 1986, it has been an independent half-an-hour programme broadcast weekly and having its own staff of three, its own budget, production and transmission time. The programme purpose is to popularize computing and therefore works on a very general level. According to the abundant feedback, this approach seems to be the right one. The programme consists of news, interviews with experts and small programming competitions for the audience, the format being a very fast magazine type.

From Autumn 1985, experiments of broadcasting software by radio have been carried out by transmitting BASIC programmes as "buzzing" lasting from 20 seconds up to 3 minutes, mostly for Commodore 64, MSX, and Spectrum computers. No problems have occurred in transmission and reception but the amount of different BASIC dialects used in the various home computers makes it difficult to reach all the interested listeners by the same transmission because the language, format and modulation of only one type of computer can be transmitted at a time. To overcome this problem, the YLE plans, in the future, after the copyright questions have been cleared up, to use the NOS BASICODE system [NOS, 1984].

2.8 Situation in Switzerland (SSR)

On an experimental basis, the SSR is broadcasting software specific to certain types of computer on the 2nd radio programme network in Italian. BASICODE 2+ is considered as being inadequate in the long term.

The Teletext AG company is broadcasting software sponsored by commercial companies, on an experimental basis. The software is for IBM PCs, or compatible machines. This is not yet a regular service, although the introduction of such a service is part of the plans of Teletext AG.

2.9 Situation in Canada

At the moment there is no permanent software service being offered. However, facilities do exist to provide such a service using the terrestrial broadcast networks. These facilities are:

1. The field blanking interval of a television channel using CCIR teletext system C.
2. An additional carrier that has been defined for data transmission in the audio channel within the television channel.
3. The Subsidiary Communication Multiplex Operation (SCMO) on FM broadcasting channels where capacity exists for data broadcasting.

2.10 Situation in Japan

Laboratory level experiments on transmission of software to personal computers have been examined. In those experiments, the data broadcasting capacity of CCIR teletext system D and the DBS data channel capability of the digital sub-carrier NTSC system (see Report 1073) have been used [CCIR, 1986-90d].

3. TECHNICAL ASPECTS OF TELESOFTWARE

3.1 Information provided by the BBC

3.1.1 Broadcast software by teletext

CCIR teletext system B provides a method of checking correct and complete reception of each page, and a method of linking pages in a chain of indefinite length. Majority methods of error correction can be used [Chambers ., 1979]. Telesoftware programmes are divided into blocks of up to one kilobyte which are sent as linked pages with special control bits [Rayers , 1984]. The method can handle any language, or any other data blocks for any purpose. Compacted codes can be used to improve efficiency. Conditional access techniques for teletext can be applied directly to telesoftware. These points are detailed in the Annex.

3.1.2 Broadcast software by radio

The NOS BASICODE 2+ system is used [NOS, 1984]. Data is encoded at 1200 Baud using an f.s.k. system widely used in domestic equipment. For each microcomputer supported by the service, there is a translation programme containing subroutines starting at common line numbers to implement functions such as "clear screen". Further details are given in the Annex.

3.2 Information provided by TDF/CCETT

Telesoftware takes its support from infrastructures which already exist or which are currently being implemented for telematic services (videotex network), for teletext, or for data broadcasting. The specific features of telesoftware nonetheless require particular attention to be given to the problems of transmission error-correction. Questions relating to access control and payment for services are more difficult to resolve than for videography: they are dealt with in France through the use of the memory card.

Telesoftware poses two quite specific problems:

- the language, which should be as universal as possible
- the control of execution, in order to impede the software pirates who risk becoming increasingly active as software becomes more readily available.

3.3 Information provided by the RAI

3.3.1 Broadcast software by radio

The RAI-Radiosoftware system [CCIR, 1986-90c, e] has been designed to reach the following targets:

- exploitation of the maximum transmission bit-rate achievable in the bandwidth of the present audio equipment and low-cost commercial re-receivers;
- adoption of a baseband data signal without low-frequency components, in order to facilitate recording on magnetic tape;
- insensitivity to possible polarity inversions of the received signal; simplicity and low cost of the user's receiving interface;
- adoption of a standard user interface independently of the personal computer type;
- possibility to update the system for future applications simply by changing the receiver software;
- exploitation of the message repetition to allow correct data reception even in bad receiving conditions.

Since the user interface functions have been limited to the baseband signal treatment only, the protocol decoding for data acquisition by the computer is carried out completely by software.

Besides simplifying the interface, this approach allows the decoding software to be modified, if requested, simply by transmitting the new version over-air, thus ensuring the maximum system flexibility with respect to future innovations.

However, the part of the receiving program operating in real time is written in the assembly language, specific for the various computers. On this purpose, the reception program has been developed for the most usual computer families: the versions based on Z-80 microprocessors and operating systems CP/M and MSX as well as those on 8086 (8088) microprocessor and operating system MS-DOS.

An outline of the RAI-Radiosoftware communication protocol is given in the Annex to Report 1207 "Reference model for data broadcasting".

4. AREAS OF STANDARDIZATION

4.1 Terminology

From the definition of "telesoftware", it is clear that a telesoftware service can make use of several different transmission means to provide software and data files to the concerned terminals. It would therefore be helpful to characterize the service and possible telesoftware systems by an appropriate and consistent terminology, as it was done in the past with reference to teletext.

4.2 Conditional access

It is clear that there will be a need for controlled-access services carrying telesoftware in order to provide subscription services in return for payment, or to provide payment for individual products. Controlled-access methods are already being studied in connection with DBS television and sound transmissions and similar principles can be applied to data such as telesoftware and teletext. There are obvious economies of scale in having a standardized common method for encrypting such data, and for distributing the necessary key information.

4.3 Transport

A transport mechanism for use in a packet-switched data system, and in the fixed-length-packet multiplex proposed for DBS transmissions, could be formulated.

4.4 Data file format

Although it is likely that several software languages would be supported in a telesoftware service, there is advantage in defining a unique format for any accompanying data such that it represents a common resource available to all versions of a programme. This is particularly important in a broadcast service where different versions of the same data for different versions of the programme would occupy the available data transmission capacity wastefully.

4.5 Indexing

There may be an advantage in defining a standard language in which the details of the telesoftware service can be broadcast, giving a complete and structured list of the options available. This has aspects in common with the SI (service identification) channel provided in the proposed DBS systems of the MAC/packet family. The principle could usefully be extended to give a teletext magazine index.

4.6 Language

From time to time, it is suggested that a standard computer language be adopted or created for telesoftware, to avoid the need to support several versions of a program for different sets of user equipment. However, the disadvantages of limited scope ("highest common factor") and lack of "future-proof"-ness (once a standard is established, it is difficult to improve its compatibility) may outweigh any advantages.

4.7 Soft decoders

Telesoftware could be used to re-define and update the operation of a teletext decoder to make it able, within the limits of available storage and processing time, to reproduce still images regardless of how they are encoded. Such a "soft" teletext decoder would remove the need to define higher "levels" of teletext, but the re-definition language would itself need to be standardized.

Already telesoftware has been used to broadcast software "patches" to modify or improve the operation of the telesoftware interpretation programme.

4.8 Execution control

In order to impede the software pirates, who might be expected to become :reasingly active as software becomes more readily available through lesoftware, execution control has to be developed. This execution control as to fight against pirate commercialisation of software acquired legitimately as a result of an access control operation.

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ANNEX

TECHNICAL CONSIDERATIONS (BBC)

1. BROADCAST SOFTWARE BY TELETEXT

1.1 Data modulation

Telesoftware for transmission by teletext is treated as data in the same way as the character codes of conventional teletext pages. The only difference is that even-parity bytes may also be included. This could, of course, give rise to long strings of all-zero or all-one bytes which might interfere with the clock and byte-boundary recovery in some decoders.

The use of the cyclic redundancy check in the normal Ceefax page output for over three years has confirmed the earlier impression that most users have a substantially error-free reception of teletext all the time. In particular, there is no need for additional coding (such as Hamming) in the data to allow the possibility of forward error correction, it is sufficient to be able to reliably detect errors and wait for a re-transmission on these occasions. It is, of course, possible to use majority logic on parts of the page [Chambers J.P., 1979] so that reception of a complete correct page is possible even if not one transmission is received perfectly.

1.2 Transmission format

A format for the transmission of computer software by teletext [Rayers D.J., 1984] was derived in consultation with other broadcasters, industry and, in particular, Acorn Computers Ltd. who were producing the BBC microcomputer. The format is designed to support any language, and it allows the language to be identified at the start of each page. It offers the choice of translating eight-bit codes into seven-bit codes within the normal character coding range or using the full eight-bit capability of teletext. The first approach produces a string of characters which can, in principle, be transcribed and interpreted manually, the eight-bit approach is more efficient as it does not extend the length of the message.

The format allows the interpretation of individual bytes to be re-defined for the remainder of a message, this includes the possibility of replacing a frequently used string of characters by a single byte, and several pre-defined decoding commands can be called in this way. These decoding commands, such as "inhibit run when loaded" and the re-definition commands themselves, are implemented as subroutines in the decoder.

Provided data can be stored as a file on a BBC microcomputer disc-based system, it may be processed for transmission. When seven-bit transmission is to be used, bytes outside the normal range of character codes are preceded by a "raise" or "lower" byte and modified by the addition or substraction of (decimal) 88. The code is then grouped into 920-byte blocks (teletext pages) including the repeat of necessary protocol sequences at the start. A raised or lowered byte is not split between blocks, neither is a line of BASIC split. This simplifies interpretation and downloading from any point in the programme.

Specific action is taken in the case of programmes in BBC BASIC language, where key-words are "tokenised" as single bytes in the hexadecimal range 80 to FE within the BBC microcomputer. It was decided that these tokens would be replaced by the abbreviated key-words for transmission.

1.3 Future-proof telesoftware

The protocol and format for transmission of data, including computer programmes, by teletext are designed to be very general in application. In particular, they can be used as the basis for enhancements to teletext character generation and graphics, and they can provide machine-readable indexes to the teletext data.

2. BROADCAST SOFTWARE BY RADIO

The technical aspect of the BASICODE 2+ system used in the BBC "The Chip Shop" broadcasts are now summarized.

2.1 Data modulation

The data for transmission or recording is at 1200 Baud rate with one full cycle of 1200 Hz for logical '0' and two full cycles of 2400 Hz for logical '1'. Each byte, least significant bit first, is preceded by one start bit '0' and followed by two stop bits '1'. Seven-bit ASCII character codes have the eighth bit set to '1'.

A programme begins with 5 s of stop bits (2400 Hz) followed by hexadecimal 8D, the entire sequence being terminated by hexadecimal 83 "stop text", a bit-wise exclusive-or'd check sum byte and 5 s of stop bits.

It is recommended that direct connection from radio to tape recorder be used, a fairly good radio cassette recorder being preferable to a hi-fi system. Manual recording level should be set just into the red area and then left alone, automatic level control almost always gives too low a level. Treble tone control should be set high, and Dolby or other noise reduction methods or filters should not be used.

2.2 Translation programme

For each microcomputer supported by the BASICODE 2+ system, there is a translation programme available on cassette. It includes a set of standard subroutines occupying BASIC line numbers in the range 0-999, with fixed starting points and written in the language of the target machine. For example, the BASICODE instruction GOSUB 260 will always find a routine at line 260 that produces a random number between 0 and 1 which is then stored in the variable RV. The other main purpose of the translation programme is to ensure that the target computer responds as specified to the statements, operators and commands in the BASICODE 2+ programmes themselves, which must occupy line numbers in the range 1001-8999. Line numbers 9000-9999 are reserved for REM and DATA statements. Line number over 10000 can be used for machine specific routines that are not part of the BASICODE 2+ programme.

In the case of the BBC microcomputer, there are two translation programmes available, each taking about 120 s to load from cassette and occupying about 6 kbytes of memory. The programme BBCLOAD allows the user to load programmes recorded in BASICODE 2+, including those broadcast with "The Chip Shop". The programme BCSAVE allows the user to save a programme written in BASICODE 2+, which can then be used with the appropriate translation programme, on any other type of microcomputer supported by BASICODE 2+.

2.3 Limitations of BASICODE 2+

Some of the limitations of BASICODE 2+ are now given to emphasize the consequence of taking the highest common factor of the target machines.

There are 41 statements (such as ABS, COS, RUN) and 11 operators (such as + and -) available, which are understood by all machines. Other necessary standard functions such as "clear screen" and "check if a key was pressed" are called as subroutines (GOSUB 100 and GOSUB 200).

The most common screen display format is 24 lines of 40 characters, but some machines have displays as small as 16 lines of 22 characters. The recommended approach is to use subroutines to adjust lines to the size of the screen.

A programme line must not exceed 60 characters, and a string must not exceed 255 characters. Variables may be only two characters long, the first being a letter, with certain pairs forbidden and certain other limitations on the Sinclair Spectrum. Numeric variables are real and accurate to a maximum of six decimal places.

Because there are no graphics, drawing facilities programmes intended for BASICODE 2+ must have output in the form of text. A standard subroutine for a printer is provided.

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REPORT 1226

CHARACTERISTICS OF A PROGRAMME DELIVERY CONTROL (PDC) SYSTEM FOR VIDEO RECORDING

(1990)

1. Introduction

A programme delivery control (PDC) system assists the user of broadcast services (video, sound and data) by the transmission of accompanying data signals specifically related to the programme.

A first application of PDC is in conjunction with video recording [CCIR, 1986-90a; ARD/ZDF, 1987]. Use of the system can simplify the process of data entry for selected programmes and can ensure accurate timing of recording under the control of the broadcaster. In the first case this reduces the opportunity for errors in data entry and in the second case this compensates automatically for rescheduling of transmission times to account for unpredictable events which may delay (or occasionally advance) programmes.

Joint Interim Working Party 10-11/5 has proposed that Study Group 11 should aim at making a Recommendation on PDC to avoid a proliferation of standards. Study Group 11 has agreed with this view and a draft new Recommendation on programme delivery control systems for video recording is to be subjected to an accelerated approvals procedure during the CCIR Study Period (1990-1994).

This report describes the main characteristics required for such a system, and in particular the service requirements and functional capabilities for the video recording application. Detailed definitions and specifications for the functions, which are considered to be central and essential to the standardization of a universal PDC system, are given.

Bearing in mind the variation in transport mechanisms already employed for data broadcasting in different countries, it is to be expected that some variation in the details of implementation and coding of PDC functions will be inevitable [CCIR, 1986-90b]. The report is therefore structured to include such details as they apply to CCIR teletext systems A, B, C and D, [CCIR Recommendation 653] and other data transports in a separate annex.

Experience with services already implemented shows the need for clear rules on how a PDC system should be operated to achieve the reaction to be intended at the receiving end. Similarly guidelines on suggested ways of implementing receiver functions in the video recorder control software may significantly improve the system performance for the user. There is therefore a need to continue the collaboration between broadcasters and industry throughout the implementation and application phases of such a system. This will be of particular benefit in ensuring the orderly introduction of specified features and of new features for which the system has a potential, but which, at service commencement, are not fully specified.

2. Service requirements to be taken into account in the development of a PDC system

Programme delivery control as a broadcasting service should allow suitably-equipped video recorders to record preselected programmes automatically and substantially completely. In order to provide this function a PDC system would ideally fulfil the following requirements:

- Programmes which differ from the scheduled time of transmission should be recorded properly.
- Facilities for the recording of non-scheduled programmes should be provided.
- Interruption of a transmitted programme for any reason may, at the discretion of the broadcaster, be accompanied by a corresponding interruption of the recording process.
- To facilitate the complete recording of a programme the system should allow for the continuation of a programme on a different channel.
- The presentation constraints on existing services (e.g. teletext and television services) should be minimized.
- The service should allow both manual or automatic preselections.
- The service should be user-friendly.
- The service should be reliable. In the case of failure of the automatic recording control of the PDC system, normal timer control of the recorder should operate.
- The service should operate consistently regardless of time-zone boundaries and changes to and from daylight-saving time. In consequence, the use of Unified Date and Time (UDT) is proposed.
- The rate of transmission of recording controls must be such that error detection/correction schemes and frequency scanning by the receiver are possible. This results in a minimum repetition rate of 1 Hz.
- The start of the recording process should be close to the start of the required programme, however, in signalling the latter, the broadcaster should make allowance for the "run-up" characteristics of recording equipment.
- The service should operate for programmes with and without conditional access.
- The data capacity for the recording control and other background functions should be minimized.

- Provision should be made for the announced data and time to be changed one or more times by the broadcaster without adverse effect on the service. Nevertheless, there may be operational rules which restrict the range of movement to within a specific time duration (e.g. 28 hours).

3. General description of the PDC system

3.1 Distinct service components of a PDC system

Programme delivery control for video recording is made up of two distinct service components, defined as the preselection function and the recording-control function as described below (see Figure 1).

- The preselection function

  The preselection function for recording control of suitably-equipped recorders performs the loading of the controller memory of the recorder with the information about all programmes required to be recorded. The viewer chooses the required programmes from television programme guides such as newspapers, magazines or teletext pages. He then enters the relevant information into the recorder, for example manually via keyboard or barcode reader or interactively using a cursor on the display screen.

- The recording-control function

  The recording-control function remotely controls suitably equipped recorders from the source of transmission. Such a function depends on the broadcaster sending a programme label in coded form together with the programme. In the case where no programme label is transmitted, the recording must be done under timer control of the recorder.

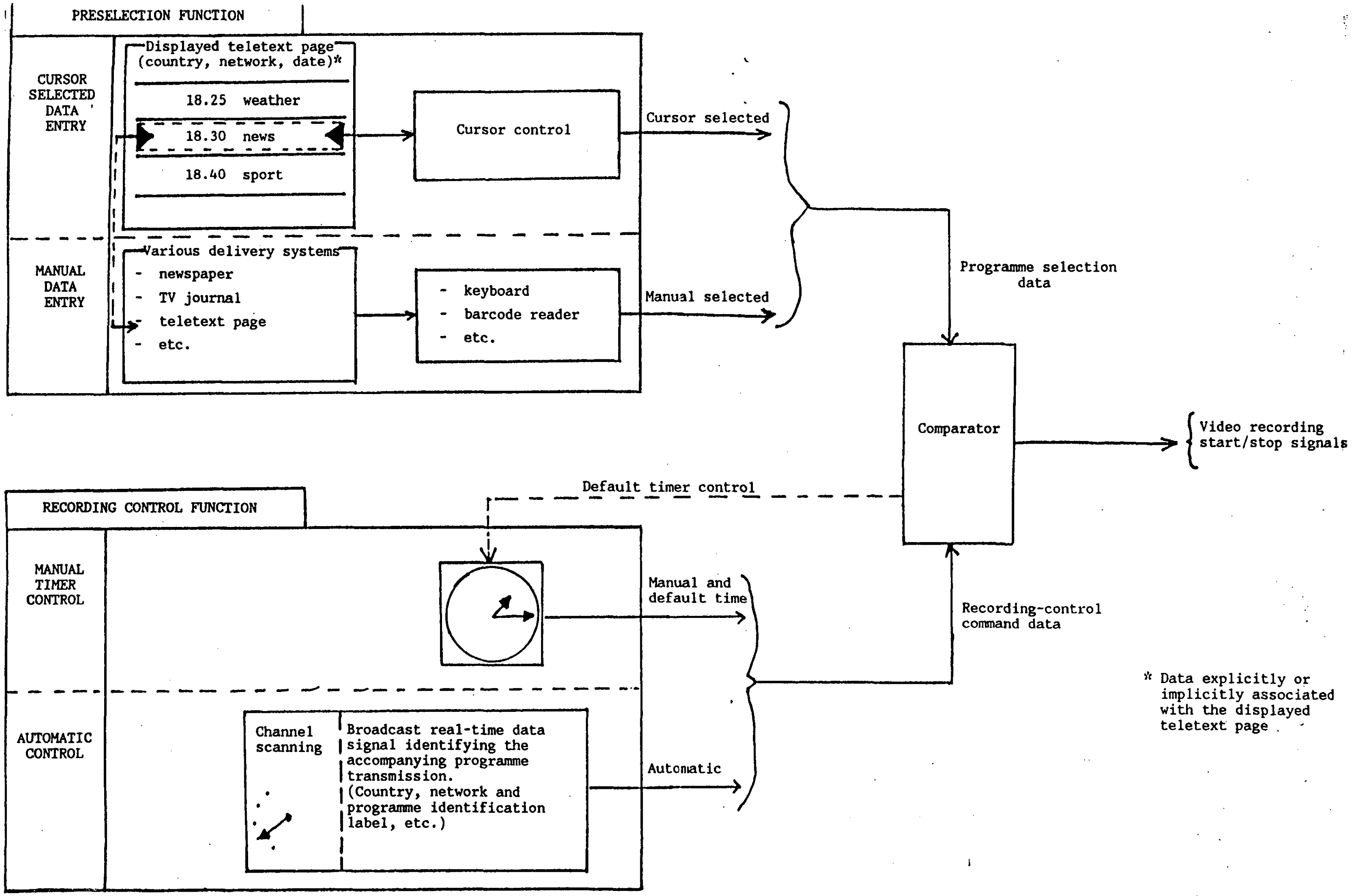

FIGURE 1

Illustration of programme delivery control (PDC) functions for video recording

3.1.1 <u>The preselection function for recording equipment</u>

3.1.1.1 Preselection via teletext under cursor control

The teletext system can be used to transmit a programme directory which includes the information needed to set up receiving equipment for the controlled delivery of chosen programmes.

Two possible methods of providing the data relevant for the preselection of programmes via teletext using cursor control are described below:

- <u>Incorporated in the displayed programme menu page</u>

  In this case, the data are incorporated into the normal teletext display page. This method takes into account the requirements for manually entering preselection data into receiving equipment.

  The data, which are of importance for programming a video recorder, are specially marked on the teletext programme-preview pages. In this way, every programme item and its associated identification data are unequivocally recognizable by a micro-computer programmed accordingly and may thus be programmed into the video recorder.

- <u>Supplementary to the displayed programme menu page</u>

  In this case, the data related to a page of text, representing a programme menu, is conveyed outside the visible text area. This method allows full editorial freedom in the composition of the page at the expense of an additional transmission data capacity. All necessary data parameters, except the "Programme title" and the "Announced time", are conveyed as machine-readable data. A parameter such as "Menu cursor position" is required to link between the programme title in the visible page and the corresponding machine-readable data.

3.1.1.2 Preselection via keyboard and barcode

The information needed to set up receiving equipment for the controlled delivery of chosen programmes may be taken from various sources such as printed lists, and visual (including the teletext programme menu) or oral announcement, and may be keyed in manually. The preselection data may also be entered with the help of a barcode reader.

If no special PDC service is offered, the parameters "Announced time" and "Announced date" together with the tuner position provide sufficient information if the programme is broadcast as scheduled. Using a programme delivery control service which includes only the recording control functions, the parameters "Announced time" and "Announced date" (together with the tuner position) allow a particular expected programme to be selected regardless of its actual transmission time.

3.1.2 The recording-control function

3.1.2.1 Specification of the recording-control commands

As stated in section 3.1, the PDC function called the recording-control allows remote control from a source of transmission of a recording made by a suitably-equipped receiver. A prerequisite is that the broadcaster sends a programme identification label in coded form together with the programme. Such a programme identification label in coded from accompanying the programme is defined as a recording-control command. It consists of a defined set of parameters selected from the list of programme identification parameters of section 3.2. Depending on the transport mechanism used the recording-control commands can be structured in several different ways (see Annex).

3.1.2.2 Repetition rate of the recording-control commands

A repetition rate for the recording-control commands of between 1 and 25 Hz is recommended.

3.1.2.3 Transport of the recording-control commands

The recording control commands may be carried in any of the CCIR teletext systems (A, B, C, and D) or in a dedicated television line (see Annex).

3.2 Programme identification parameters

A PDC system has to provide appropriate parameters for identifying a television programme in order to fulfil the preselection and recording-control functions for the automatic recording of preselected programmes. Some of these programme identification parameters are essential while other parameters are only desirable or optional. A list of the currently identified parameters is given below.

3.2.1 Currently identified parameters

a) Country and network identification (CNI)

This parameter allows identification of the country and the network or, alternatively, the programme provider.

b) Announced data (AD)

This parameter gives the scheduled date of start of the transmission of the programme in terms of years, months and days. When a local time reference is used the applicable local time offset should be made explicitly available.

c) Original announced time (AT-2)

This parameter may be divided into two groups: the first indicates the announced starting time or, where the programme has altered, the original starting time; the second gives the announced finishing time. Both are expressed in hours and minutes. When a local time reference is used the applicable local time offset should be made explicitly available in both cases as it may change between the two.

d) <u>Menu cursor position (MCP)</u>

This parameter is used to link parameters to text information displayed on the screen.

e) <u>Programme identification label (PIL)</u>

This parameter identifies the programme broadcast. For example, it may take the form of an announced broadcast time (month, day, hour, minute). Several special codes, however, may be reserved for recorder control in certain conditions.

f) <u>Programme title (PTL)</u>

This parameter provides the programme title in clear text.

g) <u>Local time offset (LTO)</u>

This parameter indicates the local time offset from UTC. More than one of these parameters may need to be sent to cover discontinuities in local time.

h) <u>Announced time (AT-1)</u>

This parameter may be divided into two groups: the first indicates the announced starting time, the second gives the announced finishing time. Both are expressed in hours and minutes. When the local time reference is used the applicable local time offset should be made explicitly available in both cases as it may change between the two.

i) <u>Programme duration (PD)</u>

This parameter shows the expected duration of the programme in hours, minutes and seconds.

j) <u>Programme control status (PCS)</u>

This parameter is used to state real-time conditions which are relevant to the programme or its broadcasting (e.g. type of sound transmission, rating of programme, access mode, ...).

k) <u>Programme type (PTY)</u>

This parameter identifies the type or series of programmes being broadcast and allows for selecting recording of certain types of programme independent of the programme identification labels.

l) <u>Conditional access flag (CAF)</u>

This parameter is used during the preselection process to signal that the programme to which it refers is not for free access.

m) <u>Unified date and time (UDT)</u>

This parameter is used for broadcasting the Coordinated Universal Time (UTC) and Modified Julian Date (MJD).

3.2.2 Coding of the parameters

Appropriate coding has to be provided in order to identify the parameters listed in section 3.2.1 for transmission. Where possible the coding of the parameters should make reference to existing specifications with the CCIR documentation: for example, for the "Country and network identification" use is made of existing ITU country codes as shown in Table I.

In Europe the codes for the "Programme type" have been classified in accordance with the "ESCORT" system [EBU, 1983] using certain principles of identification (see Table II). Further study of this system should be undertaken with a view to its adoption as a unified coding scheme.

Table I

CORRESPONDENCE BETWEEN THE CNI COUNTRY CODES AND THE ITU COUNTRY CODES

Row number coded by b_1 to b_4 (hexadecimal)
Column number coded by b_5 to b_8 (hexadecimal)

		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
	0																
	1	•	DDR	ALG	AND	ISR	I	BEL	BLR	AZR	ALB	AUT	HNG	MLT	D	CNR	EGY
	2	•	GRC	CYP	SM	SUI	JOR	FNL	LUX	BUL	DNK	GIB	IRQ	G	LBY	ROU	F
	3	•	MRC	TCH	POL	CVA	•	SYR	TUN	MAR	LIE	ISL	MCO	•	•	E	NOR
	4	•	•	IRL	TUR	•	•	YUG	UKR	HOL	•	LBN	•	•	•	S	•
	5	•	•	•	•	•	•		URS	POR	•	•	•	•	•	•	•
	6	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
F	7	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	8	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	A	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	B	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	C	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	D	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	E	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Example: The country code hex. 16 (coded by b_1-b_8 as 0001 0110) is unique to Belgium (BEL). The code hex. F6 (binary 1111 0110) also corresponds to Belgium but applies equally to Finland (FNL) Syria (SYR) and Yugoslavia (YUG).

Table II

Codes for programme type (PTY)

Code (Hexadecimal)	Principle of classification
00	Information not available
01-3E	Intended audience
3F	Alarm/emergency identification
40-7F	Content
80-BF	Codes specific to each service (to be defined)
C0-FF	Codes specific to each service (to be defined)

Code (Hexadecimal)	Programme type	ESCORT ref. number
	INTENDED AUDIENCE	
08	General audience	2.0.0
	Special Groups	
10	Ethnic & Immigrant groups	1.1.0
11	Ethnic groups	1.1.1
12	Immigrant groups	1.1.2
18	Age groups	1.2.0
19	Children (0-13 years)	1.2.1
1A	Young people (14 years or more)	1.2.2
1F	Retired people	1.3.0
20	Disabled people	1.4.0
21	Blind people	1.4.1
22	Deaf people	1.4.2
28	Householders	1.5.0
30	Occupational status groups	1.6.0
31	Unemployed people	1.6.1
32	Students	1.6.2
33	Farmers	1.6.3
34	Fishermen & sailors	1.6.4
38	Travellers	1.7.0
39	Motorists	1.7.1
3A	Tourists	1.7.2
	CONTENT	
40	Public affairs	
41	General domestic affairs	1.1.0
42	Legal and social affairs	1.2.0
43	Economic, industrial & financial affairs	1.3.0
44	Housing, environment & health affairs	1.4.0
45	Communication affairs	1.5.0
46	Educational and cultural affairs	1.6.0
47	International relations & defence affairs	1.7.0

Code (Hexadecimal)	Programme type	ESCORT ref. number
48	Science & the humanities	2.0.0
49	Natural sciences	2.1.0
4A	Social sciences	2.2.0
4B	Humanities	2.3.0
4C	Other sciences or humanities	2.9.0
50	Music	3.1.0
51	Serious music	3.1.1
52	Light classical music	3.1.2
53	Light music	3.1.3
54	Jazz	3.1.4
55	Folk music	3.1.5
56	Rock music	
57	Other music	3.1.9
58	Drama, arts	3.0.0
5A	Ballet and dance	3.2.0
5B	Drama	3.3.0
5C	Literature/poetry	3.4.0
5D	Media affairs	3.5.0
5E	Painting, sculpture, architecture	3.6.0
5F	Other drama, arts	3.9.0
60	Philosophies of life	
61	Christian religion	4.1.0
62	Non-Christian religion	4.2.0
63	Non-religious philosophy of life	4.3.0
67	Other philosophies of life	4.9.0
68	Sports	5.0.0
69	Non-instrumental ball games	5.1.0
6A	Instrumental ball games	5.2.0
6B	Winter sports	5.3.0
6C	Water sports	5.4.0
6D	Racing & equestrian sports	5.5.0
6E	Athletics	5.6.0
6F	Martial arts	5.7.0
70	Leisure and hobbies	6.0.0
71	Do-it-yourself	6.1.0
72	Gardening	6.2.0
73	Tourism	6.3.0
74	Keep fit	6.4.0
77	Other leisure or hobbies	6.9.0
78	Light entertainment, folklore and human interest	7.0.0
7A	Light entertainment	7.1.0
7B	Folklore/festivities	7.2.0
7C	Human interest	7.3.0
7F	Other light entertainment, etc.	7.9.0

REFERENCES

Technical Rules ARD/ZDF No. 8R2 [August 1987] - Second edition video programming system.

EBU Document SPG 2353 [August 1983] - ESCORT system, Geneva.

CCIR Documents

[1986-90]: a. JIWP 10-11/5-66 (EBU); b. 11/570 (Canada).

ANNEX

DATA TRANSPORT SPECIFICATIONS FOR A PROGRAMME DELIVERY CONTROL (PDC) SYSTEM FOR VIDEO RECORDING

1. Introduction

Four teletext systems have been reported at Recommendation 653. The transport mechanism used by a particular broadcaster to carry PDC functions is likely to be the teletext system adopted in the broadcaster's country. Thus, consideration of the implementation of PDC, for instance, in Canada or Japan, is likely to lead to the specification of transport coding appropriate to CCIR teletext systems C and D respectively. In Europe a specification of a PDC system has been elaborated in close cooperation with European consumer electronics manufacturing industry [EBU, 1989]. It has been designed mainly around the structure of CCIR teletext system B and used as a starting point the video programming system (VPS) developed in the Federal Republic of Germany [ARD/ZDF, 1987].

In providing a comprehensive system applicable to all of Europe, and encompassing all future requirements foreseen, particularly in an international environment (e.g. by future DSB services), downward compatibility with systems already implemented has been retained and some optional methods for performing particular functions are provided. The main characteristics of the EBU PDC system are described in the remainder of this annex.

2. Main characteristics of the EBU PDC system

2.1 Application and coding of programme identification parameters

As illustrated in the table, not all the data items specified by the EBU in the PDC system are mandatory. Some are essential to provide a minimum level of functional performance, while others may be implemented by those broadcasters who find it desirable to provide viewers with a higher level of PDC performance. Further refinement of these aspects of the service will take place as a broadcaster's "code of practice" is developed.

TABLE

Application of programme identification parameters within the programme preselection and recording-control function of the EBU PDC system

	Programme preselection	Programme recording control
ESSENTIAL	CNI AD AT-2 MCP	CNI PIL
DESIRABLE	PTL LTO AT-1 PD	PCS
OPTIONAL	PTY CAF	PTY UDT*

Appropriate coding has been provided in order to identify the parameters listed for transmission. Each parameter is described as a data field of given length and structure. The order in which the bits of the data field should be transmitted is also given.

In two cases the coding of the parameters makes reference to existing specifications within the EBU documentation: for the "Country and network identification" and for the "Programme type".

For the "Country and network identification" reference is made to the ITU country identification as also used by the EBU Radio Data System [EBU, 1984] see Table I of section 3.2.2. The codes for the "Programme type" have been classified in accordance with the "ESCORT" system [EBU, 1983]. Hexadecimal code 00 has been reserved for use when information on the programme type is not available and hexadecimal code 3F has been assigned to identify alarm/emergency messages, and the code FF indicates that no programme or series type is intended. In general, 75 out of 128 available codes between 00 and 7F have been assigned. 53 spare codes applicable to all services, and 128 codes applicable to individual services, remain to be assigned.

In the coding of the "Programme identification label" some code values have been reserved for recorder control in certain conditions, for example:

- System status code - indicating that the programme identification information is to be ignored. In this case, recording is done by timer control.

- Interrupt code - indicating a break in the programme which will continue after a short interval.

3. The preselection function via teletext

There are two methods of transporting the data relevant for the preselection of programmes via teletext:

- Together with the programme menu

  In this case, the data are incorporated into the normal teletext display page. The data, which are of importance for programming a video recorder, are specially marked on the teletext programme-preview pages using control characters. Every programme item selected and its associated identification data may thus be programmed into the memory of the video recorder.

- In extension data packets

  Related to a page of text containing data representing a programme menu, rather than within the visible text area. This method gives good error protection and allows full editorial freedom in the composition of the page at the expense of an additional transmission data capacity.

  This transport method places all necessary data parameters, except the "Programme title" and the "Announced time", as machine-readable data in extension packets of the relevant teletext page. The data items of these extension packets are placed in groups, each group being associated with one of the programme titles in the visible page. A parameter in each group is the "Menu cursor position" which points to the character and row position in the visible page close to the programme title. This provides the link between the title and the corresponding machine-readable data.

4. The recording-control function

4.1 Specification and transport of the recording-control commands

Depending on the transport mechanism in which they appear, the recording-control commands can be structured in several ways.

4.1.1 Insertion in system B teletext data packet 8/30 format 2

A recording control command is made up of the parameters "Country and network identification", "Programme identification label", "Programme control status" and "Programme type". A 20-character version of "Programme title" may also be provided.

As illustrated in Fig.1, this packet includes the prefix (5 bytes), the designation code (1 byte) and the initial teletext page (6 bytes). The next 13 bytes, numbered 13 to 25, are each (8, 4) Hamming coded using the method defined for system B teletext. The remainder of the packet (bytes 26 to 43) contains a 20-character version of the "Programme title" for display as a status message.

4.1.2 Insertion in a dedicated television line

A recording control command is made up of the parameters "Country and network identification", "Programme identification label", "Programme control status" and "Programme type".

A bi-phase modulation is used with a data rate of 2.5 Mbit/s allowing a capacity of 15 bytes for the whole data line. The first two bytes are used for run-in and the start code leaving 13 useful bytes for the identification of the relevant programme parameters (Fig.2).

4.1.3 Transport via MAC/packet systems

When the recording control commands of a domestic programme delivery service are conveyed by a member of the MAC/packet family of systems, two transport methods are applicable:

- Via teletext in the packet multiplex

  The general transport principles for teletext in the packet multiplex are given in section 2 of Part 4B of [EBU, 1986]; the structure of the relevant teletext data packet (8/30) is as specified in section 4.1.1.

- Via teletext in the field-blanking interval

  The general transport principles for teletext in the field-blanking interval of a MAC signal are given in Part 4A of [EBU, 1986]; the structure of the relevant teletext data packet (8/30) is as specified in section 4.1.1.

4.2 Repetition rate of the recording-control commands

A repetition rate for the recording-control commands of between 1 and 25 Hz is recommended. In the case of the dedicated television line the repetition rate is 25 Hz.

REFERENCES

ARD/ZDF [1987]-Technical Rules ARD/ZDF No. 8R2 [August 1987] - Second edition video programming system.

EBU [1983]-EBU Document SPG 2353 [August 1983] - ESCORT system, Geneva.

EBU [1984]-EBU Document Tech. 3244 [March 1984] - Specification of the radio data system for VHF/FM sound broadcasting, Brussels.

EBU [1986]-EBU Document Tech. 3258 [October 1986] - Specifications of the systems of the MAC/packet family, Brussels.

EBU [1989]-EBU Document SPB 459(Rev.) [May 1989] - Specification of the domestic video programme delivery control system, Brussels.

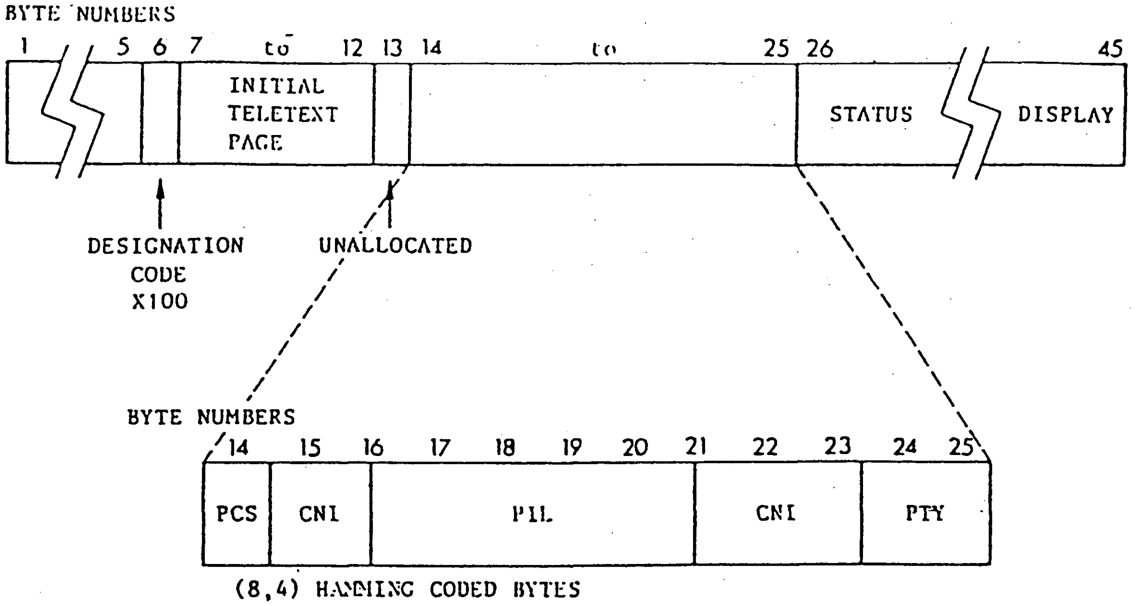

FIGURE 1 - Structure of the teletext data packet 8/30 format 2

t →

	PCS	CNI		CNI	PIL				CNI		PTY
parameter	PCS	CNI	← parameter →	CNI	day	month	hour	minute	country	network or programme provider	programme type
Byte No.	5	5	← Byte No. →	11	11	11 / 12	12	13	13 / 14	14	15
Parameter bits b_i, i =	1 2 3 4	1 2 3 4	← Parameter bits b_i, i = →	9 10	1 2 3 4 5	6 7 8 9	10 11 12 13 14	15 16 17 18 19 20	5 6 7 8	11 12 13 14 15 16	1 2 3 4 5 6 7 8
Transmission bit No.	0 1 2 3	4 5 6 7	← Transmission bit No. →	0 1	2 3 4 5 6	7 0 1 2	3 4 5 6 7	0 1 2 3 4 5	6 7 0 1	2 3 4 5 6 7	0 1 2 3 4 5 6 7
		M L			M L	M L	M L	M L	M L	M L	M L
	Bits b_1 and b_2: 0 0 don't know; 0 1 mono; 1 0 stereo; 1 1 dual sound. Bits b_3 and b_4 are reserved	country binary	Regular label	net or prog prov bin	day binary	month binary	hour binary	minute binary	country binary	network or programme provider binary	programme type binary
RESERVED CODE VALUES FOR RECEIVER CONTROL											
		N...N	System status code	N N	0 0 0 0 0	1 1 1 1	1 1 1 1 1	1 1 1 1 1 1	N.............N		A..........A
		N...N	Blank code	N N	0 0 0 0 0	1 1 1 1	1 1 1 1 0	1 1 1 1 1 1	N.............N		A..........A
		N...N	Interruption code	N N	0 0 0 0 0	1 1 1 1	1 1 1 0 1	1 1 1 1 1 1	N.............N		A..........A
		N...N	Don't care code	N N	0 0 0 0 0	1 1 1 1	1 1 1 0 0	1 1 1 1 1 1	N.............N		A..........A
		1111	Indefinite CNI row	N N	P......	......	....	.........P	N.............N		A..........A
		N...N	No special PTY	N N	P......	......	....	.........P	N.............N		1 1 1 1 1 1 1 1

Abbreviations:

CNI - Country and Network Identification
PCS - Programme Control Status
PIL - Programme Identification Label
PTY - Programme Type

M - Most significant bit
L - Least significant bit

A - bit value is that of the actual PTY code
N - bit value is that of the actual CNI code
P - bit value is that of the actual PIL code

FIGURE 2 - Data format of the programme delivery data in the dedicated TV line

REPORT 1225

DATA BROADCASTING SYSTEMS AND SERVICES IN AN HDTV ENVIRONMENT

(1990)

1. Introduction

The broadcasting of services using new television systems described in CCIR Recommendation 650 and of HDTV systems described in CCIR Report 1075 will encourage the build-up of a receiver base of high resolution and wide aspect ratio display equipment. Such equipment will offer an attractive prospect for the enhancement of existing data broadcasting services such as teletext, and for the development of entirely new services.

CCIR Recommendation 653 provides information about teletext systems developed for use with television systems of CCIR Recommendation 470 i.e. with NTSC, SECAM and PAL. This report is intended to be the basis on which a new draft recommendation, appropriate to the data broadcasting systems associated with the TV systems of Recommendation 650 and the HDTV systems of Report 1075, will be prepared during the study period 1990-1994.

The transition from conventional television to HDTV will offer the possibility of developing data broadcasting within a balanced distribution of maintaining compatibility between existing and new services. The introduction of HDTV services opens new possibilities for the broadcasting of data and accelerates the evolution of present teletext services towards the use of more sophisticated presentation features (e.g. DRCS, geometric, photographic, etc.) and completely new applications.

High resolution and wide aspect ratio displays make attractive the introduction of a variety of new teletext display formats, from computer-like 80 Latin alphabet characters per row, through to studio quality caption generator font styles and colour palette options.

Development of data broadcasting also acts in favour of the existing trend towards the integration at the technical and service levels between interactive and broadcast digital networks. In this process it is extremely important to maintain close cooperation with the CMTT, the appropriate CCITT Study Groups, the IEC and the ISO.

Emissions in digital format in an HDTV environment include integral parts of the programme such as sound and digital television components, primary programme related services such as subtitles and access control messages, and secondary digital components for non-TV-related services such as teletext, telesoftware and other data broadcasting services, which occupy capacity not used by the TV related services or freed by the removal of the TV service outside of broadcast hours.

At the present stage of development of HDTV in satellite broadcasting, two systems have been developed for use in the 12 GHz band i.e. MUSE and HD-MAC. Both systems require extensive signal processing to insert the HDTV signal into the relatively "narrow RF-band" channels (24 - 27 MHz). It is currently believed that not only will the channel bandwidth available in the 12 GHz band prevent the achievement of the full quality potential of the HDTV studio standard, but will also restrict the available capacity for data broadcasting services [CCIR, 1986-90a, b].

The CCIR has therefore envisaged the need for a further BSS band carrying HDTV in "wide RF-band" channels and offering received picture quality approaching that of the studio originated standard (see CCIR Report 1075).

To this end the WARC-ORB(88) has identified the frequency range for world-wide allocation to HDTV from 12.7 to 23 GHz. Preliminary proposals for "wide RF-band" HDTV systems, which use both analogue FM and fully digital solutions, consume from about 54 to 105 MHz depending on the system. In developing these proposals the necessary capacity for sound and data services must be adequately taken into account. The best prospect of achieving this is likely to be obtained from the fully digital approach to "wide RF-band" HDTV.

2. Harmonized evolution of sound and data services accompanying HDTV

There is a need to plan and provide adequate capacity and management flexibility for all digit components of HDTV emissions. Capacity for digital services may be located in the vertical blanking interval (VBI) or the horizontal blanking interval (HBI) of television systems which have an analogue vision part or in the multiplex of a wholly digital television system.

2.1 Integral digital components of the television service

2.1.1 Sound

All proposed HDTV transmissions make use of digital sound coding. In general the sound is likely to occupy a major proportion of the available capacity of the sound and data multiplex which could carry data broadcasting services depending on service requirements. These signals are described in Report 1075.

2.1.2 DATV

The use of DATV (digitally-assisted television) has been introduced in the HD-MAC system to improve the effectiveness of motion compensation techniques. It requires a capacity of 1.1 Mbit/sec which can be carried in the VBI, leaving in the VBI, only two lines in each field available for data broadcasting services. Wider RF-band HDTV emission systems should allow for more data capacity. DATV signals are described by [Storey, 1986] and discussed in Report 801, Part 7.

2.2 Digital services directly related to the programme

2.2.1 Subtitling

Subtitles [CCIR, 1986-90c] help viewers to follow television programmes in foreign languages. The alternative approach of sound dubbing is not only more expensive but risks the loss of much of the "atmosphere" of the artistic rendition included naturally in the original sound.

"Open" subtitles (permanently in the picture) may impair the visual quality of the television picture. Therefore the use of "closed" subtitling using data broadcasting giving the viewer the choice whether he should have subtitles or not is attractive especially in HDTV when the overall subjective response to the picture is particularly important.

The high picture quality of HDTV should be matched by a corresponding high visual quality of the subtitles. Compared with present subtitling features, the following improvements have been identified:

- smoother character fonts with proportional spacing;
- alternative fonts as well as larger character repertoires;
- enhanced colour features, such as variable saturation;
- smoother insertion into the picture;
- accuracy of timing of subtitle appearance (especially where several language subtitles are broadcast) of the positioning in the picture;
- separation of distinct parts of the subtitle service, e.g. in an interview situation, to distinguish between the speech and the name caption of the interviewed person.

The level of compatibility with present systems and services for subtitling requires study, in particular for HDTV systems which are compatible with standard TV systems.

Selection of subtitles and of the language variant, should follow a simple and standardized procedure.

Standards for the exchange of subtitles via different media should be established to avoid the need for costly reformatting.

2.2.2 *Controlled Access Messages*

Broadcasters are increasingly aware of the need for flexibility in the way they obtain revenue. Conditional access provides the means to control a mixture of advertiser supported, subscription and pay-per-view sources of revenue. This might allow the broadcaster to diversify his programming between advertisement supported and viewer supported programs.

Much effort has already been spent in the design of conditional access control systems. These systems were mainly developed for satellite delivery of scrambled services. The technology has reached a point where it is feasible to keep track of millions of subscribers at the transmit end with a reasonable size computer facility that allow channels, tiering and impulse pay-per-view to be controlled at each receiver containing a secure microprocessor.

2.2.3 *Management of channel data resource*

The time division multiplexed nature of HDTV transmission may follow a permanent structure or can be modified dynamically to suit the needs of the particular broadcast [CCIR, 1986-90a, d]. The control of such modification which must carefully synchronize the receiver with the transmission requires a data channel.

2.2.4 *Programme Delivery Control*

With the proliferation evident in the number of television services available in a given home there is an increasing need for mechanisms to be provided for the viewer to choose and watch / record selected programmes. Early systems of providing such control of Programme Delivery are operational and more sophisticated developments are being studied.

2.3. Digital data services not directly related to the programme

2.3.1 *Teletext*

The availability of HDTV will provide opportunities for enhanced presentation features to teletext services [CCIR, 1986-90e].

The wider aspect ratio and improved resolution of HDTV displays allows the presentation of much improved textual messages. HDTV displays could allow the side-by-side presentation of two full pages of text. This is a significant improvement over previous display capabilities which limits typical teletext displays to 24 rows of 40 characters.

The geometric graphics capabilities currently found in some teletext systems can be used to generate high quality graphics for HDTV displays. No modification is required other than to redefine the domain of the display area to suit the 16:9 aspect ratio and, if required, to specify data points with greater precision to suit the increased resolution of the display.

Coding schemes based on the transmission of geometric primitives, which provide compressed information to describe graphic images, offers significant advantages in transmission efficiency over other coding schemes, which rely on comparatively uncompressed data transmissions. In general, the higher the resolution of the display, the greater the efficiencies that can be obtained with geometric coding.

In addition improvements in Dynamically Redefinable Character Sets (DRCS), and photographic (still image) reproduction are possible.

2.3.2 *Telesoftware*

Such services which provide programmes for downloading into homes and business personal computers are well known.

2.3.3 Independent data services

In addition to teletext and telesoftware one way message services are another kind of such data broadcasts which can be expected to fill any available capacity. The residual data capacity available beyond the television service requirements is a scarce but powerful resource for addressing a national or international audience of receivers simultaneously. A wide variety of independent data services can be expected to fill any capacity made available in HDTV emissions.

3. Sound and data services which make use of the HDTV environment

When an HDTV transmission channel is not actively carrying an HDTV signal its capacity may be freed for other in particular independent data services. Similarly when the HDTV receiver is not in use for watching a television channel it may be put to other uses.

One application, whether delivered by the HDTV channel operating for instance in a "full channel digital mode" or by video disc, CD-ROM, ISDN or within conventional television services combines sequences of still images with sound.

A service system transmitting both still pictures of high-definition television(HDTV) quality and high quality PCM sounds using a data broadcasting channel is under development in Japan.

4. Data broadcasting resources within HDTV channels

Unlike conventional television systems in which the "unused" lines of the vertical blanking interval permitted the introduction of teletext, and digital sound capacity has been added by the use of additional subcarriers, a digital element has been a required starting component of all new television systems and HDTV systems.

Within the proposals for "wide RF-band" HDTV transmission is one fully digital example. In this case the data broadcasting service is no longer inserted within the spectral or temporal structure of the television signal, but takes its place alongside digital picture and sound components. Such fully digital solutions (which may be available also in "narrow RF-band" channels) leads to the concept of ISDB - Integrated Services Digital Broadcasting.

The locations in the television signal in which data broadcasting services may be placed are indicated in the table. In addition the complete television signal carrying the data services may be itself distributed within fibre and cable channels, and the broadband ISDN.

	Terrestrial broadcast channels	Satellite broadcast channels	
		Narrow RF band	Wide RF band
Vertical blanking interval	*	*	
Horizontal blanking interval	*	* (digital multiplex)	
Additional subcariers	*		
Full channel digital mode	*	*	*
Full channel digital multiplex for ISDB		*	*

Table - *Location of data broadcasting services in HDTV television signals*

5. Compatibility requirements for evolving data services

In the HD-MAC environment the possible coexistence of various data services in every sub-frame of the Time Division Multiplex is ensured by taking into account the opportunity of using different bit rates.

In the HD-MAC system the data capacity is split as follows:

- four lines per TV frame in the vertical blanking interval;
- forty lines per TV frame in the VBI for DATV signals;
- use of the digital line burst for sound and data transmission (including conditional access messages).

Residual capacity of the digital packet multiplex can be used for data broadcasting. A dynamic allocation of the VBI capacity can be achieved, with the highest priority given to DATV, as DATV data do not always require the use of 40 lines per frame which depends on the bit rate required. This dynamic allocation can be signalled by means of a code contained in line 625 or by other means.

To obtain better compatibility in the interface between data broadcasting channels and services, the transport mechanisms used in the HDTV channel should be identical to those of conventional data channels in the terrestrial and satellite television systems.

6. Basic model of an HDTV chain (see Fig. 1)

Specific aspects for further study include:

- integration of data services over broadcast and interactive digital networks;
- definition of data signal parameters at the physical interfaces;
- intelligent data receiver (recognition of flexible data reallocation in the digital packet multiplex, enhanced presentation features, etc.)

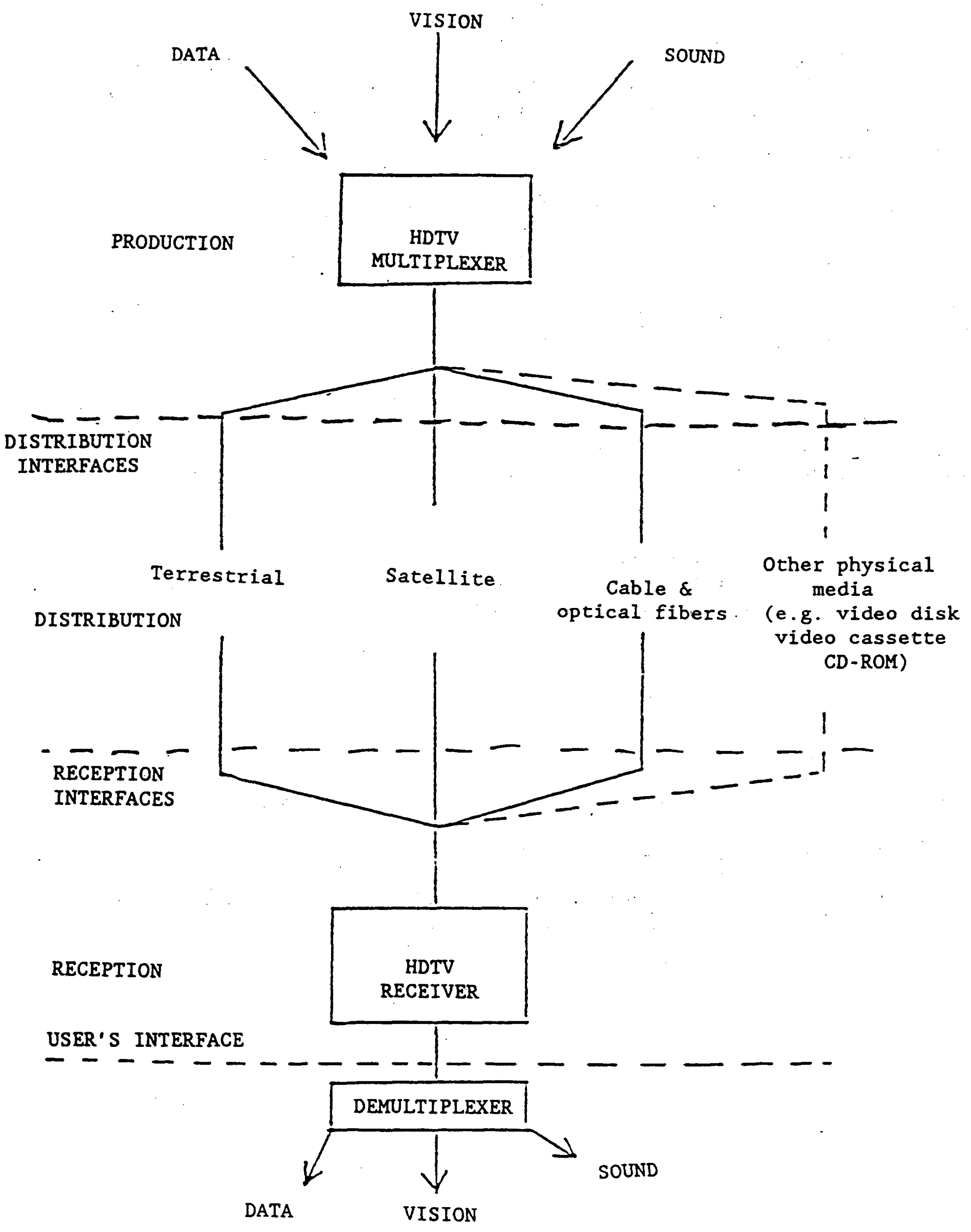

Figure 1 - *The basic model for HDTV signal distribution (vision, sound and data)*

7. Error protection strategies

The selection of error protection strategy for a particular data broadcasting service is very much service dependent. Report 1210 ———— as far as it applies to HDTV channels discusses appropriate strategies for certain service examples. Wideband HDTV transmission may require other solutions.

8. Evaluation of the quality

8.1 Data channel quality

The quality of data channel transmissions may be determined by on-line objective measurements of error ratios.

8.2 *Data service quality*

The performance of a given service in the presence of errors on reception will be measured by subjective testing methods. One example of an HDTV still image service under the influence of errors is given here. The three graphs (Fig. 2) show clearly how the removal of redundancy (going from component to subsampled and then subsampled DPCM signals) increases the subjective impairment at a given bit error ratio [CCIR, 1986-90f].

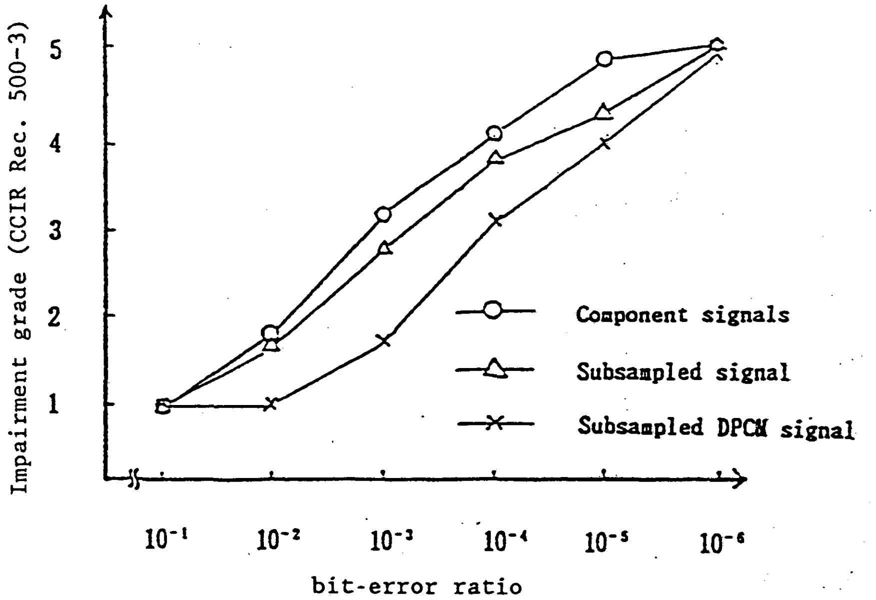

Figure 2 - *Subjective impairment due to bit errors of an HDTV still image (1125/60/2:1) at various levels of data compression*

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REPORT 956-2

DATA BROADCASTING SYSTEMS: SIGNAL AND SERVICE QUALITY, FIELD TRIALS AND THEORETICAL STUDIES

(Question 29/11, Study Programme 29C/11)

(1982-1986-1990)

1. Introduction

Data broadcasting systems utilizing television networks are already implemented in different countries for providing a multitude of services. The quality of these services depends on:

- the characteristics of the data transmission channel;
- the effect of these characteristics on the intended services.

To provide a suitable service, measurements on data transmission channels are necessary and appropriate methods have to be devised.

Part I of this Report deals with the measurement of the quality of broadcast digital data channels, Part II discusses the effects of the transmission channel on the service quality in the case of teletext*.

PART I

MEASUREMENT OF THE QUALITY OF BROADCAST DIGITAL DATA CHANNELS

1. General

Data packets inserted in some lines (data lines) of a video signal are corrupted, like the video signal itself, by noise and distortion. Given the digital nature of a data signal, the effects of these impairments are different from those produced on the analogue video signal and cannot be easily deduced on the basis of measurements carried out on conventional television test signals, such as described in Recommendation 473 (Insertion test signals) [CCIR, 1978-82a].

The quality of a digital data channel and the data acquisition circuit of its decoder may be defined in terms of percentage of data which, at the receiving site, are lost or discarded, or are accepted with errors. In this light, it is possible to define parameters representing loss or error ratios, some of which provide an indication of the performance of a data channel and the data acquisition circuit of its decoder irrespective of its use. Others refer only to particular applications, such as teletext.

In addition, the following analogue measurements can be carried out on a data signal:

- measurement of data levels,
- measurements related to eye pattern displays,
- measurement of decoding margin.

2. Digital measurements

2.1 *Data packet loss- and bit error ratios*

Digital data, inserted in a data line, consists of three parts:

- the initial run-in signal for bit synchronization;
- the framing code for byte synchronization;
- the data packet, which differs from system to system (see Recommendation 653).

* The terms "*teletext*" and "*broadcast videography*" are, at present, used interchangeably (see Appendix II to Recommendation 662).

In the case of certain data broadcasting systems, the data block is followed by a suffix for error-correction purposes.

Two impairments which can occur to the data packet [CCIR, 1978-82b, 1986-90] are:

- misinterpretation of the prefix, which results in the loss of the whole packet or a part of it, or its assignation to a wrong data channel,
- errors in the data block.

Since the data channel address is usually protected by special techniques (such as Hamming codes) the probability of a data packet being assigned to a wrong channel is usually very low. Thus, the most important parameter which quantifies the first type of impairment is the data packet loss-ratio. If the data packet does not contain a format description, it can be either totally lost or totally retained. In this case, the data packet loss-ratio can be simply defined as the percentage of transmitted data packets which has not been received. On the other side, when a format description is contained in the prefix, a misinterpretation of it can cause the loss of only part of the data, or the incorrect read-out of non-existing data. For this more complex case a convenient measurement method has not yet been proposed.

The second type of impairment (errors in the data block) is mainly characterized by the parameter "bit error ratio", defined as the percentage of the *received** bits that are affected by error. For the definition of a suitable error-correcting strategy, the knowledge of the statistical properties of errors may also be useful (for example, the probability of consecutive errors, or the distribution of errors along the data line).

2.2 *Measurements on particular data sequences*

It may be interesting, in order to investigate certain phenomena, to use fixed data sequences, so chosen as to be particularly sensitive to the distortions introduced by the system under test. An example of the fixed sequence is the "clock cracker", namely a sequence including as frequently as possible the maximum distance between transitions. This is used to test a type of clock-recovery circuit which makes use of all the data sequence, rather than solely the run-in sequence. It is also used to measure data levels [Croll, 1977].

Another example is a data sequence made of bytes, each of which contains a parity bit. This sequence allows the quality of the data broadcasting channel to be measured on a byte basis. It is also possible to make a rough estimate of the distribution of errors, which may be either random or concentrated on those bytes which produce a bit configuration particularly sensitive to inter-symbol intereference.

Measurements of various types of error and loss ratios in conventional and specially protected (bi-phase) teletext signals are described in [Cominetti *et al.*, 1976]. These parameters may also be calculated using a comprehensive mathematical model [Vardo, 1977; Cominetti *et al.*, 1978].

3. Analogue measurements

A list of analogue parameters relating to measurements of data levels and eye pattern of a data signal is given in Appendix I.

4. Data test signals

Various data test signals have been defined for digital and analogue measurements.

Pseudo-random sequences: These are used for the measurement of bit error-ratio and packet loss-ratio and for the display of eye pattern [Dublet, 1977; Noirel, 1978].

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* When a data block is lost, the contained bits are not taken into account when determining the bit error ratio.

Fixed data sequences: These are used for various purposes. An example is the sequence used in [Cominetti *et al.*, 1976] for the measurement of various types of error ratios and loss ratios. Another example is the "clock cracker sequence". This is a data line containing a character sequence including as frequently as possible the maximum distance between transitions. It is used to test the clock recovery circuit in the data receiver and to measure data levels [Croll, 1977; CCIR, 1978-82c and d].

Data pulse and bar: This signal is made up of an isolated data positive pulse, followed by a data bar (sequence of 1's), containing an isolated data negative pulse. It is used to obtain an eye-shaped diagram by superimposition of the two pulses, to measure data levels, and to analytically derive the eye pattern, in the presence of purely linear distortion [Croll, 1977].

Combined test sequence: A combination of clock run-in, data pulse and bar and a fixed data-sequence including all combinations of 7 successive bits, to provide a test half-line for inclusion in the field-blanking interval, complemented on alternate fields, has been illustrated [Holder, 1977].

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APPENDIX I TO PART I

PROPOSED DATA SIGNAL PARAMETERS – CONCEPTUAL DEFINITIONS

1. *All-zeros level:* the level resulting from a continuous stream of "zero" pulses.

2. *All-ones level:* the level resulting from a continuous stream of "one" pulses.

3. *Mid-level:* the level midway between all-zeros and all-ones levels.

4. *Basic amplitude:* the difference between the all-zeros and the all-ones levels.

5. *Zeros overshoots:* the amount by which the peak value of the signal extends beyond the all-zeros level.

6. *Ones overshoots:* the amount by which the peak value of the signal extends beyond the all-ones level.

7. *Peak-to-peak amplitude:* the sum of basic amplitude, zeros overshoots and ones overshoots.

8. *Eye height:* in a noise-free data signal, the eye height reflects the smallest difference which may exist between any "zero" pulse and any "one" pulse over all signal sampling positions. It is expressed as a proportion of the basic amplitude. (In practice, the sampling positions depend on the type of clock used, which must be specified).

9. *Decoding margin:* in a non-return-to zero (NRZ) data signal the decoding margin reflects the greatest difference which may exist between extreme logical decision levels for a given bit error-rate, when the signal samples are referred to the run-in timing and equally spaced at the data rate. It is expressed as a proportion of a specified basic amplitude.

10. *Eye width:* in a noise-free data signal, the eye width is the interval over which true data results from comparison of the signal with a specified decision level. It is expressed as a proportion of the bit period.

11. *Proportional jitter:* in a noise-free data signal, the proportional jitter at a particular decision level is the proportion of the bit period not occupied by the eye width.

12. *Decoding threshold:* this term relates to a terminal which accepts an input data signal and which provides output characters primarily intended for display. For a given degradation of a particular input signal, the decoding threshold is the smallest acceptable decoding margin of the input signal, for a defined character failure ratio.

PART II

ASSESSMENT OF TELETEXT SERVICE QUALITY

1. Introduction

For a teletext service, the picture quality is as important a parameter as for television. It should be emphasized however, that the evaluation methods and criteria described in Recommendation 500, "Method for the subjective assessment of the quality of television pictures" do not cover all aspects of the teletext picture quality assessment. Relevant material on the subjective quality of alphanumeric and graphics pictures is also found in Annex VI to Report 405 [CCIR, 1978-82a].

Hitherto the influence of errors (appearing in the teletext transmission process) on picture quality has been the aspect of main interest, in this document provisionally called the "conformity" aspect. It might be expected that a global assessment will gain in importance as teletext services become established. Such a global assessment would also include the usefulness of the typographic facilities of the system and the display performance of the receiver and would be based on the properties of the human eye and mind. The effect of these principles on characters generated by systems other than the dot matrix system requires further study.

The following text discusses in a tutorial manner the various technical factors which have an influence on the picture quality. Information access, which is an important quality aspect of a teletext service, is discussed briefly. It is based on studies carried out within the EBU [CCIR, 1978-82b].

In [CCETT, 1981] a wider choice of criteria is proposed and the complementation of objective measurements by subjective assessments is suggested.

2. Picture quality characteristics

One tentative list of picture characteristics is:

- the typographic facilities provided by the system;
- the display quality provided by the display device;
- the "conformity" of the picture as received and displayed by the receiver, related to the picture that would be displayed by the same receiver if there were no errors in the received bit stream (i.e. there are no bit errors after the data acquisition process).

This classification could be appropriate when the technical causes for a quality defect or the limits for the attainable quality are to be analyzed.

The characteristics may be difficult to separate but "typographical facilities" is intended to reflect such items as: character sets, pictorial facilities, display attributes and page layout functions given in the system specification. "Display quality" is intended to reflect the influence of the picture generating and display circuits and the picture tube of the receiver, while the "conformity" is intended to reflect the influence of the transmission, error protection and coding/decoding processes.

Another classification of picture quality parameters could be appropriate when a global assessment of the picture quality is made through viewer tests and when there is no direct interest in separating the causes of the defects. Then such properties as legibility, reading speed and visual comfort could be appropriate. This type of assessment is described in [CCIR, 1978-82a, c].

2.1 *Typographical facilities provided by the system*

A teletext specification normally specifies in a detailed way which facilities are available to form the message to be conveyed. Some important facilities are:

- the character repertoire;
- the display format, i.e. the number of rows available on a page and the maximum number of characters per row;
- the display modes, e.g. normal, boxed or mixed display;
- the display attributes, e.g. background colour, character size and flashing display, and the way they can be used.

For systems using geometrical or photographical coding principles, additional characteristics of importance can be defined.

It should be observed that a service might not utilize all available facilities. Also, receivers might be in use which cannot fully exploit all facilities in the transmitted messages. These receivers should fall back on an appropriate substitution facility or the editor should provide a substitution.

2.2 *The dependence of the picture quality on the properties of the display device*

2.2.1 *General*

Some technical parameters such as character size, luminance levels, resolution, etc., could be measured by appropriate instruments at the face of the picture tube.

With the help of human observers, performance measurements could be made, based on psychophysical methods, which measure such aspects as recognition of representative stimuli and reading speed. Such measurements are absolute in the sense that the performance is not compared with the performance of a reference display device, but the method can be used in comparisons of display devices. Appropriate test pages should be used and the viewing conditions kept under control.

Teletext may sometimes be viewed under different conditions from television. The picture is also of a different nature, and the viewing conditions specified in Recommendation 500 might have to be revised when applied to teletext [CCIR, 1978-82a, c]. This concerns both ambient conditions such as viewing distance and room illumination and conditions of the display device itself, such as the luminance of the active and inactive parts of the screen.

2.2.2 *Technical factors of importance*

With the display formats defined in Europe (24 or 25 rows per page and 40 characters per row), it is possible to reproduce most of the alphanumeric characters with a satisfactory resolution, so that they can be easily identified by the viewer.

Apart from the factors mentioned above, the quality of the display also is influenced by several factors, some of which are mentioned below:

- resolution of the character matrix and its font;
- stability of the teletext display when a noisy television signal is received;
- use of internally generated non-interlaced scanning to eliminate flicker on the teletext display;

- use of a character rounding technique in order to improve the character shape. (This technique, however, can be implemented only with conventional television scanning or by means of special receivers, e.g. those conceived for compatible but higher quality type of television display without interlace flicker);
- use of multi-level RGB signals in character representation;
- variable character spacing.

2.3 *Conformity of the picture*

2.3.1 *Classification of conformity defects*

Transmission errors cause various forms of conformity defects. The nature of the defects and their frequencies of occurrence depend on several factors.

The relative severity of the defects depends in a complicated way on the content of the page, e.g. text or pictorial material, and its composition. An exhaustive study is therefore difficult. An attempt to list the various defects that are of interest for pages containing text gives the following result:

Layout defects:
- page loss,
- page interference,
- incomplete page,
- row loss,
- row interference,
- incomplete row,
- displaced row,
- displaced string of characters.

Display defects:
- incorrect character display (false or blank character),
- display of error symbols,
- incorrect display attributes*.

For mosaic pictures, it would be appropriate to describe the conformity defects in other terms. Alpha-geometric and alpha-photographic coded pictures would require a further set of terms.

For pages with text and where there is some redundancy, i.e. where the message could be understood even if some isolated characters (letters) were missing or incorrect, layout defects are the most serious because they may lead to the loss of many contiguous characters. For pages where there is no redundancy in the message, for example when a page contains a table giving numerical values, incorrect character display is a very serious form of defect.

2.3.2 *Factors influencing conformity*

Distortion of the signal waveform during the transmission process and interference from other sources result in bit errors in the output from the data acquisition circuits in the receiver. The error characteristics are a measure of the data channel quality. Lack of data channel quality causes conformity impairment, but the grade of impairment also depends on the transmission format, coding scheme and the error control provisions, both at the transmitting and receiving end.

2.3.2.1 *Data channel quality*

The quality of the digital data channel is usually expressed through its average data block loss ratio and the average error ratio of the bits in the received blocks. Measurement and specification of the quality are described in Part I of this Report and in Document [CCIR, 1978-82d].

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* Some incorrect character size attributes might cause layout defects.

Experience shows [IRT, 1980] that errors may depend on the bit-patterns within the data block. Average bit error and data block loss ratios do not therefore always permit an accurate deduction of the performance of a receiver which is connected to the channel. The errors obtained also depend on the design of the data acquisition circuits, and therefore the performance assessed with one type of receiver or measuring instrument will not always predict the performance of another type. [IRT, 1980 and RAI, 1979] show that the relative merits of different designs depend on the type of waveform distortion prevailing.

These characteristics of the data channel, due to the data acquisition circuits of the receiver and preceding receiver circuits, have to be taken into account when test pages for conformity assessment are designed (see § 2.3.3.2).

2.3.2.2 *Transmission format and coding schemes*

Two basic transmission format principles are being used at present.

The fixed-format principle has a predefined relationship between the transmission format (i.e. the positions of the character codes on a television data line), a location in the page memory in the decoder, and for level 1 decoding, the display format (i.e. the position of the corresponding characters in the text rows). For fixed-format systems with "level 2 decoding", when the information complexity requires it, information supplementary to the "level 1" version of the page is transmitted with packet addresses corresponding to rows that are not displayed ("ghost rows"). The fixed-format principle is maintained since the addresses for the supplementary information and the associated character data are related to the transmission format.

In variable-format systems, the information is represented by a unique data stream, significant in itself (i.e. whether a code is "spacing" or "non-spacing" is defined by the codes themselves), and where separation between rows is given by a particular code (sequence). A variable-format system allows the transmitted information to be compressed.

Present teletext systems and proposed variants use a 7-bit or 14-bit code to describe the alphanumeric set. Mosaic and supplementary alphanumeric sets are obtained through videotex code extension techniques in variable-format systems. In fixed-format systems, special but related techniques are used, some of which are mentioned above.

Variable-format systems are sometimes regarded as more sensitive to layout defects than fixed-format systems, which rely on synchronization imparted by the television synchronization signals. However both fixed- and variable-format methods allow for the introduction of specific means for error correction through redundancy, obviously at some cost in transmission efficiency.

Experience with transmission of the fixed-format system operating at "level 2" has been gained and an analysis has shown that no loss of ruggedness occurs in comparison with operation at "level 1" [CCIR, 1978-82e].

Experience has been gained with a fixed format system for text, including ideographic characters, using photographic coding. Field and laboratory tests of a second generation system employing alpha-DRCS-photographic coding found little difference between fixed and variable transmission formats. The variable format was adopted because of its flexibility [CCIR, 1982-86].

2.3.2.3 *Error protection provisions* (see Report 1210)

2.3.3 *Assessment of conformity*

2.3.3.1 *Computer simulation*

The conformity under given conditions can be investigated through simulation methods. Thus, for a specified system, a statistical measure of the conformity could be calculated in the form of the relative probabilities of occurrence of the various defects by taking account of the error protection, data channel and page characteristics.

Simulation should be an efficient method both for optimizing the error protection provisions of a system or receiver and for assessing the conformity that would be obtained under given conditions.

As stated in § 2.3.2.1, experience indicates that the data channel quality might be difficult to specify in the form required by the simulation model.

2.3.3.2 *Test pages for conformity assessment*

Test pages could be used when simulation is not possible or when the representativeness of a simulation is to be checked. In addition to the representative pages that are needed in the latter case, the following two types of page could be of use:

2.3.3.2.1 *Test pages for assessing the quality of the data channel*

The quality should normally be measured by methods described in part I of this Report. When no special measuring instruments and signals are available, a rough assessment of the bit-error ratio can be made by observing a test page. The content of this page should be such that there is little risk of layout and display attribute defects occurring. This would mean that the page should comprise only characters of the GO set. For variable-format systems, some care might have to be taken to avoid codes and code sequences which a particular algorithm could decode as a control function when bit errors occur. Alternatively, the algorithm should not be used during the assessment.

The composition of the page should be such that errors are easily observed.

It could be of value to include those character sequences which are expected to be the most critical with respect to the characteristics of data acquisition circuits in use and the types of signal distortion encountered. Such a page could be said to be critical with respect to the distortion of the data signal waveform.

2.3.3.2.2 *Test pages for assessing the service quality in field trials*

A page of this type makes it possible to assess the influence of the data channel quality on the conformity of the displayed page. It should be composed so as to be more critical than a normal page with respect to layout and display attribute defects. Its actual content would depend on the system used and its typical error correction provisions. It would contain accented characters, mosaics, display attributes and layout functions to a great extent. More than one page might be needed to cover all critical points.

It might be difficult to define common test pages for different systems. Care has to be taken in the composition of the pages so that they test any combinations of decoder design principles, type of signal distortion and bit patterns that are particularly critical.

2.3.3.3 *Test pages for other purposes*

When a global assessment of the picture quality is to be made, the typographical facilities of the system and the quality provided by the display device have to be taken into account in addition to conformity aspects. The pages used should be representative for the service, or, for some types of assessment, critical with respect to legibility and visual comfort.

The teletext viewer would require means for verifying the correct function of his receiving installation. Test pages of the types described in § 2.3.3.2 could be used for this. Probably more than one page would be required to test all typographical facilities in the receiver.

There is also a need for appropriate test pages in industry and for maintenance purposes.

2.3.3.4 *Automatic methods*

It appears to be relatively simple to check the quality of reception, i.e. the data channel quality, by automatic methods. These could be based on the character parity check, a page check sum or on the regular transmission of a pseudo random bit sequence or other special signal. If the detection of the errors could be made at the display language level instead of at the transmission language level, a check of the conformity is obtained.

As the observation of test pages is a demanding task, automatic methods could be of great value both for the teletext service public and in technical studies.

2.3.3.5 *Conformity grades and assessment criteria*

Repetitive transmission is normally used and advantage is normally taken of this to provide error protection in the receivers. The assessment criteria that have been used hitherto and those that are proposed below therefore assume this. The criteria thus indicate that conformity could be a function of the access time.

When conformity is assessed with a test page of the second type in § 2.3.3.2, four grades of conformity with associated criteria are proposed:

Grade 4: there are no defects after the first acquisition of the page.

Grade 3: there are defects after the first acquisition of the page, but they disappear at the second acquisition.

Grade 2: there are defects after the first acquisition of the page, but they disappear after more than two acquisitions.

Grade 1: defects remain after successive acquisitions of the page.

The reliability of the assessment will depend on the number of "first acquisitions", i.e. samples, which are made. The grade obtained for a majority of samples should be stated. For grade 3, a larger number of samples appears necessary for a reliable assessment than for other grades.

Grade 4 could be said to reflect a conformity that would be regarded by the viewer as "normally perfect" or better. Grade 3 corresponds to a situation where correct display is obtained at the expense of an increased access time which could be accepted by some viewers. Grade 2 would provide a correct display after a normally unacceptably long access time, which, however, could be accepted in some applications of multiple-page memory decoders. Grade 1 differs from grade 2 in that the displayed page does not converge to a correct display.

The criteria are not based upon any graded scale of conformity impairments. They only very indirectly relate to the grade of conformity for the first acquired page by stating the number of repeated acquisitions that are necessary for the impairments to disappear.

Other criteria e.g. [BBC, IBA, IRT, 1975] have been used in field trials. They are:

Criterion A: no errors received in 10 s for entire data stream.

Criterion B: no visible errors in each of three consecutive new acquisitions of one page.

Criterion C: no visible errors remaining on the second writing of one page.

In general, satisfaction of these criteria will depend upon the coding strategy and will therefore correspond to different bit-error ratios for different teletext systems. It is desirable to establish the relationship between quality evaluation criteria such as B and C, and the bit-error ratio. Assumptions regarding the performance of the teletext decoder will then permit the establishment of acceptance limits for parameters such as eye height which allow the performance of the transmission path to be related to the bit-error ratio. Such a relationship has been studied in [Lucas, 1976].

3. Information access aspects

The amount of information that is available in a teletext service and the access time for a selected page are important aspects. A basic measure is the mean access time which is half the product of the number of pages in the transmission cycle and the mean page transmission time. To find the mean access time for a particular system, a representative set of pages for the service must be used as the basis for calculation of the mean page transmission time. Studies have been conducted [CCETT, 1982] on the assessment of the inconvenience caused by delay occurring between the user's request and the display of the requested information in the specific context of broadcast videography. First results, subject to confirmation, show that an access time of about 12 s corresponds to "slightly annoying". Moreover, the results obtained prove to be dependent on the semantic contents of the screens.

Other studies [Treurniet *et al.*, 1985] examined the relation between system response time and various degrees of viewer annoyance. The proportion of viewers "slightly annoyed" or worse (A_s) increased with the square root of observed delay:

$$A_s = 0.129 \cdot \sqrt{d} + 0.030$$

Corresponding equations for the proportion of viewers "moderately annoyed" or worse (A_m) and "very annoyed" or worse (A_v) were respectively:

$$A_m = 0.059 \cdot \sqrt{d} - 0.008 \text{ and}$$
$$A_v = 0.020 \cdot \sqrt{d} - 0.030$$

Multipages and other special page repetition patterns as well as use of multiple-page memories, make it more difficult to characterize the access time performance. Another factor is the relation between conformity and access time, as mentioned in § 2.3.3.5, which would mean that for a site with bad reception conditions, the access time would be longer than for a "good" site within the same transmitter service area.

Teletext system B includes a means of user friendly page access, together with a significant reduction in waiting time. The system includes, in each page, the facility to provide page address linking data for other page addresses. Associated with four of these links is an additional row of data for display. The editor can include prompting text in this row directing the user to one of four identified keys on the control unit. Operating such a key causes the linked page to be displayed by the single key stroke rather than the complete page number of 3 or 7 digits. Where a receiver decoder has multi-page storage, the linked pages are acquired automatically with each selected page and are thus available virtually immediately for display. This feature is known as "FASTEXT".

Results of field trials and theoretical studies are to be found in Report 956 (Volume XI, Part 1, Dubrovnik 1986).

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[1982-86]: 11/30 (Japan).

REPORT 1210

ERROR-PROTECTION STRATEGIES FOR DATA BROADCASTING SERVICES

(1990)

1. Introduction

Certain extensions of the display capabilities of existing teletext and subtitling services (e.g. the inclusion of non-latin based alphabets and non-alphabetic writing systems [CCIR, 1986-90a] as well as new data services, some of which are already identified in CCIR Report 802, require the adoption of error-protection strategies able to guarantee a high degree of confidence in the recovered message without undue repetition.

Sophisticated and powerful decoding strategies are now feasible thanks to progress in consumer microelectronic technology and can be implemented today, at low cost in commercial receivers. Thus, additions of a means of forward error correction will allow data to be corrected before they are decoded when the data packets are organized as an error correcting code [CCIR, 1982-86a]. Provided adequate buffer storage exists and time between data acquisitions permits sophisticated software programming techniques for error correction can also be used to acquire the service components correctly [CCIR, 1986-90b].

Section 2 outlines the general considerations for error protection strategies. Section 3 reports some studies of error protection strategies applied to present terrestrial broadcasting systems. Section 4 reports examples of error protection strategies for data transmission using satellite broadcast channels.

2. General considerations on error protection methods

The quality of a data broadcasting service depends mainly on the influence of transmission errors on the correctness of the recovered information message and appropriate error protection methods used. The following factors should be taken into account:

- the nature of the data to be transmitted;
- the quality of the transmission path;
- the unidirectional nature of the transmission path;
- the use of common strategies for the broadcast environment and their extension, if possible, to other media;
- efficiency of the coding technique.

Major methods for error protection can be divided into the following categories:

- Parity Check
- Forward Error Correction (FEC)
- Cyclic Redundancy (CRC)
- Majority Logic (ML)
- Bit Variation (BV)
- Error Concealment

Generally one or more of the above error control methods may be combined to provide satisfactory error performance.

For teletext services, in severe reception conditions, a residual error probability is usually tolerated for alphabetic and syllabic writing systems due to the high redundancy in the displayed text. In particular this applies to those systems where data synchronization is maintained and the displayed character position is fixed. Hence decoding can use a simple parity check at character level, combined with a cyclic transmission sequence without penalizing the majority of the audience served by satisfactory reception conditions. In other systems, simple FEC in each data packet both improves the reception and provides a check against errors. A high level of confidence can be provided by including a CRC at page level.

The quality requirements are more severe as regards enhanced teletext services, teletext for non-alphabetic writing systems and services such as telesoftware and transparent data services, either with cyclic or non-cyclic transmission. For these services, a high degree of confidence is of utmost importance and, in principle, no residual error probability can be tolerated because of the effect of these errors on the decoded message. The addition of suitable redundancy for error control, often associated with message repetition, is necessary in order to ensure a satisfactory reception quality in severe reception conditions. In such conditions, an eventual increase of the access time, resulting from the need for repeated message acquisitions to recover the correct information, will generally be acceptable, provided that the decoding strategy allows a high probability of success at the first attempt for the majority of the audience.

3. <u>Studies based on the transport mechanism derived from CCIR teletext systems</u>

3.1 <u>Studies in France</u>

It is shown /‾CCIR, 1986-90c_/ that the use of a CRC on the packet level of the DIDON data broadcasting system is effective in reducing the residual bit rate. Majority logic and error detection by CRC (e.g., a family and strategy as well as error correction by the CRC was studied through computer simulation of a transmission channel. The results show that the error processing can be adapted to yield a desirable residual BER for a range of input BERs (Table I).

TABLE I

INPUT bit error rate	Minimum number of repetitions for a residual bit error rate $< 10^{-6}$ C.R.C. processing: error detection	error correction
10^{-3}	4	2
5×10^{-4}	2	2
2×10^{-4}	2	1
10^{-4}	2	1
5×10^{-5}	2	0
2×10^{-5}	1	0
10^{-5}	1	0
5×10^{-6}	1	0

3.2 Studies in Italy

Laboratory tests and field trials have been carried out in Italy [Cominetti et al. 1986] [CCIR, 1986-90d] to assess the performance of error-protection strategy used in the telesoftware system developed by the RAI and using the structure of CCIR teletext system B.

This strategy is based on the adoption of a (40,34) Hamming code, for forward correction of any single error in a block of 4 bytes, associated with a cyclic redundancy check (CRC) for the detection of residual errors on each data row [Cominetti and Morello, 1985].

From the results the following conclusions have been drawn:

- The telesoftware service requires a reception quality higher than a teletext service (level 1), both for the high sensitivity to transmission errors and for the greater length of the data "files" (e.g. about 10 pages for a 10 kbyte telesoftware file).

- The use of a (40,34) Hamming code represents a satisfactory compromise between transmission efficiency (80%) error correction/detection capability and decoding implementation economy.

- The efficiency of the error-correcting code against the occurrence of repetitive critical data patterns can be improved by masking the transmitted data with pseudo-randon sequences.
  With the above error protection strategy it was possible to recover 1 kByte file, error free, at the first acquisition with 85% probability of success at BER of about 10^{-3} .
  Without using this error protection strategy the same probability of success was achieved at a BER of about 2×10^{-5}.

3.3 Studies in the Federal Republic of Germany

A technique called bit variation has been studied in the Federal Republic of Germany. It is a highly effective error correction control scheme in the case of poor reception conditions. The technique is based on a two-fold transmission of data. Where the received bit values differ at the same position within two acquisitions of a data block, the bit values are successively modified until the error check is satisfied. In combination with a low-redundancy FEC (about 5%) and error detection by CRC, such a correcting strategy will provide 99.9% probability of correct reception of subtitles, teletext pages and 10 kbyte data files at bit-error rates up to 5.10^{-2} [CCIR, 1986-90e].

3.4 Studies in Japan

Error-protection schemes for data broadcasting has been extensively studied in Japan since 1977, bearing in mind application to teletext services. Using error pattern data collected in field tests, simulations on the performance of many kinds of error-correcting codes have been carried out. Field experiments to compare the error-correcting capabilities of several kinds of proposed codes have also been carried out. Based on these simulations and experiments, the (272, 190) difference set cyclic code was adopted for the data broadcasting system for the CCIR teletext system D. This code has an efficiency of 70% and an estimated capability of correcting 11 incorrect bits in a 272-bit block [CCIR, 1982-86b]. A block error rate of 10^{-5} can be obtained at a bit-error rate of 10^{-2}.

In addition to the (272, 190) code, the use of the continuity index in packet transmission and the cyclic redundancy check (CRC) in the data group level have made the transport mechanism of the system a very reliable one. Figure 1 shows the error protection capability of the (272, 190) code and CRC.

In general, reliable transmission can be expected when the above mentioned strategies are applied to services other than teletext whether they are transmitted terrestrialy or by satellite. Studies are being carried out on the application of the error-protection strategies on various types of data broadcasting services (Figure 2).

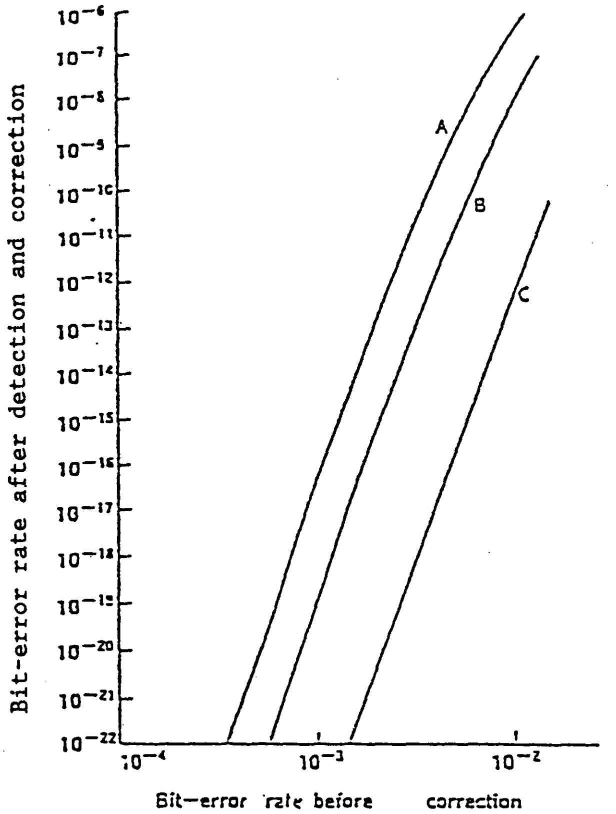


FIGURE 1

The error protection capability of (272, 190) code and CRC

curve A: error correction capability of the (272, 190) code

curve B: error detection capability of the (272, 190) code

curve C: error detection capability of the (272, 190) code combined with CRC

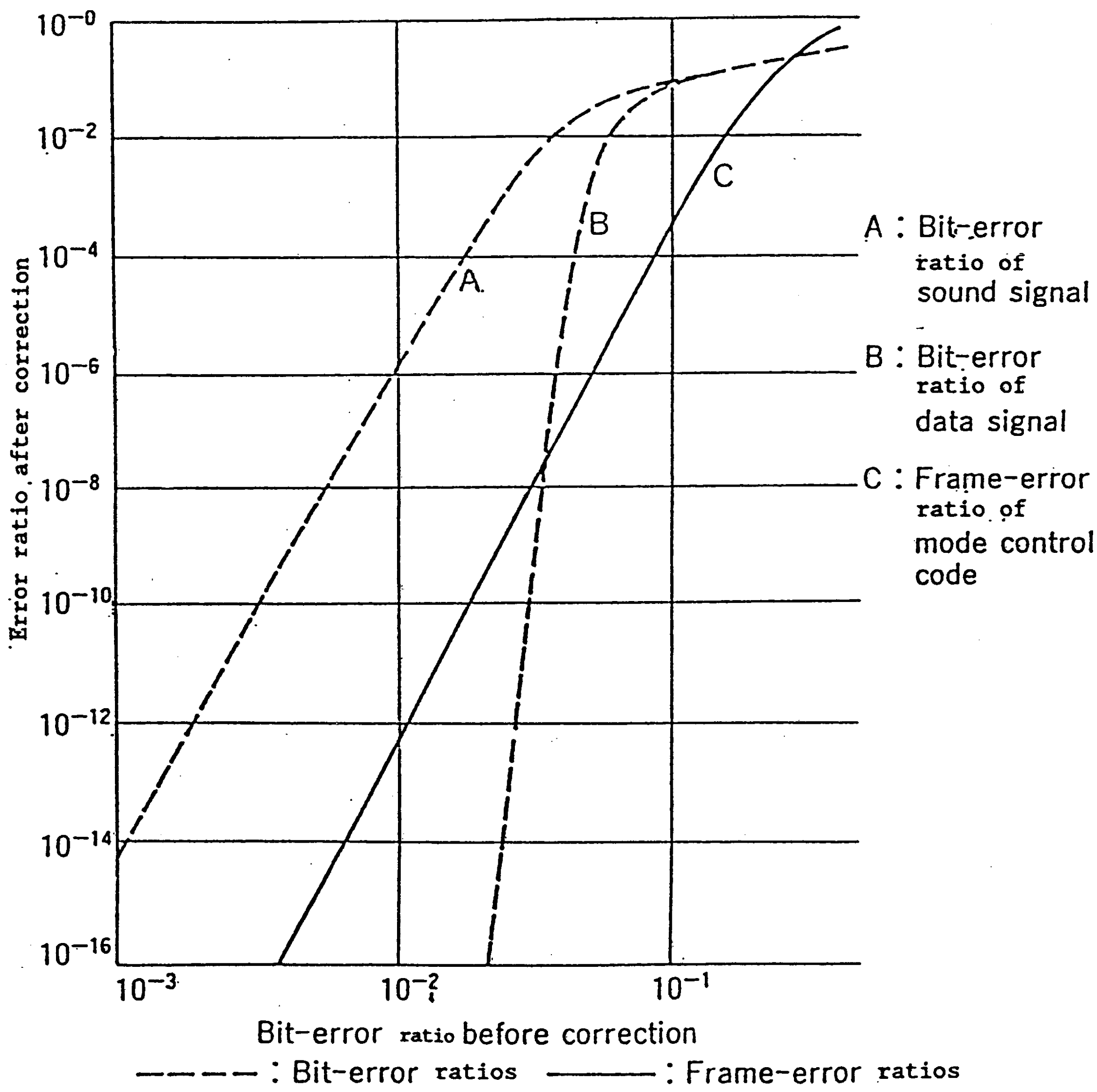


Fig. 2 Performance of the error-correction strategy

4. Examples of error protection strategies for data broadcasting using satellite broadcasting channels

4.1 Data transmission in the MAC/packet digital multiplex

The EBU has studied various error-protection schemes [CCIR, 1986-90f] for standardization of a suitable transport mechanism for data services in the digital multiplex of the MAC/Packet family of systems [CCIR, 1982-86c, d]. These strategies may be applicable to other transport mechanisms than those of the MAC/Packet digital multiplex.

Two particular error protection schemes have been defined by the EBU [CCIR, 1986-90g] for the transport of teletext of CCIR Systems A and B in the MAC/packet digital multiplex. The first level utilizing cyclical redundancy check coding alone is primarily intended for cycled data services where error correction can be provided by using majority logic or bit variation at the receiver. The second level—— utilizes (24,12) Golay forward error correction to provide a high level of protection on a single transmission of teletext data.

4.1.1 Error protection strategies

Various error-protection strategies have been proposed [Cominetti and Morello, 1985] and [Eitz and Moell, 1988] which make use of one or more of the following main error-control elements:

- cyclic redundancy check (CRC)
- error correction by majority logic (ML) or bit variation (BV)
- forward error correction (FEC).

Depending on the error-protection strategy chosen, both at the transmitter and at the receiver, different decoder behaviour in the presence of errors can be achieved whereby the error performance under non-satisfactory reception conditions could be moved between the following two extremes: high level of confidence that a data message will be error-free at the first acquisition, at the expense of an additional amount of redundancy for forward error correction, or the need for message repetition and multiple acquisitions to obtain error-free reception.

While error detection can be efficiently implemented by low-redundancy codes, forward error correction in poor reception conditions (BERs greater than 10^{-3}) requires a large amount of additional redundancy.

When the offered service is not inherently cyclic, the adoption of powerful FEC codes often gives better error performance than multiple transmissions and majority logic [BSB, 1989] or bit variation decoding, provided that the transmission efficiency is kept constant. However, when the service is cyclic, the repetition does not involve a reduction of transmission efficiency. In this case, it could be more appropriate to exploit the message repetition rather than introduce very powerful FEC codes thus avoiding an increase in access time in regions where receiving conditions are good.

It is important to point out that, when the error rate on the channel exceeds the error-correcting capability of the code, the forward correcting procedure may occasionally introduce new errors. In contrast, error correction by majority logic can usually operate in such conditions, thereby reducing the channel error rate.

The behaviour suggests combining majority logic, or error correction by bit variation, with forward error correction; the first will reduce the BER to an acceptable level for the code correcting capabilities, and the second will eliminate the residual errors; in this way, it is possible to keep the additional redundancy to a low level, while assuring the required service quality. The choice of the optimum error-protection strategy in the receiver is then a trade-off between the exploitation of cyclic message repetition and the use of forward error correction. In general it seems necessary to identify some basic strategies and compare their correcting capabilities as a function of the channel bit-error rate.

4.1.2 Typical values of data content

The EBU has used the following values of data content to characterize and assess service quality:

- a typical teletext page: 1 kbyte
- a typical two-row subtitle: 80 bytes
- a typical unit of telesoftware: 10 kbytes

4.1.3 Criteria for satisfactory performance

The following limits of a service conveyed in the digital multiplex of the MAC/Packet family of systems have been considered:

- teletext : at a random BER of 3×10^{-3}, two or three acquisitions will provide an error-free display with a probability of success larger than 97%
- subtitling : a two or threefold repetition of each subtitle will provide error-free subtitles at a random BER of 3×10^{-3}
- telesoftware: to assure an adequate probability of success in acquiring a 10-kbyte telesoftware message at a random BER of 3×10^{-3}, a fivefold acquisition may be required.

It is reasonable to choose a protection scheme that provides satisfactory data service quality at a random BER of 3×10^{-3}. For MAC/packet DBS systems, this figure corresponds to a sound and vision quality worse than CCIR grade 3 ("fair").

4.1.4 Decoding strategies

The decoding strategies described in the annex, refer only to the useful part of the message (data block), assuming that all the complementary information needed for the correct reconstruction of the message (packet header) are correctly recovered by the receiver. In the MAC/packet system, this information is highly protected by forward error correction codes, such as the Golay (23,12) code and the Hamming (8,4) code. As reported in the MAC/packet family specification [EBU, 1986], the Golay (23,12) code is able to correct up to three errors in a group of 23 bits, and the packet loss probability is about 7.5×10^{-5} at a BER of 10^{-2}, and 4.5×10^{-3} at a BER of 3×10^{-2}.

A proposed protocol for the General Purpose Data (GPD) type of MAC/packet service component [CCIR, 1986-90h] allows the optional use of error detection by data segment CRC, optional error correction by FEC coding, and an optional format extension to provide an extended data segment continuity index to support error correction by repetition. A theoretical study of the error performance of the GPD type of service component is presented in [BSB, 1989].

4.1.5 Conclusions of the EBU studies

These studies provide some general indications on the choice of an efficient error correcting strategy:

- To guarantee good service quality in the case of high BERs (up to 10^{-2}), it would be necessary to combine error-correction methods using multi-acquisition, such as majority logic or bit variation, with forward error correction (e.g. BCH codes) which does not need to be very powerful (e.g. a code able to correct up to two errors).

- In such a case, the additional amount of redundancy for error control should not significantly penalize the capacity for data transmission (redundancy 5%).

- Under good or satisfactory reception conditions, forward error correction should eliminate residual errors at the first acquisition, thereby reducing the access time.

- Under poor reception conditions, additional acquisitions (T = 2 or 3) will be necessary in order to obtain error-free data message.

- In the case of subtitles, a very high probability that the text rows will be displayed without errors could be assured by arranging a consecutive twofold transmission of each subtitle.

The choice between the above-mentioned strategies, and the many variants that can be imagined to improve their performance, is still under EBU study.

4.2 Data transmission in the digital sub-carrier NTSC system

The digital sub-carrier NTSC system described in Report 1073 used for operation of the satellite broadcasting television services in Japan has a transmission capacity for use as a satellite broadcasting data channel.

4.2.1 Error protection strategies in the sound/data multiplex

The sound/data multiplex carried by the 5.73 MHz digital subcarrier has a bit rate of 2.048 Mbps and a frame structure the length of which is 1 ms (i.e. 2.048 bits). The frame has a matrix structure of 32 by 64 bits. The bits contained in each row of the matrix except the first bit, which is a sync or control bit, comprise the (63,56) BCH code. Since the transmission sequence of bits in the matrix is in the column by column direction, successive errors likely to occur in differential QPSK demodulation do not affect the error protection scheme with the BCH code.

The data channel area is defined as the remaining area in the matrix not used for the transmission of sound, range control, frame sync, frame control and error protection [CCIR, 1986-90i].

4.2.2 Error protection strategies in data transmission scheme

A set of nine frames comprises a super frame which has a matrix structure of 288 X 64 bits. A packet having a fixed length of 288 bits (32 x 9 = 288) is arranged in the data channel area in the super frame in a manner similar to a sawtooth pattern so that the bit sequence of the packet is orthogonal to the bit transmission sequence as well as the bit sequence of the error correction code given below. Thus concentration of errors on a packet can be avoided.

The packet is composed of a header and a data part. The header, having a length of 16 bits, is a code word of the (16,5) BCH code which can correct all errors up to three bits and detect errors up to four bits.

No particular error protection scheme is specified for the data part; however, a (272, 190) majority logic decodable difference set cyclic code (see section 4.3) can be applied.

The frame control code contains five bits to indicate the mode of sound transmission and two bits for suppressing sound and data used in such transtions as changing the sound mode or switching the earth transmission station. The data channel mode is identified by the bits indicating the mode of sound transmission.

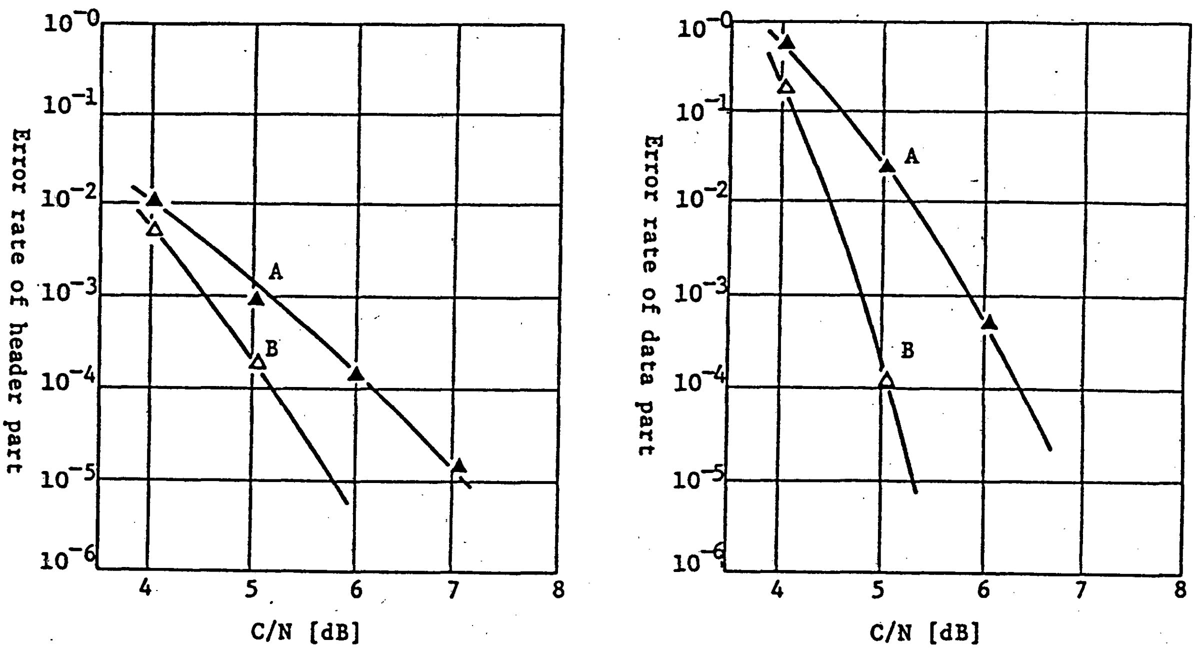
To strengthen these control bits, 36 repeated transmission in a master frame, of which the interval is 36 mS, is specifieda. One bit in the control code is used to indicate the master frame period. At the receiving end, a majority decision of more than 19 out of 36 in the master frame is recommended.

4.2.3 Results of satellite transmission experiments

Using the operational direct broadcasting satellite BS-2b, packet transmission experiments through the data channel have been carried out.

Figures 3 (a) and (b) show the error rate of the header and the data part respectively. The (272, 190) cyclic code is applied for the data part. Also shown is a product effect with the (63, 56) BCH code.

A block error rate of 10^{-3} was obtained at a C/N ratio of 4.5 dB for the header part and one of 10^{-2} at the same C/N ratio for the data part. As the C/N ratio increased to 8 dB, the error rate became negligibly small (less than 10^{-9}).



A : (16, 5) BCH code only

B : Combination of (16, 5) BCH code and (63, 56) BCH code

(a) Header part

A : (272, 190) cyclic code only

B : Combination of (272, 190) cyclic code and (63, 56) BCH code

(b) Data part

Figure 3 Block error rate of header and data part of packet transmitted through satellite broadcasting data channel

C/N : carrier to noise ratio (27 MHz band)

4.3 Data transmission in the sound-only satellite broadcasting system DSR

The Digital Satellite Radio system DSR recommended in Recommendation 712 and specified in Report 1228, Annex 1, used for the transmission of 16 high-quality stereophonic or 32 monophonic sound channels in the Federal Republic of Germany has the potential for use for satellite data broadcasting [Assmus, 1989]. Each of the 32 monophonic sound channels offers 352 kbit/s of protected and 96 kbit/s of unprotected data capacity. The protected part uses the 11 MSBs in combination with a (63,44) BCH-Code.

This code can correct two bit errors within a 63 bit coding block. The measured corrected BER versus C/N in a broadcasting satellite channel in the 12GHz range is outlined in Table II. The final entry in the table shows the uncorrected BER for a C/N of 12 dB.

TABLE II

C/N (dB)	7	8	9	10	12	12 uncorrected
BER	4.3×10^{-4}	6.0×10^{-5}	6.6×10^{-6}	6.9×10^{-7}	8.1×10^{-5}	3.6×10^{-5}

A comparison of the BERS's of C/N = 12 for protected and unprotected data transmission indicates the substantial improvement of the BER in the protected channel of about 4×10^{-3} In other words, the reduction of the BER achieved by the (63,44) block coding method corresponds to an improvement of the C/N by about 4dB.

5. Error-protection strategies for FM multiplex broadcasting on other types of data broadcasting services

5.1 FM multiplex broadcasting system

An FM multiplex broadcasting system capable of transmitting digital sound and data signals has been developed. The system multiplexes a 48 kbps digital signal and is suitable for stationary reception [CCIR, 1986-90 j]. The digital multiplex signal has a frame structure which consists of an 18 bit framing code, a 16 bit mode control code and 34 blocks of (272, 190) majority logic decodable difference set cyclic code (See Section 3.4).

The sound signals are protected by the (272, 190) code, while the data signals are protected by the product of two (272, 190) codes.

The mode control code which defines the contents in the frame is protected by the (16,7) extended BCH code which has a 2-bit error-correction capability and a 3-bit error-detection capability in a 16-bit block. It is recommended in the studies to decode this code after a majority decision made on each bit of 5 continuous mode control codes, because the same mode control code is transmitted in the same FM multiplex broadcasting program.

Sampled digital sound signals are arranged orthogonally on the error-correcting codes and the bit transmission sequence in the frame to avoid concentration of errors in both the error-correction blocks and the sampled sound data.

The performance of the error-correction strategy used in the system is shown in Figure 1 as described in section 3.4.

5.2 Facsimile broadcasting multiplexed with FM-FM sound system using television system M

As to the signal format of digital broadcast facsimile system, the system employs a packet type signal which incorporates a majority logic decodable (272,190) shortened difference set cyclic code for error correction. In addition, the signal is supplemented with a 16 bit mode control code to identify the content of the transmission channel; and then is further written into a frame with 32 lines and 288 columns. When reading out the signal, a bit interleaved transmission method is used to prevent signals being affected by burst errors due to multipath propagation.

As to the controlling signal format of analogue broadcast (272,190) shortened difference set cyclic code is incorporated [CCIR 1986-90k].

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[1982-86]: a. 11/129 (Japan); b. 11/29 (Japan); c. 10-11S/164 (EBU); d. 10-11S/165 (EBU).

[1986-90]: a. JIWP 10-11/5-13 (China (People's Rep. of)); b. JIWP 10-11/5-15 (Germany (Fed. Rep. of)); c. JIWP 10-11/5-11 (France); d. 11/101 (Italy); e. JIWP 10-11/5-39 (Germany (Fed. Rep. of)); f. JIWP 10-11/5-7 (EBU); g. JIWP 10-11/5-36 (EBU); h. JIWP10-11/3-117 (UKIBA); i. 11/420 (Japan); j. 10/204 (Japan); k.

ANNEX

THE CLASSIFICATION AND ASSESSMENT OF ERROR PROTECTION STRATEGIES

This annex gives the method of classification of error protection strategies and relationships used to evaluate these strategies.

A. Classification of error protection strategies

As shown in Table I, the various error-protection strategies can be grouped into three basic families which are identified by the amount of additional redundancy introduced at packet level.

TABLE I

FAMILY	REDUNDANCY	BYTE CODING	APPLICATION
A	Parity check at character level	7 + 1 bit	Conventional teletext and subtitling
B	CRC (16 bits)	8 bits	Enhanced teletext systems A and B, subtitling, telesoftware, transparent data services
C	CRC (16 bits) + FEC		

Assuming that the performance of error protection based on a parity check at character level, as used in present CCIR teletext systems A and B, does not require further study, attention will be concentrated on new protection strategies based on 8-bit coding. However, the basic relationships for 7-bit coding + parity are given in the Annex, together with those for 8-bit coding.

The results presented in Figures 1 - 7 relate to transport by the MAC/packet multiplex with a data block length of 90 bytes. The result is given as the probability of correctly displaying a page (or recovering a file) after T acquisitions (P(s,T) where s=success, T= number of acquisitions.

a) Strategy of family A

Strategy (A-1)
(PARITY CHECK)

Applied to conventional teletext and subtitling (7-bit coding + parity) and adopted in CCIR teletext systems A and B:

- Error detection is carried out at character level by a parity check bit. Parity check failure leaves blanks in the page memory.

- Error correction is obtained by successive acquisitions of the page by filling the empty spaces with characters estimated as being error free. This mechanism does not avoid displaying wrong characters in the occurence of even errors. The degree of confidence in the displayed page can be increased significantly by including an error detecting code (CRC - cyclic redundancy check) in any data row or page.

b) Strategies of family B

For the case of enhanced teletext, subtitling, telesoftware and transparent data services (8-bit coding), two strategies of this family have been identified. Each data packet (90 bytes) is protected by a 16-bit suffix (CRC).

Strategy (B-1)
(CRC)

The following decoding procedure is adopted:

- The data blocks are accepted when the CRC is correct and are rejected in the other cases.

- In the presence of channel errors, the information unit (e.g. a teletext page, a two-row subtitle, a data file, etc.) is recovered error-free after several consecutive acquisitions.

As shown in Fig. 1, this strategy is only suitable for very good reception conditions.

Strategy (B-2)
(CRC + ML + CRC)

The decoding procedure is the following:

- The data blocks are accepted when the CRC is correct, otherwise they are stored in the receiver's memory for further processing. The memory locations reserved for consecutive acquisitions of the same data block affected by errors are different (no over-writing).

- After 3 (or 5) acquisitions affected by errors, the receiver performs majority-logic error-correction on a bit-by-bit basis.

- A final CRC error detection allow validation of the decoded message.

This strategy, which is an improvement upon strategy (B-1), allows correct message decoding at the first attempt in good reception conditions, and presents a higher ruggedness in the case of high BER (see Fig. 2).

These results have been verified by laboratory tests /Cominetti and Morello, 1985/ carried out by an intelligent receiver (see Table II). The probabilities for display (or file recovery) with a residual BER (i.e. before final validation by the CRC) are also given.

TABLE II

TYPE OF SERVICE	REPETITION T	MAX BER	PROBABILITY OF DISPLAY (RECOVERY)	RESIDUAL BER
TELETEXT (1 KBYTE)	3 3	5×10^{-3} 10^{-3}	100% 97%	10^{-4} 0.
SUBTITLING (80 BYTES)	3 3	10^{-2} 3×10^{-3}	100% 98%	3×10^{-4} 0.
TELESOFTWARE (10 KBYTES)	3 5	3×10^{-4} 3×10^{-3}	97% 97%	0. 0.

c) Strategies of family C

In this series of error-protection strategies, each data packet is protected by a forward error-correcting code (e.g. Hamming or BCH codes) in addition to the suffix (CRC).

Strategy (C-1)
(FEC + CRC)

The decoding procedure is as follows:

- Through the error-correcting capabilities of the FEC code in use, the receiver performs a forward error correction.

- A final CRC error detection on each data block assures the necessary degree of confidence.

Depending on the error-correcting capabilities of the FEC code, a high probability of confidence that data messages will be error-free at the first acquisition could be achieved at the expense of an additional amount of redundancy for the FEC (see Figs. 3, 4 and 5).

Strategy (C-2)
(FEC + CRC) + (ML + FEC + CRC)

Use of majority-logic error-correction in combination with forward error correction.

The decoding procedure is the following:

- The first two steps are the same as for strategy C-1, but the data packets with CRC failure are stored as received (without FEC).
- After 3 (or 5) unsuccessful acquisitions, the receiver performs, in sequence, majority-logic error-correction and forward error correction of the residual errors.
- A final CRC error detection on each data block allows validation of the decoded message.

Compared with strategy B-2, some additional redundancy for the FEC needs to be inserted into the message; however, the correcting code does not need to be very powerful since the residual bit-error rate after the majority-logic processing is normally low.

The strategy is especially suitable for severe reception conditions (see Fig. 6).

Strategy (C-3)
(FEC + CRC) + (BV + FEC + CRC)

In place of the majority logic, the FEC is preceded by an error-correction process using bit variation (BV) at each position within a data packet at which two successive acquisition attempts give different results. In these positions, the bit values are varied until the CRC on the data packet is found to be correct.

The decoding procedure is as follows:

- The first two steps are the same as for strategy C-1, but the data packets with CRC failure are stored as received (without FEC).
- On the packets where the above steps failed, the receiver performs, in sequence, bit-variations, forward error correction and CRC error detection. When the CRC is correct, the data block is accepted.

In common with strategy C-2, some additional redundancy for the FEC needs to be inserted into the message, but in contrast to majority logic, only two acquisition attempts are needed. With regard to practical limits for the computing power in the decoder, bit variation would probably allow the correction of up to 9 or 10 errors (corresponding to a maximum of 2^9-2 or $2^{10}-2$ variations respectively) within a data packet.

This strategy is similar to strategy C-2 and is especially suitable for severe reception conditions; particularly in the case of subtitles, the probability of decoding the data error-free can be considerably improved when a consecutive twofold transmission of the corresponding data packets is provided (see Fig. 7).

TELETEXT PAGE
(1 kbyte)

SUBTITLE
(80 bytes)

DATA FILE
(10 kbyte)

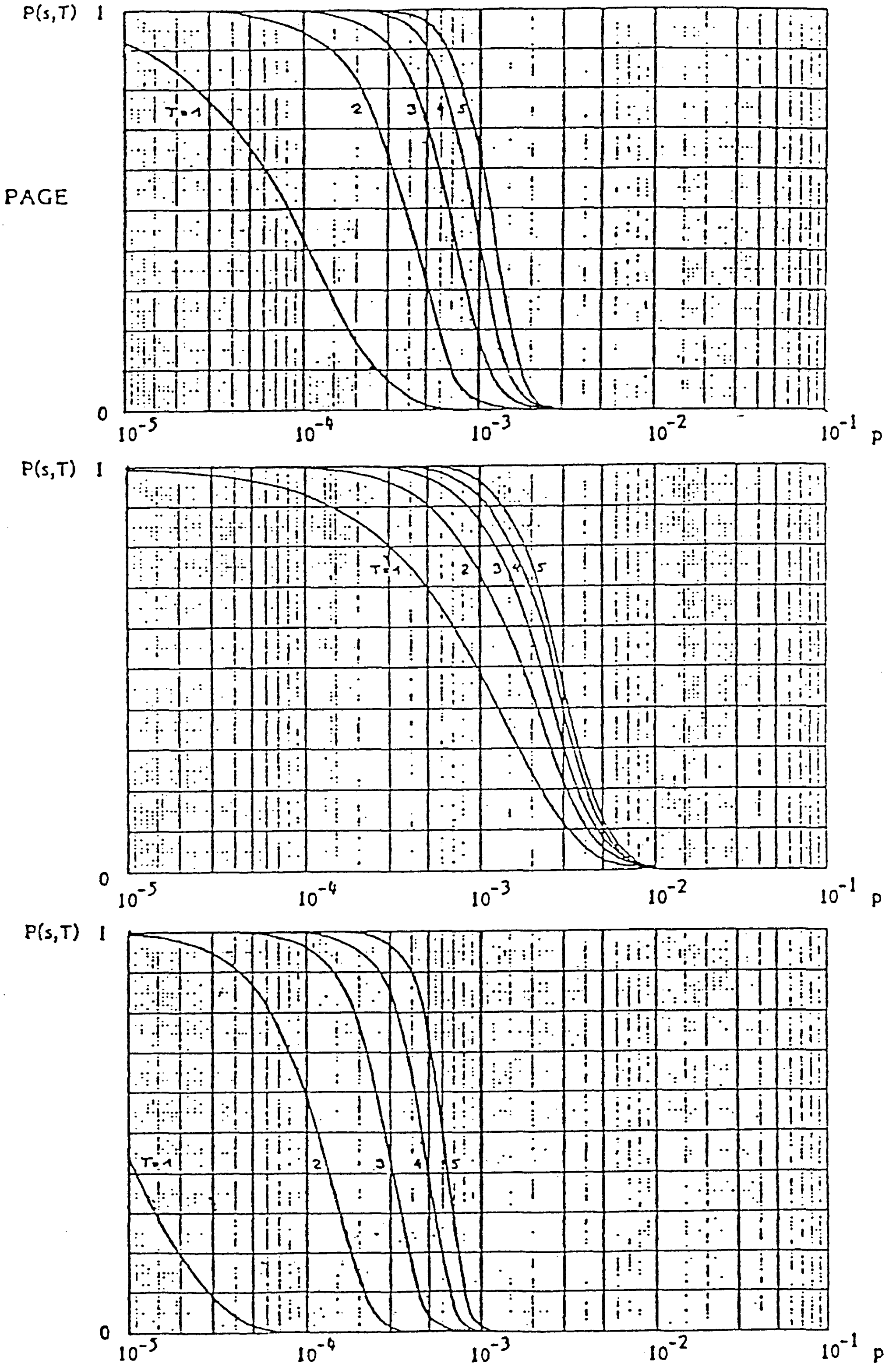
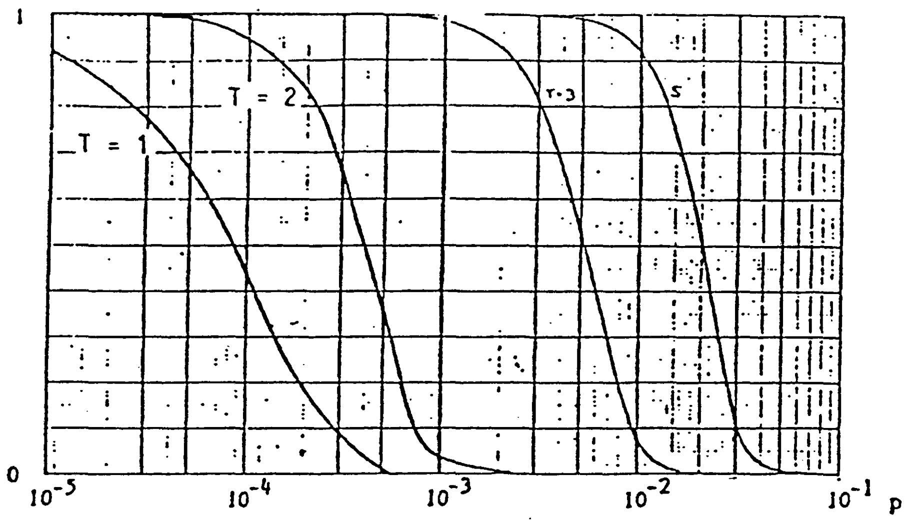


Fig. 1

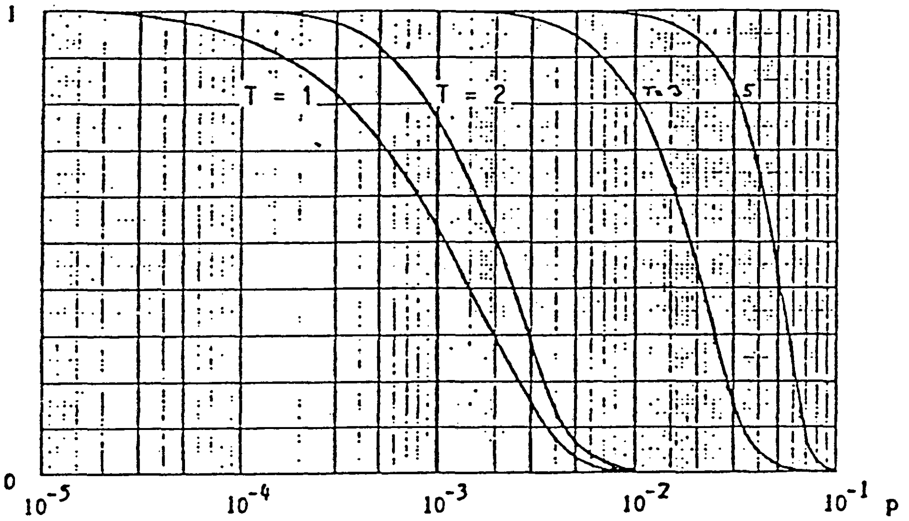
Strategy B-1 : Probability of correctly accepting the three basic Information Units with CRC error detection

Block length: 90 bytes, CRC: 2 bytes

TELETEXT PAGE
(1 kbyte)



SUBTITLE
(80 bytes)



DATA FILE
(10 kbyte)

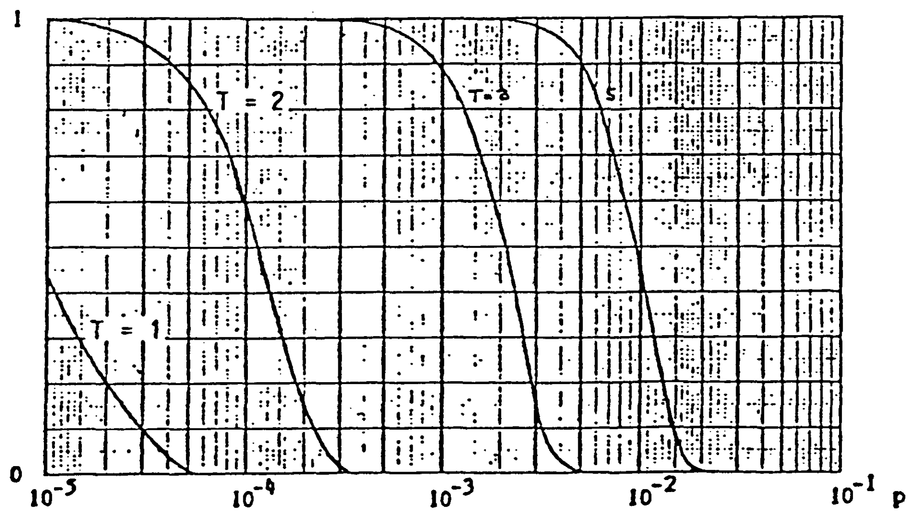


Fig. 2

Strategy B-2: Probability of correctly accepting the three basic Information Units with Majority Logic error correction after T acquisitions and CRC error detection

Block length: 90 bytes, CRC: 2 bytes

TELETEXT PAGE
(1 kbyte)

SUBTITLE
(80 bytes)

DATA FILE
(10 kbyte)

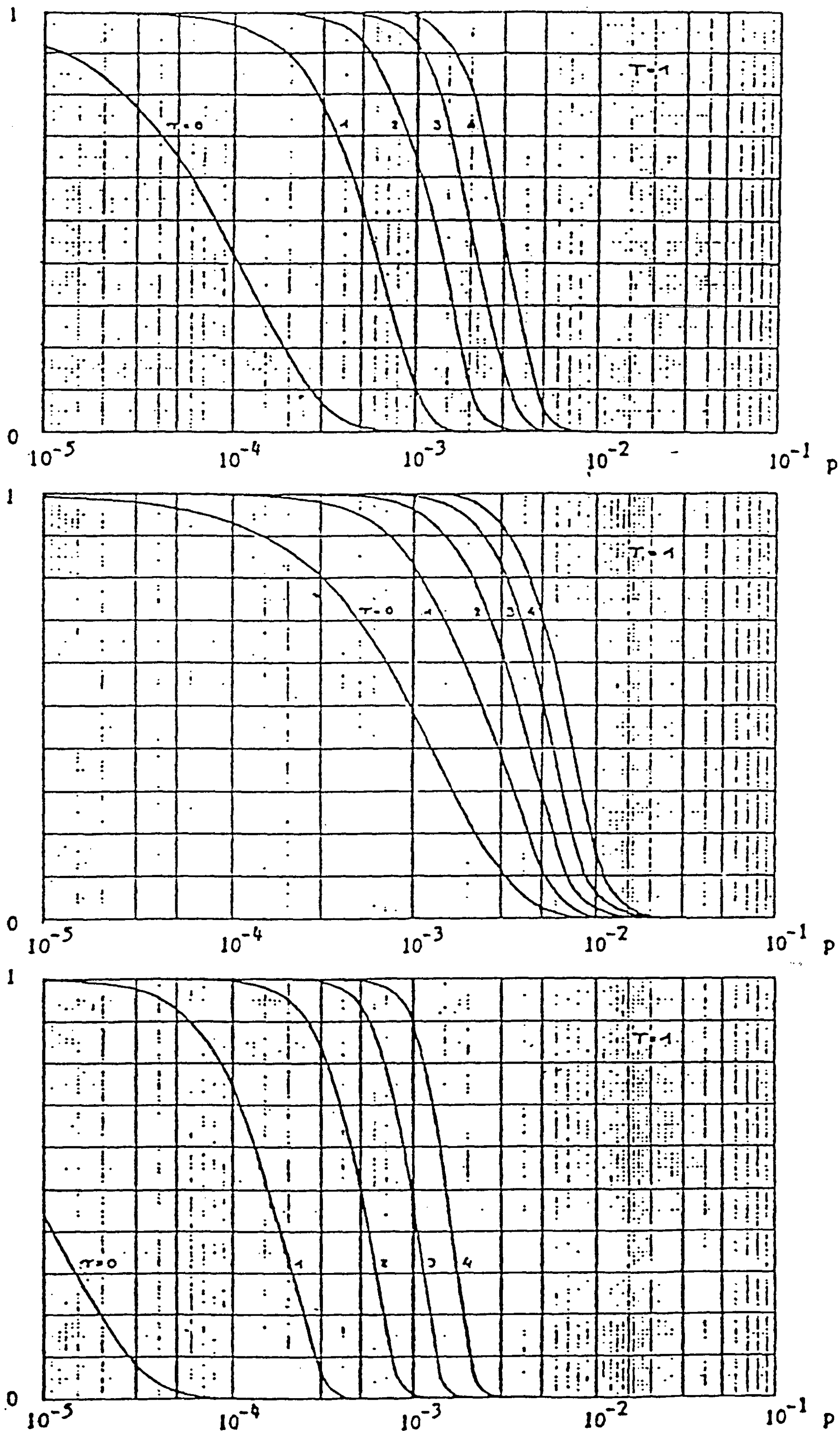
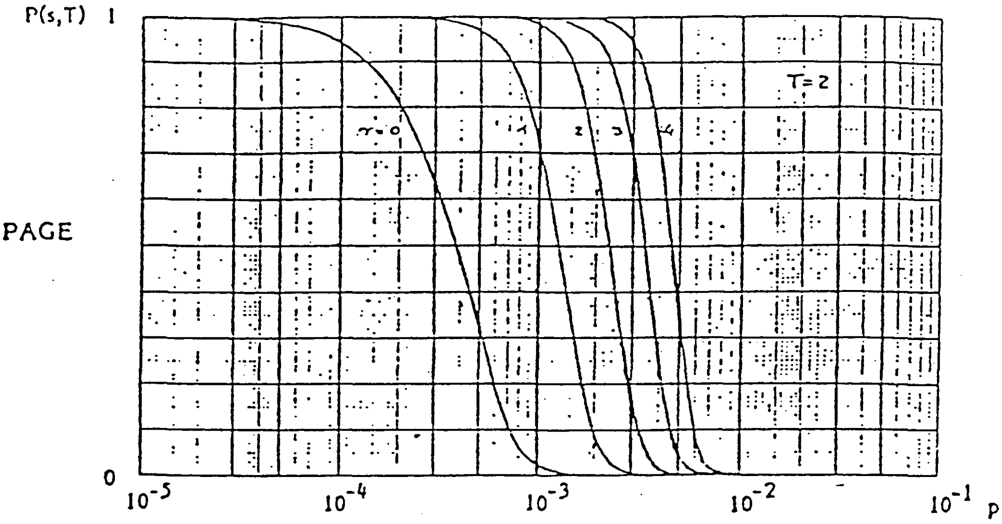


Fig. 3

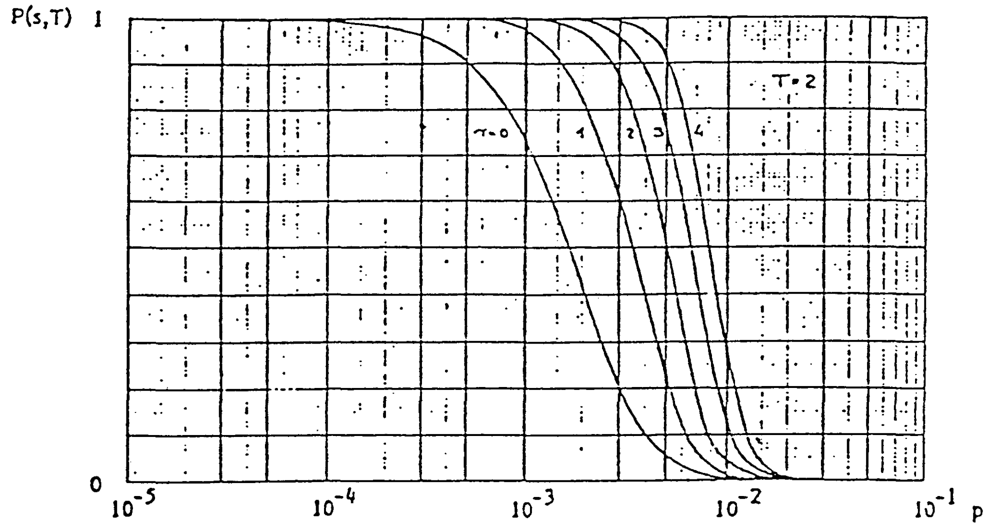
Strategy C-1(1): Probability of correctly accepting the three basic Information Units after 1 acquisition with FEC (correcting 0, 1, 2, 3, 4 errors) and CRC error detection

Block length: 90 bytes, FEC: 0, 10, 20, 30, 40 bits, CRC: 2 bytes

TELETEXT PAGE
(1 kbyte)



SUBTITLE
(80 bytes)



DATA FILE
(10 kbyte)

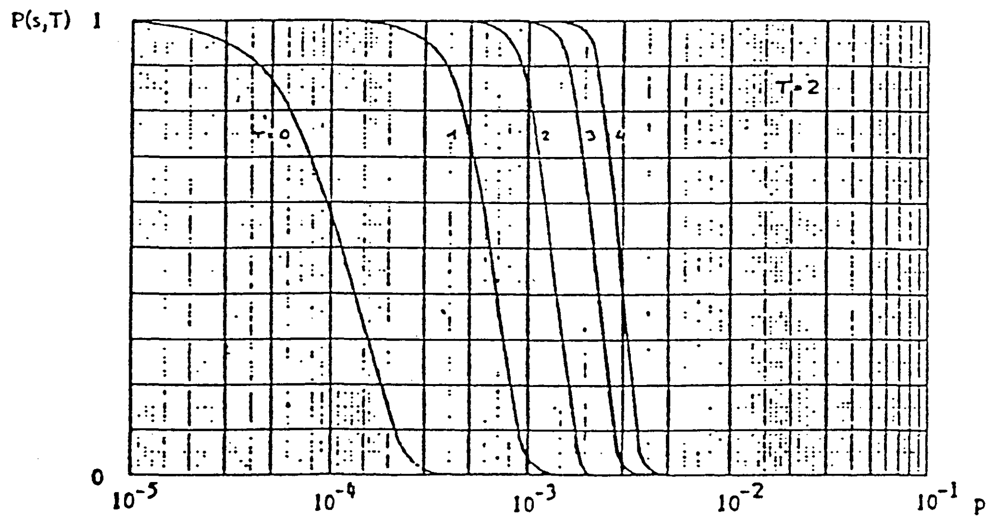


Fig. 4

<u>Strategy C-1 (2):</u> Probability of correctly accepting the three basic Information Units after 2 acquisitions with FEC (correcting 0, 1, 2, 3, 4 errors) and CRC error detection

Block length: 90 bytes, FEC: 0, 10, 20, 30, 40 bits, CRC: 2 bytes

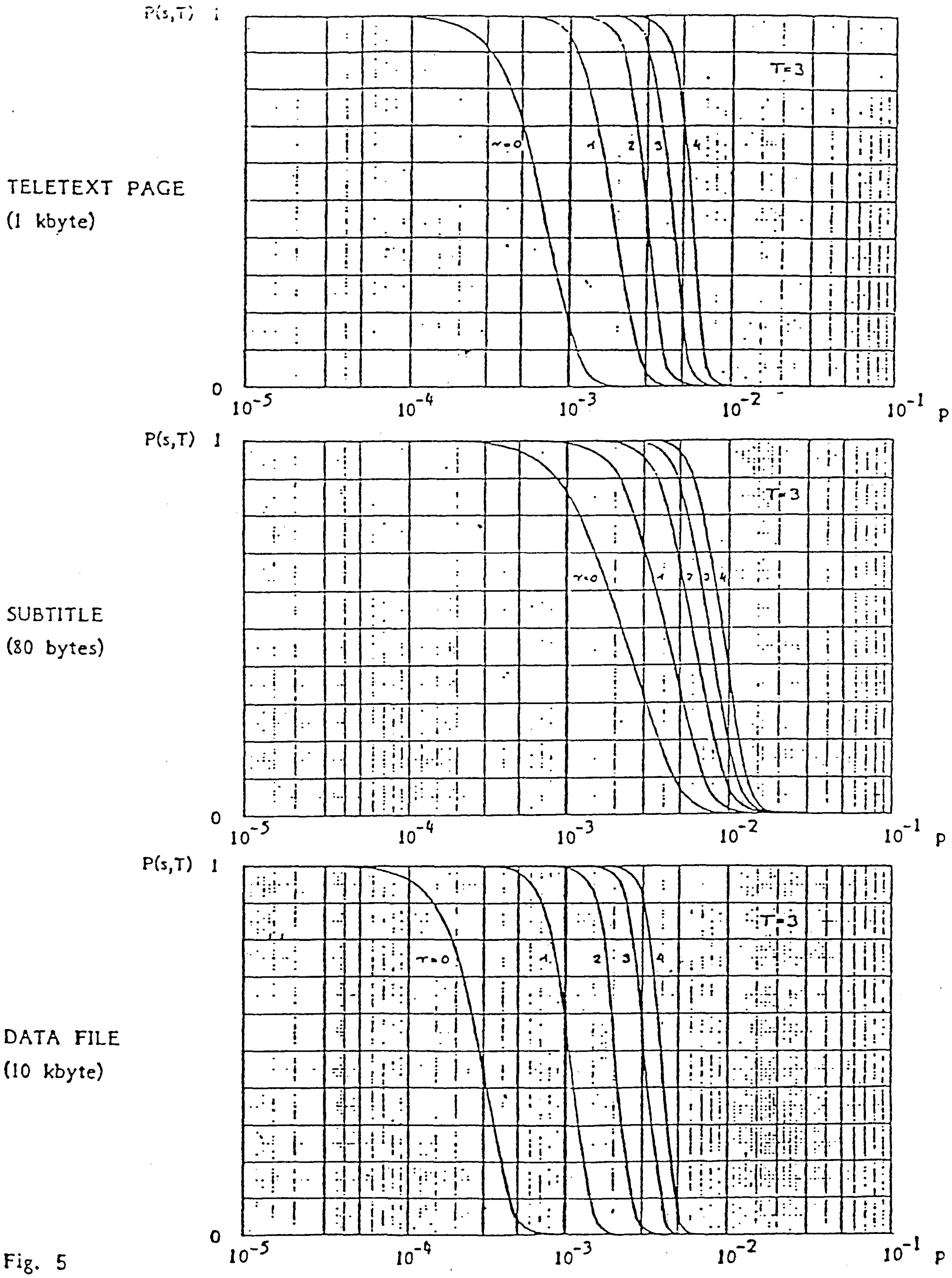


Fig. 5

<u>Strategy C-1 (3):</u> Probability of correctly accepting the three basic Information Uni after 3 acquisitions with FEC (correcting 0, 1, 2, 3, 4 errors) ar CRC error detection

Block length: 90 bytes, FEC: 0, 10, 20, 30, 40 bits, CRC: 2 bytes

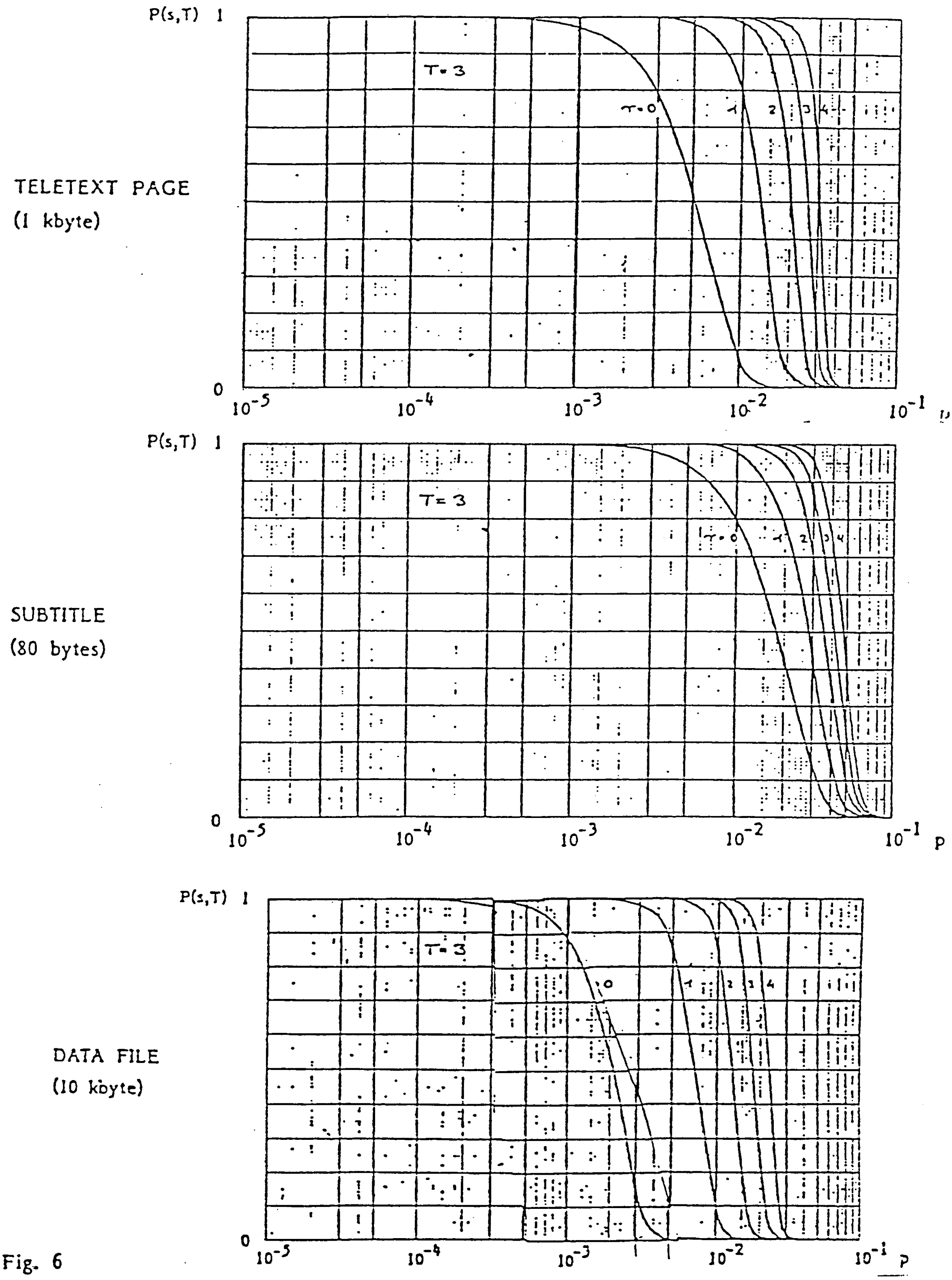


Fig. 6

Strategy C-2: Probability of correctly accepting the three basic Information Units with Majority Logic error correction, FEC (correcting 0, 1, 2, 3, 4 errors) and CRC error detection

Block length: 90 bytes, FEC: 0, 10, 20, 30, 40 bits, CRC: 2 bytes

The values of P(s,T) for T = 1 and 2 are given in Figs. 3 and 4 respectively

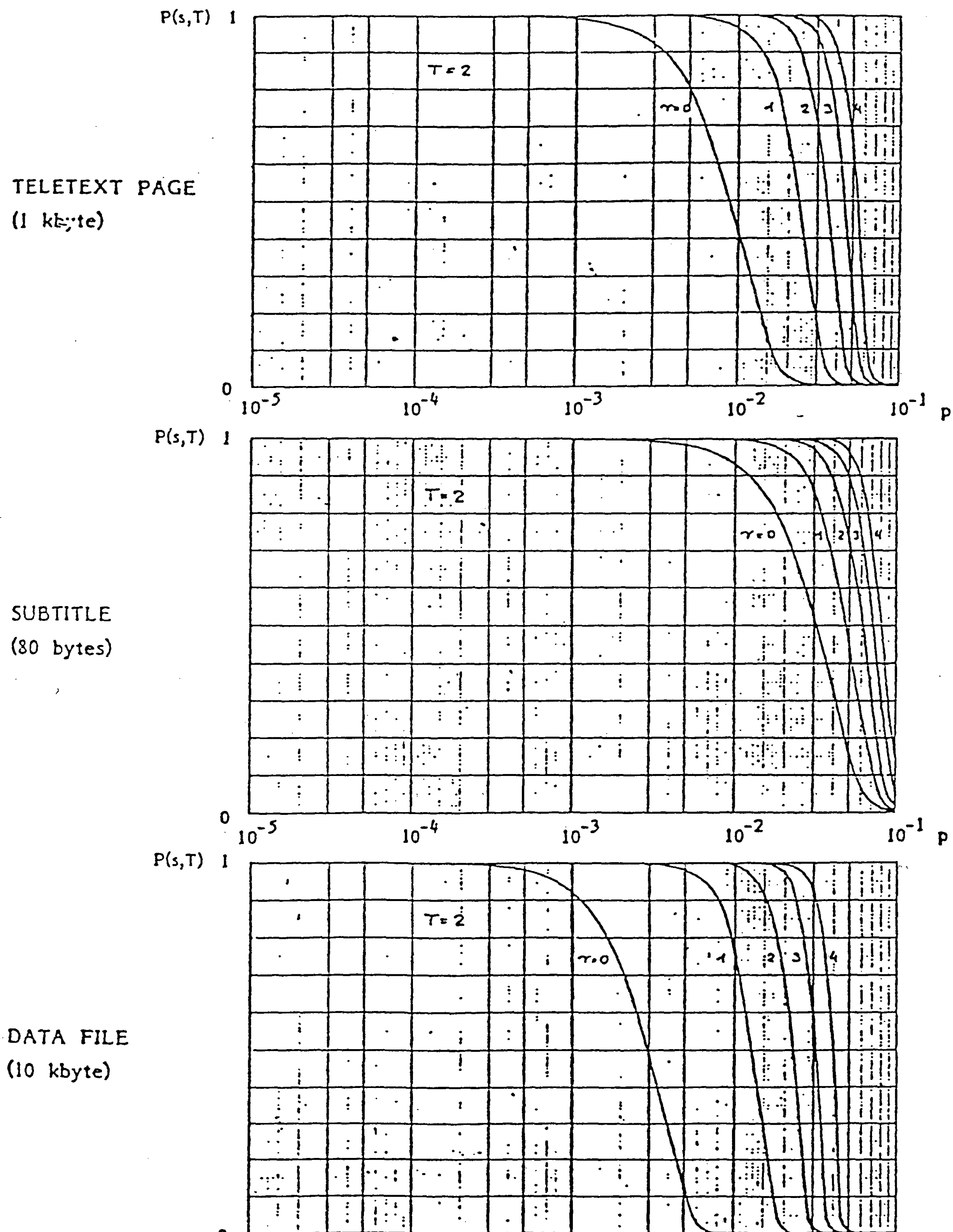


Fig. 7

<u>Strategy C-3:</u> Probability of correctly accepting the three basic Information Units with error correction by bit variation, FEC (correcting 0, 1, 2, 3, 4 errors) and CRC error detection

Block length: 90 bytes, FEC: 0, 10, 20, 30, 40 bits, CRC: 2 bytes
The values of P(s,T) for T = 1 are given in <u>Fig. 3</u>

B. Relationships used for the assessment of error protection strategies

The statistical independence of the errors (memoryless, binary, symmetrical channel) is assumed.

The following notation is used:

P = bit-error rate on the channel
M = number of bytes per data block
R = number of data blocks per file (or teletext page)
T = number of tentatives of acquisition
P(s,T) = probability of success (correctly recovering the file or the teletext page) after T tentatives.

FAMILY (A): PARITY BIT AT CHARACTER LEVEL

7-bit coding + parity: conventional teletext page.

Strategy (A-1)
(PARITY CHECK)

Probability of error-free data message, after T tentatives:

$$P(s,T) = Pn\ (1-Pu)$$

Where:

Pn = parity check success on the M bytes of the teletext page

$$Pn = (1 - Poe^{T})^{MR}$$

Poe = probability of odd errors

$$Poe = 8p\ (1-p)^{7} + 56\ p^{3}\ (1-p)^{5} + 56\ p^{5}\ (1-p)^{3} + 8\ p^{7}\ (1-p)$$

Pu = probability of unrecognized errors on the page

$$Pu = 1 - (1-Pee)^{MR}$$

Pee = probability of even errors

$$Pee = 28\ p^{2}\ (1-p)^{6} + 70\ p^{4}\ (1-p)^{4} + 28\ p^{6}\ (1-p)^{2} + p^{8}$$

FAMILY B: 16-BIT CRC

8-bit coding: teletext with enhanced presentation features, telesoftware.

Strategy (B-1)
(CRC)

$$P(s,T) = (1-<1-(1-p)^{8M}>^{T})^{R}$$

Strategy (B-2)
(CRC + ML + CRC)

$$P(s,T) = P\ (dc,T)^{R}$$

where:

$P(dc,T)$ = probability of correct data block, after T tentatives -

$$P(dc,T) = P(CRC/OK) + <1-P(CRC/OK)>\ P(ML/OK)$$

$$= 1-<1-(1-p)^{8M}>^{T} + <1-(1-p)^{8M}>^{T} \cdot (Q_{BT})^{8M}$$

where:

Q_{BT} = Probability of error-free bit after majority-logic error-correction

$$Q_{B3} = (1-p_1)^3 + 3p_1\ (1-p_1)^2$$

$$Q_{B5} = (1-p_1)^5 + 5p_1\ (1-p_1)^4 + 10\ (p_1)^2\ (1-p_1)^3$$

where:

p_1 = BER on the data blocks with CRC not correct

$$p_1 = p\ /\ <1-(1-p)^{8M}>$$

FAMILY C: 16-BIT CRC + FORWARD ERROR CORRECTION

8-bit coding: teletext with enhanced presentation features, telesoftware.

Strategy (C-1)
(FEC + CRC)

$$P(s,T) = <1-(1-Pa)^{T}>^{R}$$

where:

Pa = probability that the errors of the data packet can be corrected by the code (r or less errors)

$$Pa = P_0 + P_1 + \ldots + P_r$$

$$P_0 = (1-p)^n$$

$$P_1 = n\ p\ (1-p)^{n-1}$$

$$P_2 = \frac{n\ (n-1)}{2}\ p^2\ (1-p)^{n-2}$$

$$P_r = \frac{n!}{(n-r)!\ r!}\ p^r\ (1-p)^{n-r}$$

r = error-correcting ability of the code

n = number of bit in the code word

Strategy (C-2)
(FEC + CRC) + (ML + FEC + CRC)

Probability of error-free data message, after T tentatives:

$$P(s,T) = \{P(FEC + CRC/OK) + \langle 1-P(FEC + CRC/OK)\rangle . \langle P_{m0} + P_{m1} + \ldots + P_{mr}\rangle\}^R$$

where:

$$P_{m0} = (1-p_m)^n$$

$$P_{m1} = n\ p_m\ (1-p_m)^{n-1}$$

$$P_{m2} = \frac{n\ (n-1)}{2}\ p_m^2(1-p_m)^{n-2}$$

$$P_{mr} = \frac{n!}{(n-r)!\ r!}\ p_m^r\ (1-p_m)^{n-r}$$

with:

$$P_m = 3\ p_1^2 - 2\ p_1^3 = 1 - Q_{B3}.$$

$$p_1 = p\ /\ \langle 1-P(FEC + CRC/OK)\rangle = p\ /\ (1-Pa)^T$$

$$P(FEC + CRC/OK) = 1-(1-Pa)^T$$

Pa = <see strategy (C-1)>

Strategy (C-3)
(FEC + CRC) + (BV + FEC + CRC)

Probability of error-free data message, after T tentatives:

$$P(s,T) = \left\{ P(FEC + CRC/OK) + \langle 1-P(FEC + CRC/OK)\rangle \ (P_{b0} + P_{b1} + .. + P_{br})\right\}^{R}$$

where :

$$P_{b0} = (1-p_b)^n$$

$$P_{b1} = n \ p_b \ (1-p_b)^{n-1}$$

$$P_{b2} = \frac{n \ (n-1)}{2} p_b^2 \ (1-p_b)^{n-2}$$

$$P_{br} = \frac{n!}{(n-r)! \ r!} p_b^r \ (1-p_b)^{n-r}$$

with:

$$p_b = p_1^2$$

$$p_1 = p / (1-Pa)^T$$

P(FEC + CRC/OK) = <see strategy (C-2)>
Pa = <see strategy (C-1)>

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REPORT 1079-1

GENERAL CHARACTERISTICS OF A CONDITIONAL-ACCESS BROADCASTING SYSTEM

(Question 37/11)

(1986-1990)

1. Introduction

The present Report presents principles for conditional-access systems worked out by the EBU for application to satellite television by France and the United Kingdom, where the principles have been applied to teletext services. Some details of these applications are given in Table I at the end of the Report.

The principles may also be applied to conventional television and sound broadcasting systems as well as to additional services other than the teletext services listed in Report 802.

2. Components of a conditional access system

There are two distinct and in many cases independent components:

2.1 *Scrambling**

This is the process of rendering a service of no value to unauthorized users by changing certain of its characteristics under the control of the conditional access system at the sending end.

2.2 *Access control**

This is the provision of information to enable authorized users to descramble the service. The availability of this information is controlled by transmitting it in encrypted* form.

3. The requirements to be satisfied by a conditional access system

3.1 *Security*

The security of the system is the degree of difficulty encountered by an unauthorized user in attempting to gain access to the service.

There are two aspects:

- descrambling the signal without reference to the access control process. This is a function of the nature of the services and the scrambling method;
- obtaining the access control key* in an unauthorized manner. This is a function of the security of the algorithms used and the method of key distribution.

3.2 *Access modes*

A conditional access system will be more effective if there is a range of access modes.

Examples are:

- period availability – authorization runs from a starting time to a finishing time;
- programme or service item – availability is for a specific service item, whether or not it is completely used;
- service charge (commonly called "pay per view") – the charge or use of credit is proportional to the duration of use and/or the value of the service involved.

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* See Annex I for definitions.

The access modes need to be variable with respect to several parameters, for example:

- time;
- various segments of the service;
- groups of intended users.

3.3 *Equipment standardization*

To provide maximum economy of manufacturing scale for receiving equipment and to simplify management and maintenance:

- common equipment should be standardized so that it can cater for as many service options as possible;
- the "secret" components should be within a secure module with a standardized interface**.

3.4 *Access management*

The definition of conditional access is based on the formal concept of *entitlement* to access, which can be implemented in various forms. An entitlement gives to its holder an *authorization* to access the related service.

3.5 *Avoidance of impairments to the service*

Three types of impairment are significant:

- impairment to the finally available service due to the scrambling/descrambling process;
- impairments due to faulty or unreliable acquisition of the access control data;
- uneconomic use of the resources due to the management or transmission overheads involved.

3.6 *Interaction with digital processing*

It should be noted that certain scrambling processes may conflict with some operations of digital signal processing techniques, for instance bit-rate reduction.

4. General description of a conditional access system

4.1 *General*

Conditional access requires that the information must be *scrambled* before it is broadcast. This process is under the control of a scrambling sequence obtained from a *pseudo-random generator*.

The descrambling process at the receiving end requires the same sequence (in this case the descrambling sequence) to recover the original signal.

To provide this sequence and to ensure synchronism between the sending and receiving processes, the starting condition of the pseudo-random bit stream generator is controlled by an *initialization word*.

** This subject has already been discussed in the EBU in connection with the specifications for conditional access for the broadcasting-satellite service (BSS) (see Report 1073).

To achieve security, access-related information permitting recovery of the initialization word is transmitted in an encrypted form, according to the access modes in use (see Fig. 1). The detailed structure of this process is given in Fig. 2 and in the following sections.

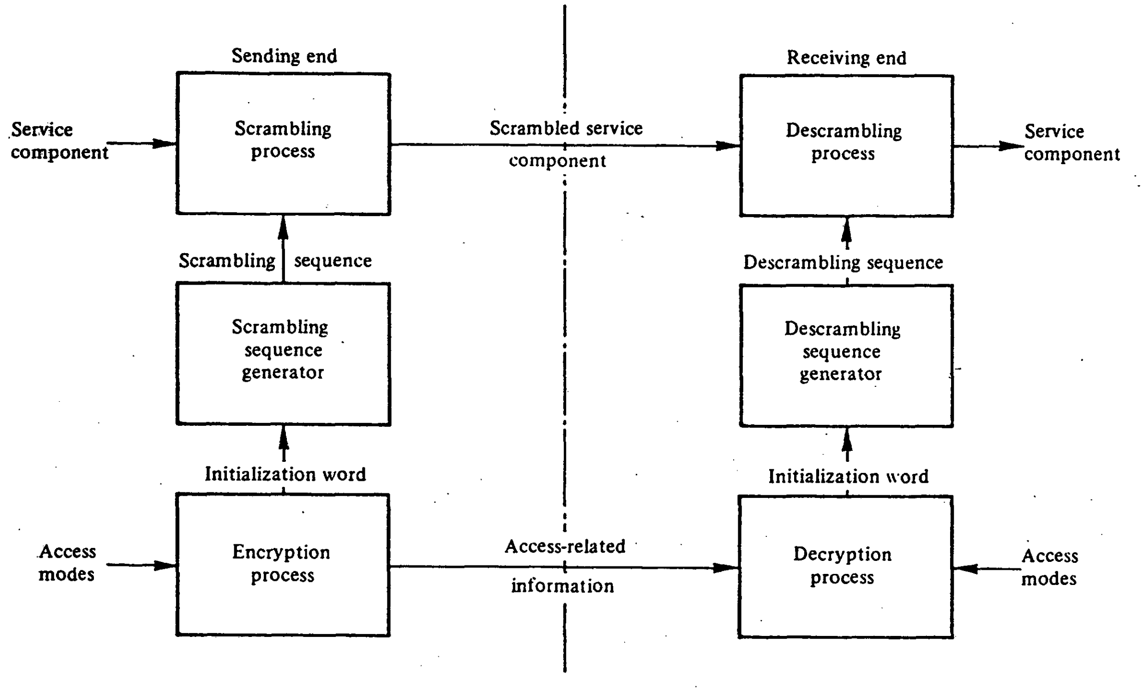

FIGURE 1 – *Basic conditional access system*

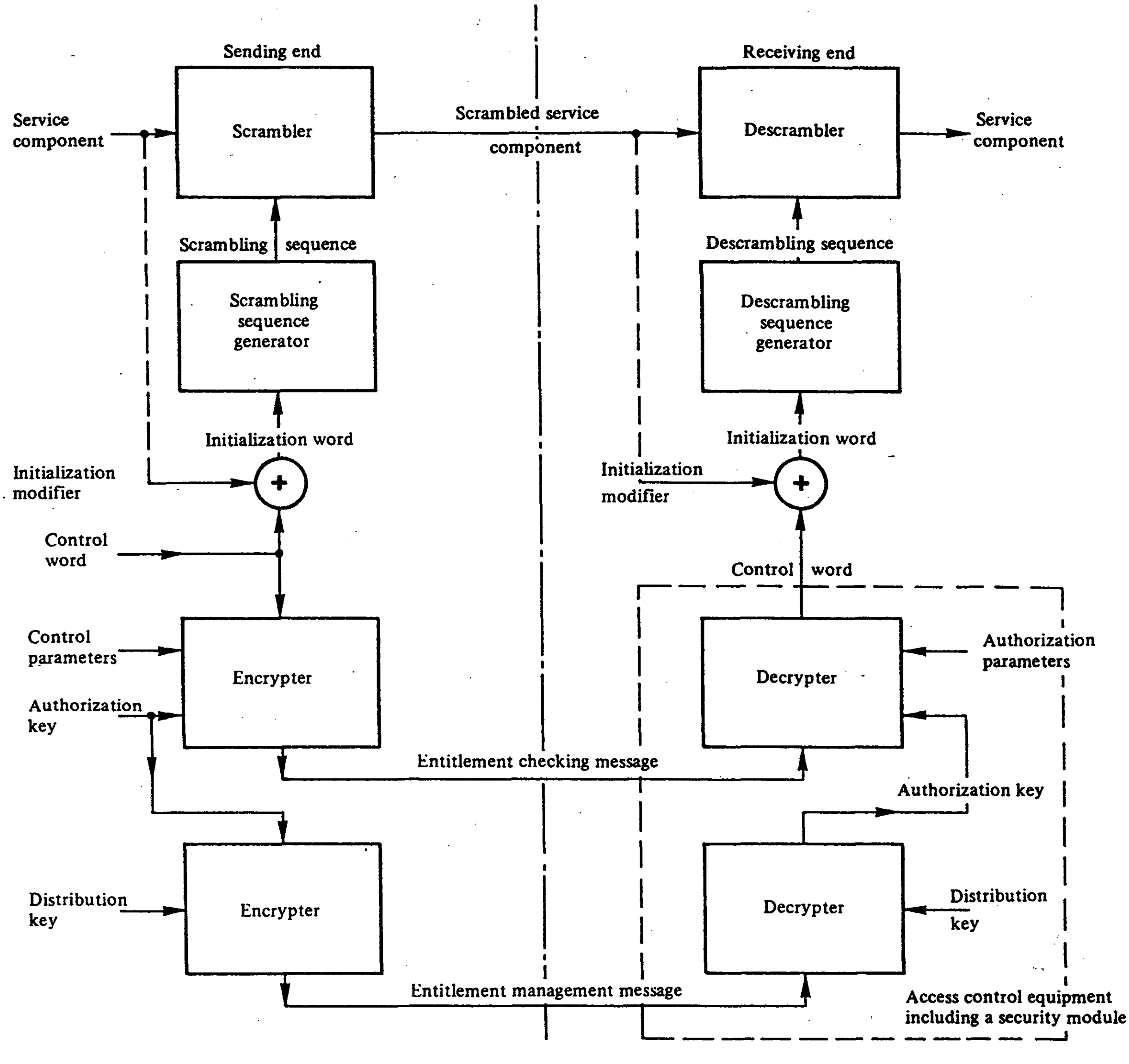

FIGURE 2 – *Functional description of a conditional access system*

Note. – Two encrypters and decrypters are shown in this figure for clarity. In practice, only one of each may be necessary if the encryption algorithm controlled by the authorization key and the one controlled by the distribution key are the same.

4.2 *Initialization word*

Conditional access to a service component is in fact equivalent to conditional access to the initialization word, which has two components: the *control word* and the *initialization modifier.*

4.3 *Control word*

The control word is the basic element of security. Its value is chosen arbitrarily and it may be changed during the service operation to enhance security.

The control word is communicated to the receiver as follows:

- at the sending end, according to the access mode in use, an encryption algorithm supplies encrypted versions of the control word, which are transmitted in special records. These are the *access entitlement checking messages*;
- at the receiving end, the access control equipment applies the inverse algorithm to regenerate the control word.

4.4 *Initialization modifier*

The initialization modifier is used in order to impose sufficiently short scrambling sequences to provide security, while avoiding the need for too frequent calculation of the control word. Thus, the use of different initialization modifiers for each structural unit of scrambled information causes the initialization word to change sufficiently frequently.

4.5 *Control word index*

To operate a segmented service, it is necessary to manage several related control words. These are identified by means of *indices.* The control word index used to access a unit of scrambled information must be obtainable from the transmitted signal.

5. Access entitlement checking messages

Each of these messages comprises:

- the control word index;
- a control word change flag: a change of state indicates a change of value of the control word;
- an *authorization pointer* which identifies the authorization key located in the receiver security module to which the message is addressed;
- a *control parameter* which supplies value (e.g. date, price, etc.) for comparison limits set to these values, in the receiver security module, called the *authorization parameters*;
- the encrypted control word.

In order to descramble a unit of information, the receiver must previously have acquired the control word from an access entitlement checking message bearing the appropriate index.

For optimum efficiency, access entitlement checking messages relating to the same control word but corresponding either to different user groups or to different types of access control equipment should be grouped under the same index. Although this is not its only application, the indexing system described above enables the advance transmission of entitlement checking messages.

The conditional access equipment creates a table of active control words which is updated by the access entitlement checking messages independently of the scrambled data. To identify the correct control word, the descrambling device supplies the access control equipment with the corresponding index. The management of this table is a part of the facilities provided at the interface between the descrambler and the access control equipment.

6. Access entitlement management messages

The processing of an access entitlement management message validates or provides the entitlement. This process takes place within the security module associated with a cryptographic calculation involving a *distribution key.* This distribution key is used to encrypt and decrypt messages and/or authorization keys addressed to individual receivers. The corresponding cryptograms constitute the validation signal and are carried as part of the access entitlement management message.

In conditional access broadcasting systems, the access management messages may be broadcast. This is known as "over-air addressing". The cycle time associated with the distribution of over-air keys may be significantly reduced by the application of the principles of shared key encryption (see section 2 of Annex II). The access management messages may also be distributed by other media.

In the case of payment, per unit of time or per programme, the management messages convey an encrypted cost code, transmitted as part of the service. The credit held in the receiver may take the form of encrypted money tokens which are transmitted as part of an over-air addressing service (see section 3 of Annex II). Alternatively credit may take the form of stored money tokens distributed by other means. Payment consists of decrementing the stored credit according to the received cost code.

7. Access control equipment

This equipment includes a security module that is supplied with entitlement checking messages. This module may be buried or detachable (for example, smart card). The access control equipment communicates with the descrambler through a physical interface and logic circuits. The standardization of this interface is important in order to permit:

- the independence of the security module and the descrambling function built into the receiver;
- further development of the access control equipment.

If the security module contains an authorization with the same identifier as the authorization pointer in the entitlement checking message, it provides a control word if, in addition, the control parameters fulfil the conditions of the received authorization parameters. These may include:

- a date requirement, with the date in the control parameter falling between the starting and expiry dates in the authorization parameter;
- a price requirement by which an authorization may be provided only if a charge is accepted by the security module.

A transaction involving the security module may include three distinct stages:

- preliminary instructions, if present (e.g. password, user acceptance, etc.);
- operating instructions using the security module;
- result processing (e.g. delivery of control word).

Because a variety of security modules may be used, it would be desirable for the access control equipment to be independent of specific transactions. This independence can be provided if the access control equipment can interpret a sequence of instructions arranged in a specific language and transmitted within specific messages.

8. Applications

Conditional access techniques have been applied to some page organized teletext systems, to the use of independent data broadcasting systems (see Recommendation 653), satellite-broadcasting systems (see Report 1073) and terrestrial broadcasting systems (see Report 802). Some examples are given in Table I.

TABLE I

Examples of implementation of a conditional-access system

Reference in this Report	Page organized teletext systems		Data broadcasting systems		MAC/packet family (Report 1073, C-MAC/packet and D2-MAC/packet)
	Teletext system A [CCIR, 1982-86, Part I, Chapter 5]	Teletext system B [CCIR, 1982-86, Part II]	Independent data lines in teletext system B	Layers 1 to 4 of teletext system C adopted in France	
Scrambling process § 4.1	Exclusive-OR combination of the data bytes with the bytes of a pseudo-random generator. An interpretation byte in the header indicates whether the record is scrambled or not. See § 3.1	Exclusive-OR combination of the data bytes with the bytes of a pseudo-random generator. Packet 27 links designate the page as scrambled. See § 20.1	Exclusive -OR combination of the data bytes with bytes from a scrambling stream generator. Regular occurrence of user-data-key blocks designates the service as being scrambled.	Exclusive -OR combination of the data bytes with the bytes of pseudo-random generator. A byte in the initialization modifier indicates whether the data group is scrambled or not Data groups with GT=0 or 1 are not scrambled.	*Picture:* double cut component rotation or single cut line rotation under the control of a pseudo-random generator *Sound:* exclusive-OR combination bit by bit of the data bits with the bits of a continuously running pseudo-random generator
Pseudo-random generator § 4.1	Combination of three multi-stage linear feedback shift register. See Annex I	Use of one-way function employing cipher feedback algorithm. See Notes to § 20	Scrambling stream generator uses deciphering algorithm connected in output feedback mode (ISO DIS 8372).	Combination of three multi-stage line feedback shift register.	*Picture:* two multi-stage linear feedback shift registers *Sound:* two multi-stage linear feedback shift registers initializing a further multi-stage linear feedback shift register
Pseudo-random generator synchronization § 4.1	First byte following the first US-X-Y sequence of the record. See § 2.3	First data byte of packet 0 of a designated page. See § 20	First byte of user data in user data block.	First byte following the initialization modifier.	Start of each picture frame
Initialization word § 4.2	12 bytes, see § 2.3	56 bits page key. See § 20.1	Scrambling stream initial variable is single byte at start of data block replicated eight times.	12 bytes	60 bits
Control word § 4.3	8 random bytes, see § 2.1	56 bits current system key. See § 20.1.3	64-bit user key	8 random bytes	60 bits being either randomly chosen or a cryptogram of the 256 frames counter
Initialization modifier § 4.4	4 bytes following the record header. See § 2.3	Not applicable	Not applicable.	4 bytes following the data group header.	The 8 bits frame-count

Entitlement checking messages (ECM) § 5	Designated records with classification numbers FFF and Y_{11} = 1; byte Y_{12} gives the index of the control word. Each message is introduced by the sequence US-3/F-3/F and comprises: – 3 bytes for the authorization pointer – 3 bytes for the control parameter – 16 bytes for the encrypted control word. See § 3.2	Designated packets include 22 bits authorization and control parameters, 112 bits encrypted control word. See § 20.1.3	One type of control block carries a user-data-key to all users who have a valid system key which enables them to decipher it.	Data groups for which GT (data group type, see Recommendation 653, Table Ia point 4.1) is equal to 14. The data groups are constituted of commands, each command identified by a command identifier and a command length identifier and composed of parameters identified by parameter identifier and parameter length identifier; two types of commands are defined: CI = 0 reference to the security module to use; CI ≠ 0: entitlement checking command where each parameter carries an ECM and comprises: - 3 bytes for the authorization printer - 3 bytes for the control parameter - 16 bytes for encrypted control word	Packets designated in the service identification channel. In the conditional access system for D2-MAC/packet used among others, on the French direct broadcasting satellite system TDF1-TDF2, packet coding is in accordance with the provisions of the specifications in "EUROCRYPT conditional-access system for the MAC/packet family" (March 1989) [CCIR, 1986-90a] In the United Kingdom where D-MAC/packet has been adopted, British Satellite Broadcasting will commence BSS operations using the "EuroCypher a conditional access system for use with the MAC/packet family of transmission formats" [CCIR, 1986-90b]
Control word index § 4.5	Byte Y_{14} of scrambled record for descrambling and byte Y_{12} of ECM for updating. See § 3.1 and 3.2	Not applicable	Not applicable.		Not applicable
Change of control word and flag § 5	Bit b_8 of byte Y_{12} of ECM. See § 3.2	Current and new key words included in a designated packet of the user addressing See § 20.2	The correct versions of keys are identified by matching lable keys sent with the keys and the data blocks requiring these keys	Bit b 8 of parameter identifier of entitlement checking command	A new control word is transmitted every 256 frames and becomes the current control word when the frame count equals 0

Entitlement management message (EMM) § 6	Entitlement is currently managed by a Videotex system on a telecommunication network. See § 1.3	Entitlement is managed by over-air addressing of receiving equipment using shared and unique user addressing packets. See § 20.2	Entitlement managed by over-air addressing of access control module using shared and uniquely addressed data blocks. Data blocks for over-air addressing are multiplexed into same channel as message data.	Not yet standardized. Entitlement may be managed by a videotex system on a telecommunication network.	Packets designated in the SI channel. For conditional access to D2-MAC/packet services used among others on the French direct broadcasting satellite system, TDF1-TDF2 the packets are encoded in accordance with the provisions of the specifications in "EUROCRYPT conditional access system for the MAC/packet family" (March 1989) [CCIR, 1986-90a] In the United Kingdom where D/MAC/packet has been adopted, British Satelllite Broadcasting will commence BSS operations using the "EuroCypher a conditional access system for use with the MAC family of transmission formats" [CCIR, 1986-90b]
Access control equipment § 7	Built into the receiver and including a smart card reader. See § 1.3	Built into the receiver or functionally separate at service provider choice	Completely contained within security module. Accepts serial data from packet decoder and provides deciphered serial data to user.	Built into the receiver and including a smart card reader.	Functionally separated from the other parts of the receiver, by means of an interface to be standardized
Security module § 7	Smart card, with interface proposed for ISO standardization [ISO, 1986]	Built-in or detachable module or smart card	Microprocessor based unit loaded with application software to perform all data protocol handling and deciphering algorithms.	Smart card with interface proposed for ISO standardization.	Two solutions are proposed: – the smart card or – a built-in module

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[1982-86]: 11/139 (EBU); 11/307 (France); 11/308 (France); 11/379 (Canada).

[1986-90]: 11/35 (United Kingdom); 11/36 (United Kingdom); 11/40 (United Kingdom); 11/122 (France).

ANNEX I

SOME TERMS AND DEFINITIONS RELATED TO CONDITIONAL-ACCESS BROADCASTING SYSTEMS

Scrambling [in broadcasting] (Embrouillage, aleatorización)

Alteration of the characteristics of a broadcast vision/sound/data signal in order to prevent unauthorized reception of the information in a clear form. This alteration is a specified process under the control of the conditional-access system (sending end).

Descrambling [in broadcasting] (Désembrouillage, desaleatorización)

Restoration of the characteristics of a broadcast vision/sound/data signal in order to allow reception of the information in a clear form. This restoration is a specified process under the control of the conditional-access system (receiving end).

Note 1. – The terms scrambling and descrambling are applicable to both analogue and digital signals.

Note 2. – The terms should not be used to describe processes such as energy dispersal in a satellite system.

Conditional access control

The function of the conditional-access control at the sending end is to generate the scrambling control signals and the "keys" associated with the service.

The function of the conditional-access control at the receiving end is to produce the descrambling control signals in conjunction with the "keys" associated with the service.

Note. – The word "key" is used in the above definitions in a general sense equivalent to that of Question 37/11.

Encryption and *decryption* are terms used for methods which are used to protect (and interpret) some of the information within the "access-related messages" which have to be transmitted from the sending end to the receiving end of the conditional-access control functions.

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ANNEX II

CONDITIONAL-ACCESS BROADCASTING SYSTEMS: EXAMPLES OF THE PRINCIPLES OF SHARED KEY ENCRYPTION SYSTEMS FOR DIRECT BROADCASTING SATELLITE SERVICES AND DATA BROADCASTING SERVICES INCLUDING TELETEXT

1. Description of conditional access system using over-air addressing used in the United Kingdom

1.1 Over-air addressed conditional-access systems

The basic functions in an over-air addressed direct broadcasting satellite television encryption system are shown in figure 1. A control word (CW) which changes, typically every 10 seconds is used to control the scrambling process of the television signal A. This forms the scrambled signal, CW(A). The control word is transmitted to the receiver after its encryption with the supplementary key S. This cryptogramme which also includes data concerning the programme, e.g. price, is transmitted in an ECM packet [EBU, 1986]. The supplementary key S is common to all subscribers but unlike the control word changes infrequently, typically once per month. The long intervals between the changes of the S key allow time for it to be transmitted to each subscriber by means of the over-air addressing process. The S key together with subscriber entitlement messages (M) are encrypted with each subscribers distribution key D. These cryptogrammes are sent in EMM packets which are individually addressed to separate receivers. A full description is given in [Mason, 1986]

1.2 Reduction of the validation cycle time - the shared cryptogramme

Figure 2 shows the format of a shared cryptogramme that reduces the total number of bits needed to be transmitted in the subscriber validation cycle. 23 subscribers are included in the cryptogramme of figure 2 and these represent a subscriber group. Each member of the group shares the same main address which is used to access the cryptogramme, and the same distribution key which is used to unlock the cryptogramme. Since the 56 bit supplementary key is needed by each member of the group to recover the television signal, its 'overhead' in bits is shared amongst 23 subscribers. The same is true for the 4 bit mode word and the 24 bit main address. The total of 84 bits is sent to the entire group rather than to each subscriber individually. Thus for a group of 23 members, only 3.65 bits per subscriber need to be transmitted. This budget allows for a 12 bit subscriber word which can cater for 12 independent basic subscription services, 6 independent tiered services or pay-per-view tokens. These latter may be used for any services provided that they are all managed by a common service operator. The mode word identifies which option is being transmitted. If less bits are used for the subscriber word, e.g. a basic single service subscription system would only require one bit. This would enable the subscriber validation cycle time to be reduced by a much larger factor, for example the use of a 12 bit subscriber word typically reduces the cycle time by a factor of 6.5, whereas a the use of 1 bit subscriber word reduces the cycle time by a factor of 20.

1.2.1 Strategy for eliminating stolen distribution keys

If a subscriber is identified as having became a pirate, that key must be removed. A method is required to avoid disabling other subscribers who share the same key.

This is achieved by storing two secret keys in the receiver security device, rather than just one. The first key is the shared distribution key and the second is a unique key (U) which is not shared but is different for each subscriber. When a pirate is detected a new shared distribution key (D_{new}) is individually sent to each of the remaining genuine subscribers by encrypting it with their unique key (U), see figure 3. As an example, X, Y and Z are the subscribers in a given group sharing the distribution key (D_{old}) and X is identified as a pirate. Subscribers Y and Z are sent the key (D_{new}) by transmitting UY (D_{new}) and UZ(D_{new}). Clearly the format for the transmission of U(D) is much less efficient than the shared key but this is not important since only a small number of subscribers are involved. A broadcaster can be confident that the genuine subscribers have received the new shared distribution key (D) by transmitting U(D) until the subscribers have returned two subscription payments. Since the cycle time is likely to be less than one minute the broadcaster can be confident that the new shared key has been received. This confidence relies on the assumption that each subscriber of the group will be watching the programmes for more than one minute during a subscription period that has been purchased.

1.3 Over-air credit and programme price transmission for pay-per-view

High security must be provided for the over-air transmission of credit for a full pay-per-view service. This can be achieved with confidence if the appropriate principles are followed.

1.3.1 Over-air credit information

The value of a sum of money cannot be sent over-air encrypted with a key K in the form K(MONEY). This is very insecure since the message MONEY is not unique. Assume that MONEY is a transmitted code which represents a monotonically increasing sum of money and that the transmission of the value "all zeros" for the code represents zero credit for a subscriber. Encrypting this code with the key K produces some bit pattern for K(MONEY). A pirate can add money to the credit stored in the receiver without knowing the key K by simply altering the bit pattern of K(MONEY). When the receiver decrypts this new message with the secret key K the plaintext must be non-zero. This is because there can only be one mapping of the ciphertext to the plaintext. Since the original ciphertext meant "zero credit" any change must mean "non-zero credit". The pirate can thus add credit but does not know the amount.

This problem is avoided by appending a key to the money, without recognition of which the receiver will not accept it. This is achieved by sending the signal D(M,S) where D is the distribution key and S the supplementary key. For the receiver to validate the money bits (M) with key S it must be certain that the supplementary key S has been correctly received. For this purpose the signal S(P,CW,S) is transmitted, see section 1.3.4.

1.3.2 Transmission of money tokens

Since the validation cycle repeats, a method of transmitting the money tokens must be used which allows the receiver to accept a new payment but prevents it from continuously accumulating the same payment at each repetition of the cycle. Equally, local "replays" of old ciphertext must be incapable of deceiving the security device in the receiver into accepting previous payments more than once. Since the broadcast channel permits only one way communication, these requirements must be fulfilled when the rate of making payments is not in step with the rate at which the security device receives them.

The only known method of achieving these essential criteria is to transmit the total sum of all payments ever sent to the broadcaster on the signal (M_T). The security device stores the total sum of all payments it has ever received (M_R) and the payment value (M_P) separately in its money stores. M_P is the difference between M_T and M_R:

payment made $M_P = M_T - M_R$ for M_P greater than zero.

In this way payments can never be missed and replays of old payments will not cause M_P to increase because each time a payment is accepted M_R is set to the received M_T value. Thus a payment is only accepted if $M_T - M_R$ greater than zero. In order to keep the cycle time short a limit must be placed on the number of bits used to transmit the value M_T. The MAC/packet system specification [EBU, 1986] uses 12 bits for MT providing for up to 4096 tokens.

1.3.3 Programme pricing

The programme related data (P) may represent the price of a programme. One method of pricing causes the money store to decrement every 10 seconds by a given value as the programme is received. An alternative is to request a single payment at the begining of the programme for its complete purchase. If the alternative method is used an identification number is stored when the programme is purchased in order to prevent the programme from being purchased twice, if for example the receiver is switched off during its transmission.

The programme related data (P) is "signed" as being correct by the supplementary key (S) in the same manner as for the subscriber money bits. This "signing" is by including the S key in the plaintext of the signal S(P,CW,S). It only requires the receiver to check that the S key has been correctly received in order to verify both the programme related data (prices) and the subscriber messages (money), see section 3.4.

1.3.4 Knowledge of correct supplementary key

The security check on the supplementary key (S) is performed by means of the signal S(P,CW,S). This signal has the property that the S key is both contained in and also used to encrypt the plaintext. The security check in the receiver first obtains the key that appears to be the correct supplementary key S by decrypting the validation signal D(M,S). It then uses this received key S to decrypt the signal S(P,CW,S). Provided that the security device can decipher the signal S(P,CW,S) and obtain the same value for the supplementary key S, within the plaintext, there is a high degree of certainty that it has received the correct supplementary key S.

The probability that the security device will give false information is approximately 2^{-n} where n is the number of bits used for the S key. The system of /EBU, 1986/ uses 56 bits for the S key which gives a probability of false detection of 10^{-17}.

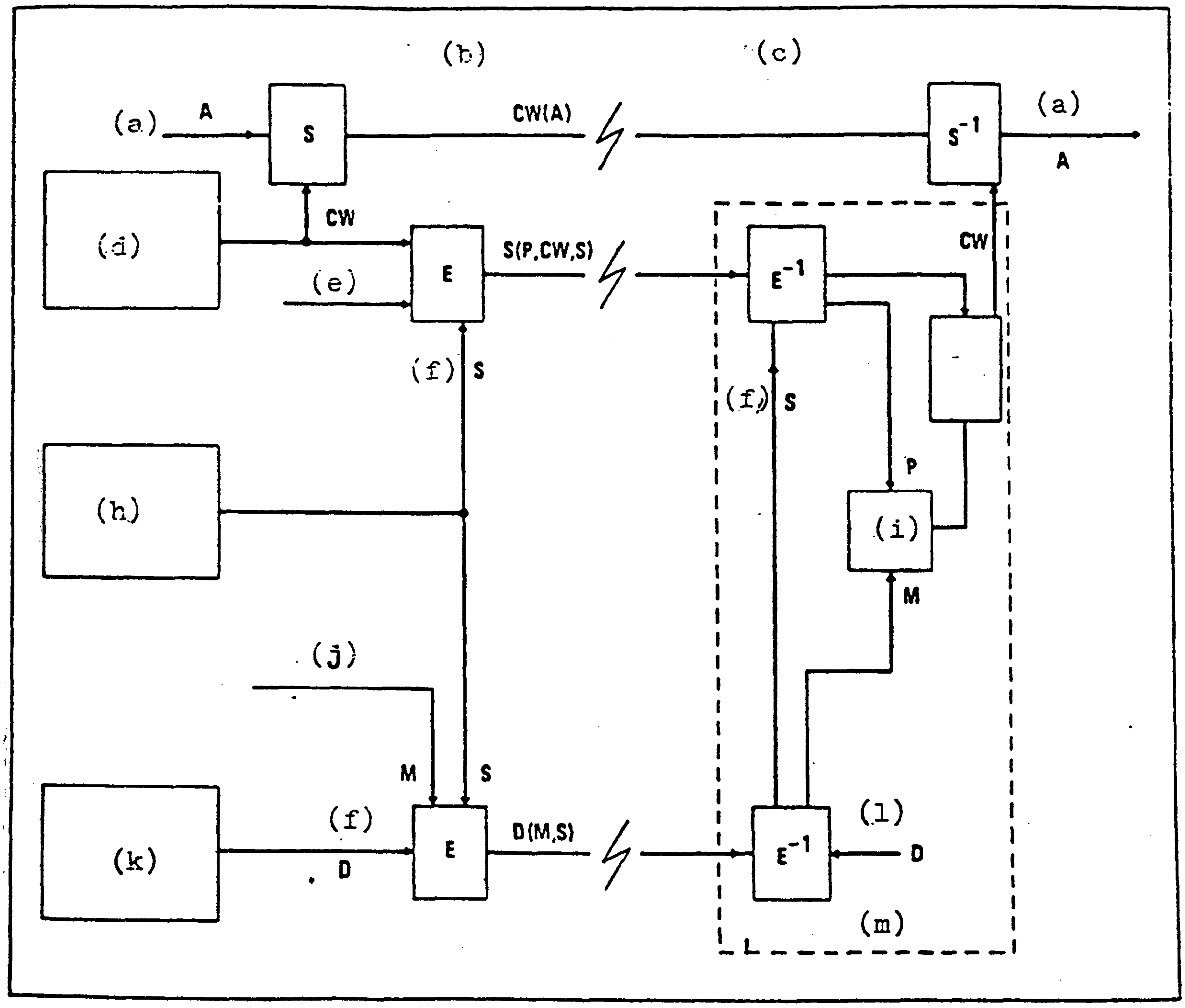


FIGURE 1 - Basic encryption system

(a) television signal
(b) transmitter
(c) receiver
(d) control word CW. changed every 10 seconds
(e) programme data P
(f) key
(g) gate
(h) supplementary key S. changed each month, say
(i) store
(j) customer message
(k) customer distribution key D
(l) secret customer key
(m) security devices

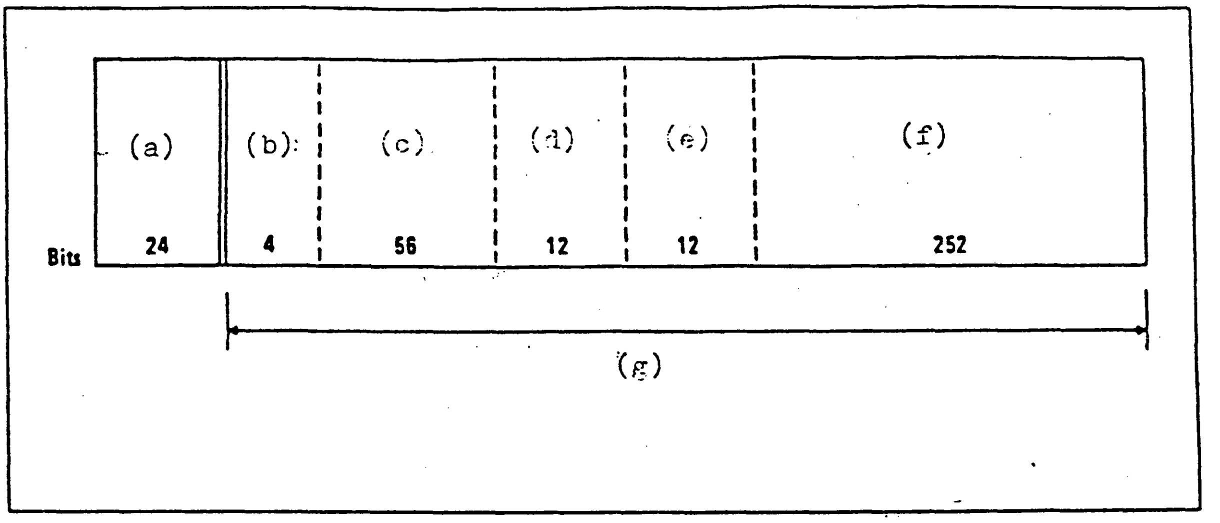


FIGURE 2 - Shared validation block

(a) shared address (b) mode (c) supplementary key S
(d) customer 1 (e) customer 2 (f) customers 3-23
(g) shared block encrypted with the shared distribution key D
Note. Error protection (not shown) - thirty (24,12)Golay code words

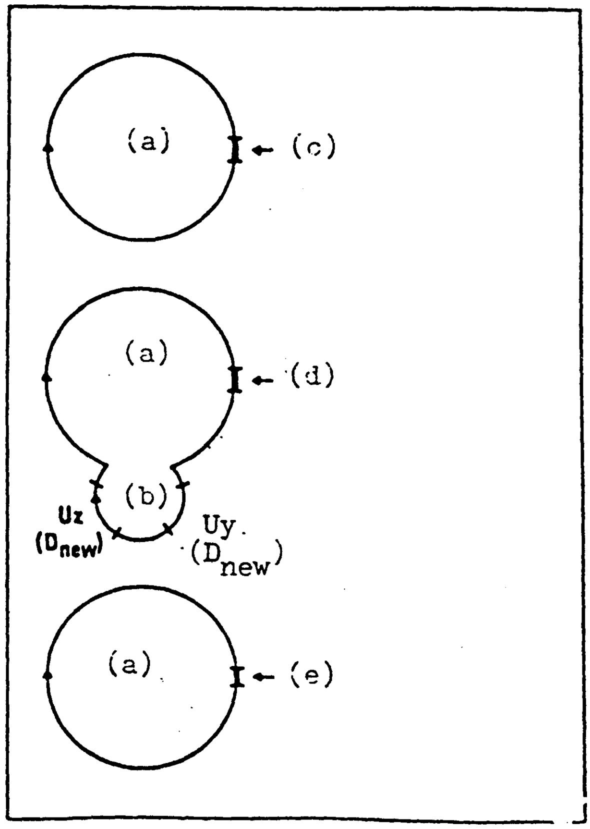


FIGURE 3 - Replacement of shared D key

(a) D cycle
(b) U cycle
(c) D_{old} (X,Y,Z) customers X,Y,Z, share key D_{old}
(d) D_{new} (Y,Z) X becomes a pirate and is eliminated
(e) D_{new} (Y,Z) the broadcaster is sure that Y and Z have received D_{new} because they have both sent two subscriptions "

2. Description of a conditional access system using over-air addressing the Eurocrypt system

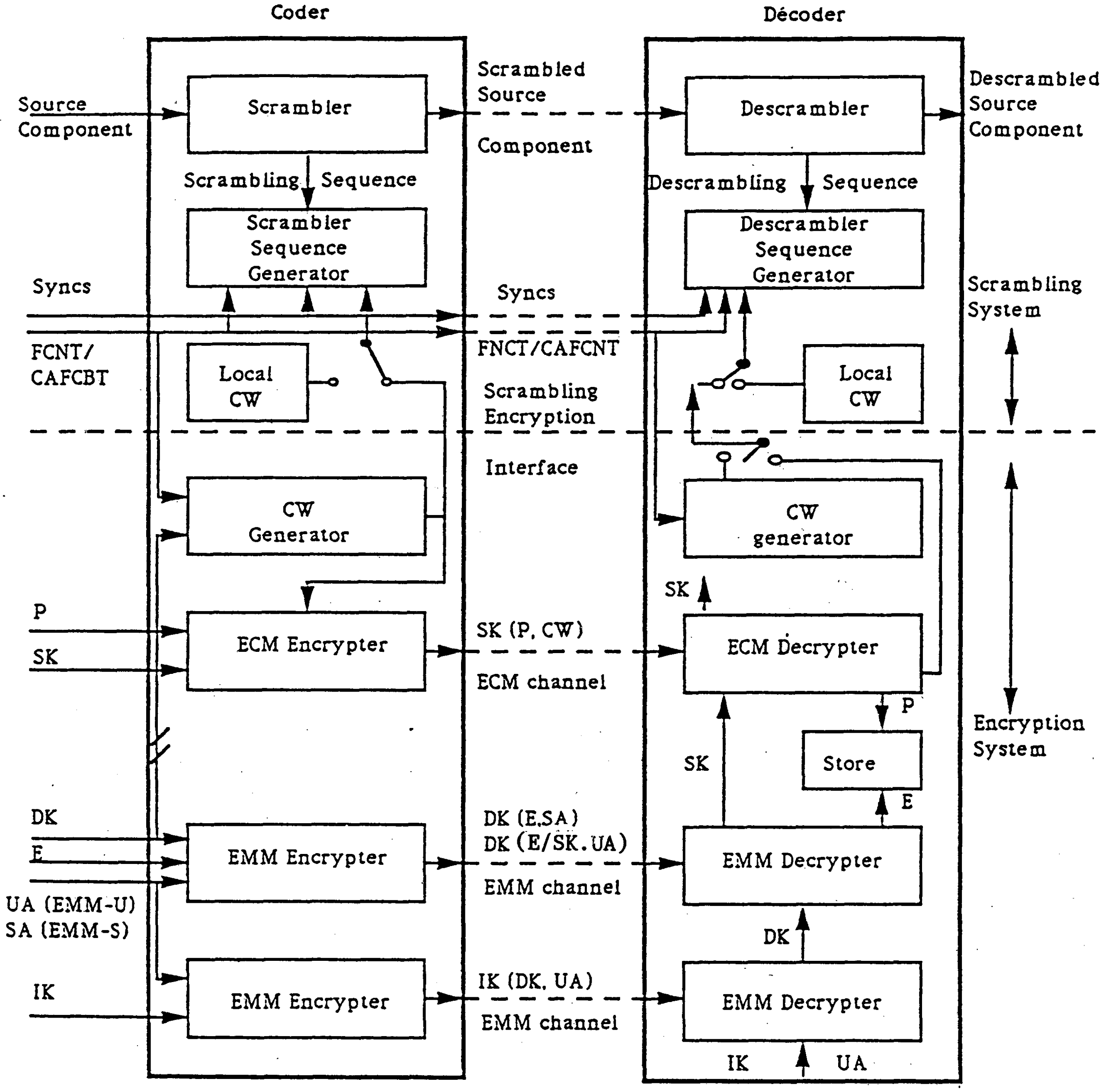
2.1 The scrambling and encryption systems

With reference to Figure 4, a control word (CW) is used to initialize the scrambling/descrambling sequence generator.

The control word is sent, encrypted by the session key (SK), in entitlement checking messages (ECM). Data relevant to the conditional access mode of the programme are also present in the ECM. The contents of the ECM is protected against falsification by a signing procedure. The session key (SK) is a secret information stored in a security processor. If the authorization parameters (entitlements) of the receiver are recognized by the security processor to match with conditional access parameters of the programme, the session key (SK) can be used to decrypt the CW.

The session key is a common to all users. The entitlements are updated periodically (every month for example) ; the session key can be changed under exceptionnal circumstances. Both, entitlements and session keys, may be sent to the users using over-air addressing methods in entitlement management messages (EMM). The session keys are sent encrypted with a distribution key DK specific to the program supplier. The contents of the EMM is (as for ECM) protected using a signing procedure. The distribution key may be specific to each user or to groups of users (or even to the entire audience). If the distribution key is specific to the user, then it may be used only to send entitlements or keys to a unique user referenced by his unique address (UA) in an unique EMM (called EMM-U). If the distribution key is common to a group of users, it may be used to send entitlements to the all group of users using a common shared EMM (called EMM-S). Since this would allow for a data rate reduction in the EMM messages it is used preferably to the first one. The first method would be best suited to the rare case where a change of the shared distribution key is needed.

The first distribution key of a programmer itself is also sent in EMM, encrypted with the issuer key IK. This key has the highest priority in the key system and is the only able to open the access for a new programmer in the security processor. The issuer key is specific for each user and is used in EMM-U.



ECM : Entitlement checking Msg
EMM : Entitlement Management Msg
CW : Control Word
SK : Service Key (or session Key)
FNCT : Frame Count (from line 625)
CAFCNT : Conditionnal Access from Frame Count (from line 625)
E : Customer Entitlements
IK : Issuer Key
UA : Unique Receiver Address
P : Program Data
SK (P;CW) : P and CW encrypted with SK
DK (E;S) : E and S encrypted with DK
IK(DK;UA) : SK encrypted with IK
DK : Distribution Key
SA : Shared Receiver Address

Figure 4 : General Block Diagram Showing the key hierarchy of the Conditionnal Access System

2.2 Key hierarchy and key update

The functional use of the different keys are illustrated in Figure 5.

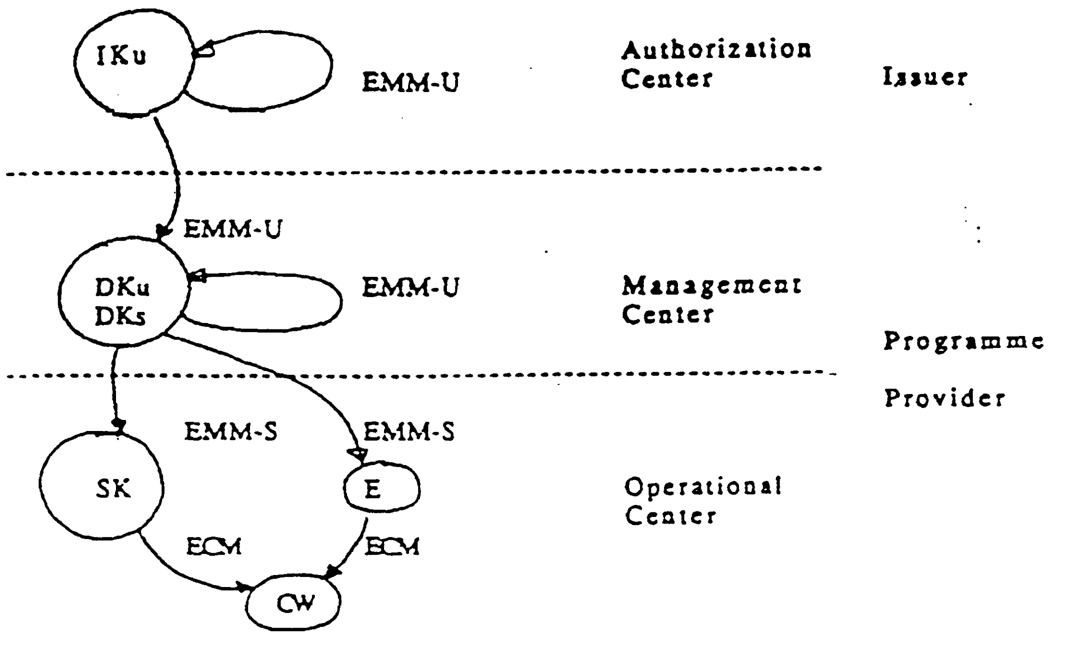


Figure 5 : Key hierarchy

2.2.1 Issuer key

- the issuer key sets and updates any kind of secret keys (DKu, DKs, SK, IKu).

- the issuer key is only able to open an access for a new programme provider in the security processor, by loading the first distribution key

- the issuer key is used only in unique messages (EMM-U).

2.2.2 Distribution key

- The DKu (unique distribution key) may update the DKs of the service via the EMM-U.

- the DKs (shared distribution key) sets or updates the session key (SK) and the entitlements E via EMM-S ; DKu may also be used for that purpose with EMM-U, but it is of less interest because of the overhead on data rate.

2.2.3 Session key

- SK is used to sign ECM and to encrypt the control words.

2.2.4 -Organization of key hierarchy

Two main scenarii are possible :

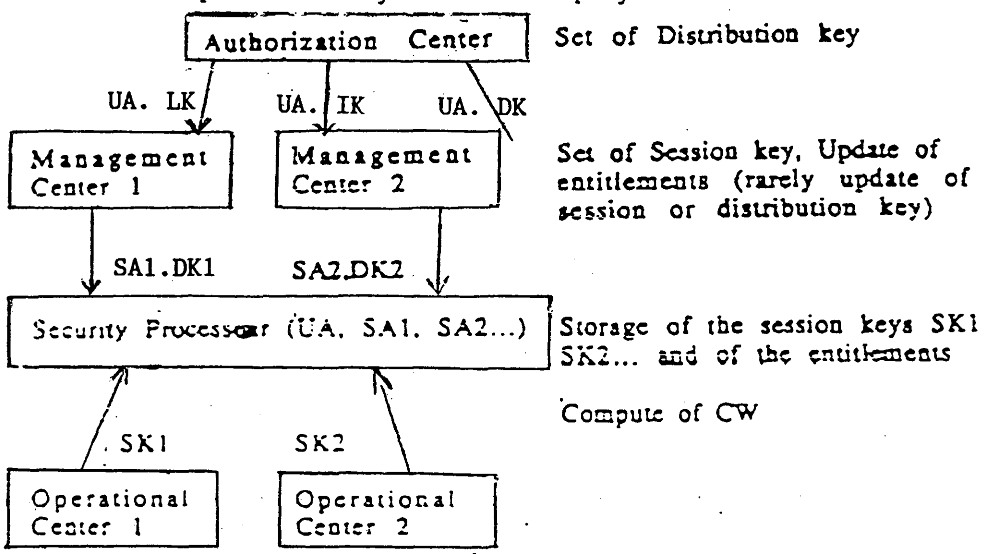
- the authorization center is in charge of the management of the secret keys (set and update) :

  . the issuer sets and updates DKs and SK with IKu
  . the programme provider updates the entitlements E with DKs.

- the authorization center is in charge of initialization of the programme provider but delegates afterwards the management of the keys belonging to the service :

  . the issuer sets DKu (using IKu)
  . the programme provider sets and updates DKs, SK and E.

The flowchart of operations may be summed up by :



2.3 Security of the system

2.3.1 Integrity of ECM and EMM

Two levels of data are transmitted in ECM or EMM :

- the secret data that will be transmitted in an encrypted form (CW, secret key)

- the non secret data whose content should have a high degree of protection (conditional access parameters, entitlements, address unique or shared) and which uses a "signing" procedure.
  For national regulation reasons, it may be necessary to send the entitlements in a confidential way. In that case, the entitlement contents is scrambled; this function is optional.

The structure of the message is then a clear text, followed eventually by an encrypted field and ended by a hashing field which signs all the message.

Structure of EMM :

user address (UA, SA) entitlement	[secret key]	hashing
scrambled * or clear text	encrypted	signature

[secret key] : optional
* The scrambled text is optional and applies only to entitlement description. This option may be chosen for national regulation reasons.

Structure of ECM :

conditional access parameters	CW	hashing
clear text	encrypted	signature

The modification of any field is barred through the hashing check.

2.3.2 Security through key hierarchy

The security of the system is achieved by introduction of two different levels of keys : the unique key and the shared key. The possession of the keys for a service is the first condition to get access to it ; the second condition is that the entitlements (subscription, pay-per-view credit...) must fit with the access conditions of a programme to allow the use of the session key SK. When a subscriber is removed the keys need not be changed and the entitlement will no longer be updated. Only when session keys are discovered by pirates will DKs be used to update. The use of unique keys (IKu or DKu) is exceptional and is reserved to update DKs. The update of DKs takes more data capacity because it needs EMM-U for individual addressing to all members of the group. Although the piracy of a unique key is of less interest because it applies only to one user ; this key may be also updated.

2.3.3 Security through the security processor

The security processor should provide secret data storage capability including an algorithm to decode encrypted fields and to check the integrity of the data. The system is flexible enough to upgrade the security processor changing the algorithm, increasing the processing capacity (introducing a new access condition)... without the need to change the receivers. This feature is made more easy if the security processor is present in a detachable form (smart card...). The software of the security processor should be designed in away to avoid any other use of the security mechanism than those it is built for.

2.3.4 security of transmission

The integrity of transmission of all the parameters describing the entitlement (theme/level, dates, credit, programme number...) is achieved through the hashing method. It is then impossible to modify successfully one or more bits of the message because of the failed checking.

For transmission of the credit, two methods have been retained :

- transmission of the total amount of credit acquired for an element of service. This total amount of credit is stored in the security processor. The purchase of any new programme is possible only if the remaining credit (total amount of credit - total amount of cost) is superior or equal to the cost of the programme. The total amount is transmitted together with an accreditation date.

- Transmission of a supplement of credit for an element of service. This supplement of credit is added to the total amount in the card. This supplement of credit is associated to an accreditation date to be sure that the same credit has not been added more than once in the security processor.

2.4 Shared messages EMM-S

The aim of the EMM-S is to reduce in a consequent way the data rate for management messages. Users of the same group receive the same update of their entitlement.

Supposing that an entitlement E must be sent to update a subscription to users, the message will be :

- a general EMM (EMM-G), interpreted by any receiver, to describe the common entitlement

- EMM-S messages to address groups of users.

EMM-G	entitlement E		
EMM-S	SA1	ADF1	Hashing 1
EMM-Sn	SAn	ADFn	Hashing n

Where :
- E is the entitlement to be renewed
- SA1 is the shared address of the group of 256 users
- ADF1 is the address field (256 bits) where one bit is allocated per user (if bit equal 1 then the entitlement is updated, if bit equal 0 then entitlement is not updated)
- Hashing is the signature of E, SAi, ADFi using the distribution key DKi.

This method allows a consequent reduction of data rate, 256 users sharing the same message (to be compared with EMM-U where 1 message is used per user).

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SECTION 11C: CONTROL, MEASUREMENT AND INTERNATIONAL EXCHANGE OF TELEVISION PROGRAMMES

REPORT 628-4

AUTOMATIC MONITORING AND CONTROL OF TELEVISION OPERATION

(Question 15/11)

(1974-1978-1982-1986-1990)

1. Use of insertion reference signals (IRS) in the television studio complex

1.1 *Purpose of insertion reference signals*

Study Programme 12A/11 recognizes the possibility of using insertion signals as a reference and certification tool for adjustment of the waveform characteristics of a distorted programme signal, so that the original characteristics of the picture may be restored. Such insertion signals are called "insertion reference signals".

1.2 *Insertion points*

Insertion reference signals are inserted on the video signal at all certification points; that is, at all points where qualified personnel are present who can verify that the technical parameters of the programme signal are correct, and that the content of the programme picture, as seen on a picture monitor, is also correct. The insertion reference signals stay with the programme signal at all times, and may only be erased and replaced at recertification points down-stream (if any).

As an example, the outputs of film and slide scanners, television cameras or vision mixers, etc., can be certification points; at these points technical personnel check that the inserted IRS are undistorted and that the programme signal parameters are correct. In particular, they verify that the level of the programme peak white does not exceed the level of the white bar in the IRS.

1.3 *Correction points*

Automatic correctors that can correct most of the linear distortions of the IRS signals are available on the market. The correctors may be used for instance automatically to correct luminance level, chrominance level, burst amplitude and sync amplitude, etc.

An automatic correction by means of IRS can be effected on the output of the switcher in the continuity suites that feed the television distribution networks; in this way, all signals distributed on the networks conform to the standard and to the artistic intention of the programme director. It should be noted that in the USA particular insertion reference signals (VIR) are fed throughout the television system, down to the user's television receiver, which could incorporate an IRS correction circuit.

Manual correction with IRS may be carried out at recertification points; this occurs in the case of a studio vision mixer that corrects, switches on the output and recertifies a remote signal such as one coming from a film scanner.

IRS may also be used to advantage to make small adjustments in the alignment of television tape-machines when playing programme tapes. The output of television tape-machines can thus be considered to some extent as a correction point.

1.4 *Waveform of the national insertion reference signals*

Many countries believe that the waveforms adopted for IRS should preferably be the same as certain of the waveforms adopted for international insertion test signals (ITS) [CCIR, 1978-82a]. However, it may not be necessary to adopt all the ITS waveforms for certification purposes [CCIR, 1978-82b; Zaccarian, 1978]. Other countries prefer to use a different and much simpler waveform for the insertion reference signal. In any case, it is important to make sure that, at the input to the international distribution network, the IRS are deleted after they have been used to make the necessary corrections. This is in order to ensure that there is no possibility of confusion with ITS which may subsequently be inserted, in accordance with Recommendation 473.

The EBU has recommended [CCIR, 1978-82a] that its member organizations operating with 625-line 50 field television systems and wishing to introduce IRS should employ the signals shown in Figs. 1 and 2 (taken from Recommendation 473), preferably inserted in lines 17 and 330 respectively. If, for reasons of economy, it is desired to use only one of these signals, the signal shown in Fig. 1 should be inserted only in line 17, or alternatively, the signal shown in Fig. 2 should be inserted only in line 330.

In the United States of America the VIR signal is transmitted by all major television networks and is inserted locally by many television stations. A complete description of the VIR signal is contained in an engineering bulletin published by the Electronics Industry Association [EIA, 1982]. The waveform of the signal is depicted in Fig. 3.

2. Use of insertion test signals (ITS) for the automatic monitoring of television systems

2.1 Television emission stations

During recent years, it has been the custom to design transmitting stations for unattended operation. This has led to a growing demand for automatic measuring systems capable of checking transmitter performance and providing alarms and status information for control stations. This automatic equipment is generally arranged to measure important characteristics of the television signal such as the synchronizing pulses, blanking intervals and the main features of an insertion test signal located in the field-blanking period. The equipment may also check the frequency of the vision and sound carriers and, in some cases, the continuity of the sound channel may be checked by detecting the presence of a super audio pilot signal. In the case of transposers, the insertion test signal measurement results may be regarded as sufficient evidence of correct operation of the sound channel.

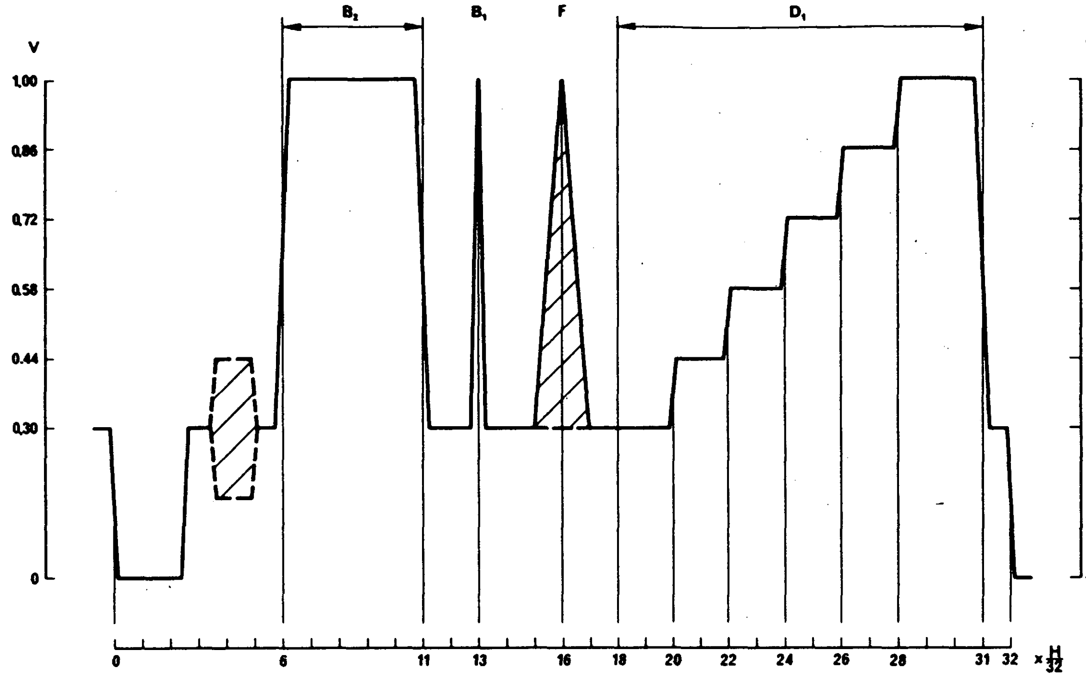

FIGURE 1 – *IRS signals recommended by the EBU for insertion in line 17*

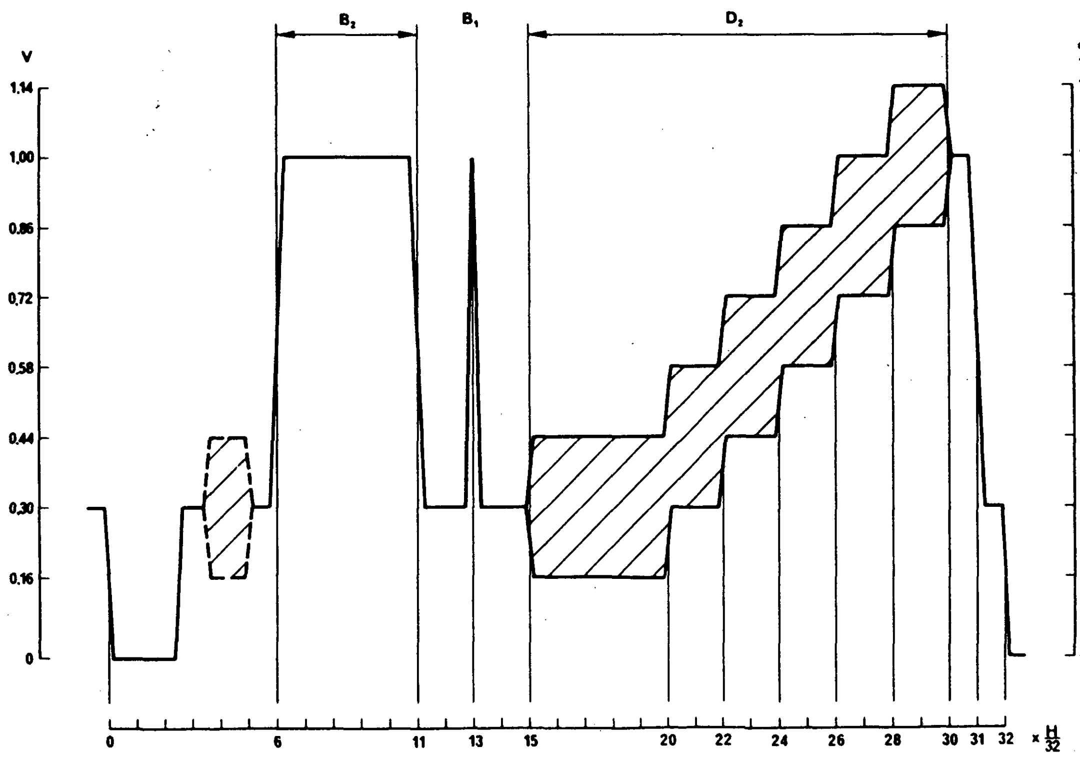

FIGURE 2 – *IRS signals recommended by the EBU for insertion in line 330*

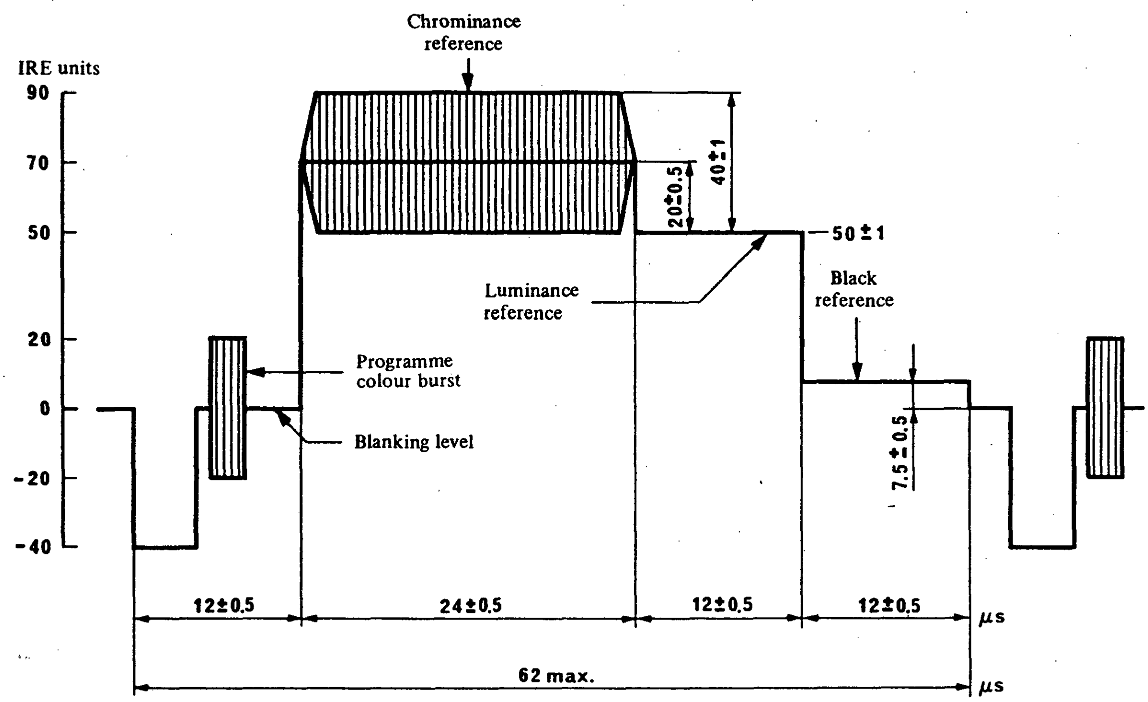

FIGURE 3 – *The VIR signal recommended for use in the United States of America*

Note 1. – The VIR signal is inserted on line 19 of both television fields.

Note 2. – Peak-to-peak variation of any nominally constant level: 0.5 IRE max.

Note 3. – Luminance transitions rise and fall times (10%-90%): 0.25 ± 0.05 μs.

Note 4. – Chrominance reference rise and fall times (10%-90%): 1.0 ± 0.25 μs.

Note 5. – Chrominance reference phase: same as programme colour burst ±1°.

Note 6. – Chrominance reference harmonic distortion: 1% max.

Note 7. – All tolerances are provisional and apply at the point where the VIR is inserted into a programme.

The facilities needed for the automatic monitoring of a network of broadcasting stations may either be located at each of the stations to be monitored, or, in another method, a central master station may employ a more comprehensive system which is able to make measurements by direct reception of the remote stations. While the transmitter is in programme service, it is convenient to monitor the radio-frequency signal by feeding the measuring system from a high quality receiver or demodulator. A similar set of measurements may be needed for the point to point link network which distributes the signal to the main transmitting stations. Both sets of measurements may often be performed by the same operational system which is able therefore to supervise the link networks as well as the transmitters.

The recent emergence of the integrated circuit micro-processor has led to the design of equipment which allows wholly digital measuring techniques to be applied to on-site test line parameter analysis and noise measurement [James and Watson, 1975]. This approach results not only in greater versatility, but affords appreciable economies in both size and cost over comparable analogue measuring equipment capable of taking executive corrective action.

Report 411 discusses automatic methods of measuring and supervising video test signals. The methods decribed are equally applicable to the monitoring of transmitting stations.

2.2 Systems carrying MAC/PACKET signals

Automatic measurement methods and test signals for MAC/PACKET family signals have been described in [CCIR, 1986-90a] and are being studied by CMTT. Results of these studies are given in Report 1096.

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REPORT 311-6

THE PRESENT POSITION OF STANDARDS CONVERSION

(Question 2/11, Study Programme 2B/11)

(1963-1966-1970-1974-1978-1982-1986)

Although early methods of standards conversion involved electro-optical image transfer techniques, methods of conversion which do not require the use of the image-transfer method have been developed, and are employed in the United Kingdom and in Japan. These are field converters for both monochrome and colour television which, in the past, used ultrasonic delay lines as the storage medium.

Work in the United Kingdom and in Japan has led to the successful development of digital field converters, employing stores based on dynamic shift registers or random access memories having the capacity to store two, three or four fields. These digital converters are now in wide use at earth stations and broadcasting centres throughout the world. Operations with these equipments have confirmed that converters of this type can be relatively small in size, and are likely to prove very stable in service and economic in terms of running costs. In general, they include far fewer pre-set and operational controls than corresponding analogue equipments. The performances of the digital equipments are noticeably better than that of previous converters and the signal-to-noise ratio at the output can be significantly better than that at the input.

A new standards conversion algorithm has been developed [CCIR, 1982-86a] which uses a position interpolation technique for frame rate conversion in addition to the conventional linear interpolation in order to solve the problem of motion judder. This algorithm was successfully applied to a standards converter from 1125/60 to PAL in order to meet the requirement that the high-definition television should be converted to the existing television systems keeping a quality essentially equivalent to that of those systems.

The results of the subjective test for the output picture quality of this converter carried out by several broadcasting organizations show that the quality difference between the converted pictures and the direct PAL pictures is small. It is believed that a quality essentially equivalent to PAL quality will be possible within a reasonable period of time [CCIR, 1982-86b].

The conversion algorithm used in this converter can be applied not only to the conversion between the existing television systems but also to the conversion between television systems and film systems.

A considerable amount of work on the design and production of converters has been carried out in several countries. For the benefit of workers in this field of activity, a bibliography follows.

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REPORT 804

DEFINITIONS OF PARAMETERS FOR AUTOMATIC MEASUREMENT OF TELEVISION INSERTION TEST SIGNALS

(Question 15/11, Study Programme 15D/CMTT)

(1978)

At the Interim Meeting of the CCIR, Geneva, 1976, the need for definitions of parameters for automatic measurement of insertion test signals (Recommendation 473) was recognized. At that time a draft text for such a Recommendation was prepared by the CMTT and contributions were invited from all administrations on the application of those definitions.

The CMTT at their meeting in 1977 adopted a revised text specifying a set of parameters in the form of Recommendation 569. It is believed that it would greatly simplify operational procedures if a unified set of parameter definitions could be adopted for use on point-to-point links, transmitters and studio signals. It is, therefore, desirable that the set of definitions given in the CMTT Recommendation should be used in the studio and transmitter areas. Further contributions are needed on the application of these parameter definitions at all points in the studio and transmitter chain.

REPORT 1081-1*

THE RELATIVE TIMING OF SOUND AND PICTURE SIGNALS

(Question 35/11)

(1986 - 1989 -1990)

1. Introduction

A television programme may be impaired by a lack of synchronism, that is a relative timing error, between the sound and picture signals.

Loss of time relationship between sound and picture can occur in two principal areas:

- in equipment used for studio effects or interconnect and pre-emission processing; such as video digital production effects units, synchronizers, standards converters and audio digital encoding equipment. This equipment will of necessity be different for the sound and picture signals and therefore may introduce appreciable differential delay between these components. Although the amount of differential delay introduced by individual items of equipment may be relatively small, the cumulative effect occurring when such equipment is cascaded in the programme path may be significant.
- where sound and picture are sent over separate circuits, particularly if one circuit is terrestrial and the other satellite.

2. Effects of variations in the relative timing of sound and picture

In real life it is unnatural for a sound stimulus to be perceived before the corresponding visual stimulus. Sound is normally delayed with respect to what is seen but the degree of acceptable delay is based on subjective experience. In television broadcasting, this allows a certain tolerance of the onset of the point of subjective annoyance with increasing delay. There will be inherent delays due to fundamental factors such as source to microphone and reproducing loudspeaker to listener distances. The subjective stimuli will be affected by the choice of camera shot e.g., long, medium or close-up, the latter often provided by long focal length telephoto lenses.

Studies have been carried out by the EBU [CCIR, 1986-90a, b] and in Australia [CCIR, 1982-86] which suggest that delay of sound with respect to picture when in the order of 40 ms is often detectable. This corresponds to a path length in air from source to listener in the order of 13 metres.

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* This Report should be brought to the attention of Study Group 10 and the CMTT.

Table I summarizes the conclusions of these studies:

TABLE I

CCIR input documents	Criteria	Sound advanced with reference to vision	Sound delayed with reference vision
Australia [CCIR, 1982-86]	"detectable" "subjectively annoying"	20 ms 40 ms	40 ms 160 ms
UK [CCIR, 1986-90a]	recommended limit (EBU) for outputs intended to feed broadcasting transmitters	40 ms	60 ms

These results compare with those reported in Report 412.

3. Methods of adjustment

In practice, adjustment is performed by introducing additional delay into the sound or picture signal. It is generally preferable to delay the sound because this is less expensive.

Analogue sound signals, unfortunately, contain no timing information suitable for controlling the operation of equipment which can automatically correct timing differences that may accumulate in a programme's path to final transmission. Manual correction can be performed with difficulty by a skilled operator by observation of the audible and visual cues. Ideally, alterations of the relative delay of audio signals should be made only during silence as manual changes can create disturbing effects. It is therefore more desirable to carry out such correction before commencement of transmission, possibly during a rehearsal, e.g., by means of a manual "clapper board" such as used in the film industry or an equivalent test signal. Where changes of the relative video timing varies during the course of a transmission it would be desirable to produce a control signal to automatically insert a corresponding audio delay. An example of one type of such equipment, which is now available, in at least one television standard, is a frame synchronizer incorporating a matched audio delay unit.

An Australian contribution proposes that one method could use the channel status data which is specified in Recommendation 647 for the digital audio interface. The Document (CCIR, 1986-90c) describes a method for deriving an 11-bit code which could be added to the video signal for the use in downstream restoration of the video and audio time relativity.

In the case of digital sound signals, timing information could be incorporated into the data to control automatic correction equipment.

Digital processing equipment treating both sound and picture should be capable of matching process delays to ensure there is no relative timing error at the output.

4. Accumulation of delays

In longer circuits involving several organizations, it is not uncommon for small delays to be introduced by each organization. While each individual delay may be acceptable, the cumulative error can become excessive. Moreover, when a programme is compiled from different segments received from different origination points each having different relative timing errors, subsequent retiming is impractical.

5. Conclusion

It is important that the relative timing of sound and picture be kept to a minimum to avoid unacceptable impairment to the programme. It is desirable that each organization processing the signal ensures that the timing is correct at the point of exchange.

Even with relatively uncritical material, experience suggests that a sound advance in the order of 40 ms, or a delay in the order of 160 ms will be disturbing to a significant number of viewers. Where the programme contains frequent audible and visual cues, e.g., lip synchronization, the relative timing error exceeding 20 ms advance or 40 ms delay has found to be detectable.

Further studies are required to minimize these timing errors and to standardize the methods of correction.

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REPORT 1237

SATELLITE NEWS GATHERING

(1990)

The text of this Report as jointly approved by Study Groups 10, 11 and CMTT can be found in the Annex to Volume XII.

REPORT 1218

MEASUREMENTS IN HDTV*

(Question 27/11, Study Programme 27C/11)

(1990)

1. Introduction

High-definition television (HDTV) is currently under development. Measurement of HDTV parameters represents a new task, and such measurement techniques should be defined in advance of the development and implementation of the associated hardware.

2. General considerations

In generating HDTV signals, the luminance components require a bandwidth of approximately 30 MHz (for progressive scanning the bandwidth is approximately 60 MHz) and the colour-difference signals occupy a bandwidth of the order of 15 MHz each (30 MHz for progressive scanning).

[CCIR, 1986-90a] states that the requirements for accuracy in the generation and transmission of HDTV signals (before and after coding) increase significantly since their distortion is more noticeable on large screens. The specific features of HDTV measurements are primarily conditioned by the wideband nature of the signals used [Krivocheev and Dvorkovitch, 1989].

[CCIR, 1986-90a] further states that HDTV signal distortions may also be due to inadequate transient response and the static and dynamic non-linearity characteristics of the HDTV signal encoding and transmission equipment, as well as different types of additive and multiplicative interference. Given the broad band of frequencies and the need for accurate control of signal level, digital processing techniques are required to allow adequate assessment of the signal. A mathematical treatment of the situation is provided in [CCIR, 1986-90a,b].

3. Testing methods

[CCIR, 1986-90a] suggests that the following transfer characteristics must be examined:

- very long-time distortions due to scene changes (at frequencies below the frame or field frequency);
- long-time distortions (at frame or field frequencies and their harmonics);
- line-time distortions (at the line frequency and its harmonics);

* See Recommendation 567 concerning test signals for conventional television systems.

- short-time distortions (at low to medium video frequencies);

- very short-time distortions of fine details (at the upper video frequencies).

The requirements for a series of test patterns and test signals adequate to accomplish the above have been studied and described in [Krivocheev, 1976; Dvorkovitch, 1988a and b; Krivocheev and Dvorkovitch, 1989; CCIR, 1986-90a].

Test signals have also been proposed in [CCIR, 1986-90b]:

- a multiburst sequence with two references for use in measuring the amplitude-frequency response* (Fig. 1);

- a complex signal sequence used to measure the transfer functions and the pulse characteristics of the luminance channel and the colour-difference channels* (Fig. 2);

- a sweep frequency waveform used to measure the continuous amplitude-frequency response and group delay (Fig. 3);

- a pair of step signals carrying pulsed signals of different polarities and sine test tones of different video frequencies, respectively, for evaluating static and dynamic non-linear distortions (Fig. 4).

[CCIR, 1986-90c] suggests elements of possible test patterns for high definition television and proposes examples of test patterns (Figs. 5 and 6):

- an HDTV test pattern consisting of black and white parallel lines of varying resolution and at different angles to the horizontal and vertical axes. This may be used for resolution estimation;

- an HDTV test pattern consisting of a circle of a specified diameter on a field of dots and orthogonal lines. This may be used in determining fixed pattern noise and raster distortions.

Study Programme 27C/11 also covers measurements on performance of transmission channels, and its effect may depend on the signal format used in the transmission.

For the MUSE transmission [CCIR, 1986-90d] reports that the resultant picture quality can well be described with measured values of amplitude errors at the sampling points by using a logistic function.

An HDTV C/N ratio checker and an HDTV digital audio bit-error counter, for use with satellite broadcasting of MUSE signal, have also been developed [CCIR, 1986-90e].

* The groups of elements contained in this signal could be arranged either alternatively in the interval of one line of the signal or sequentially in several lines of the signal.

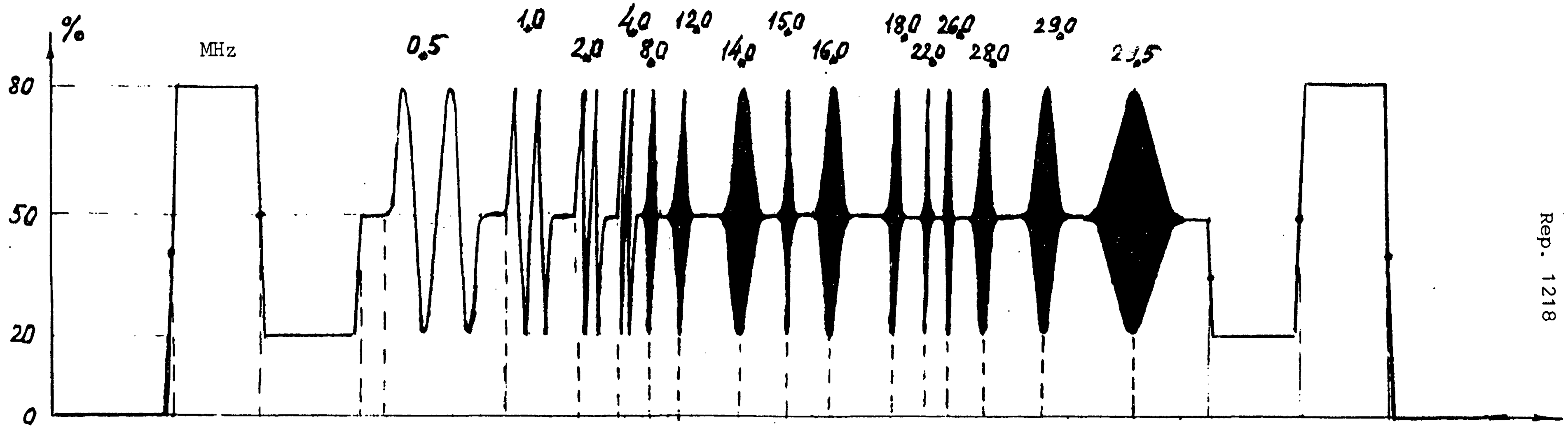

FIGURE 1

Test signal for measuring the amplitude-frequency response at a number of frequencies

Note: T = 16.67 ns

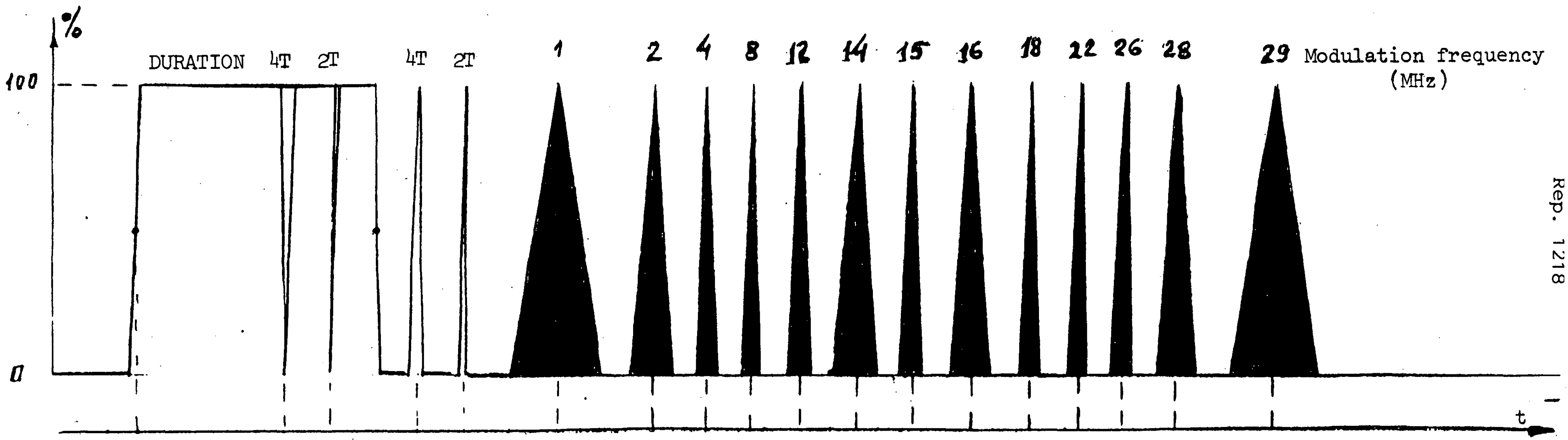

FIGURE 2

Test signal for the measurement of transfer functions and pulse characteristics

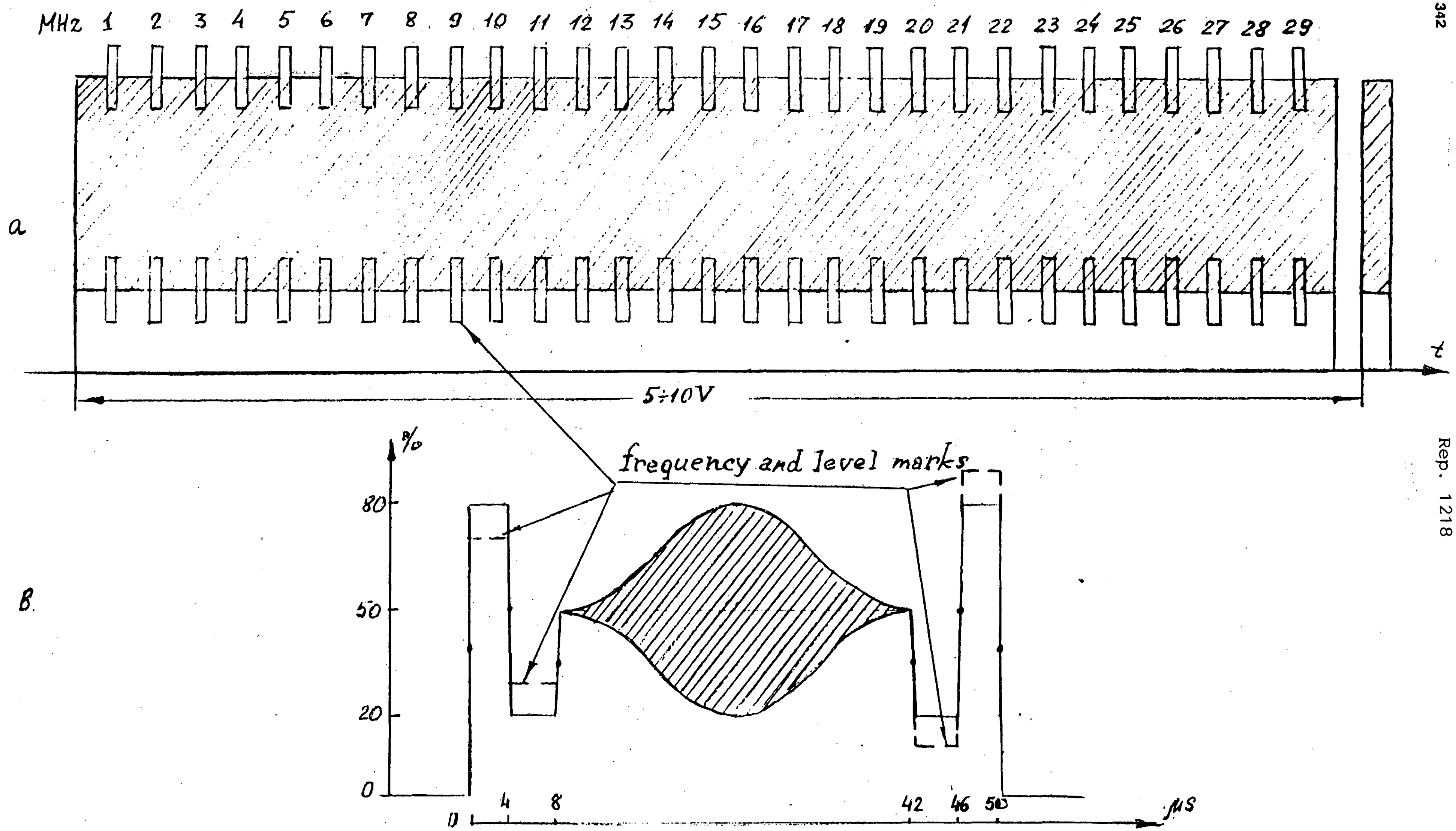

FIGURE 3 - Test signal for the measurement of continuous amplitude-frequency response and group delay

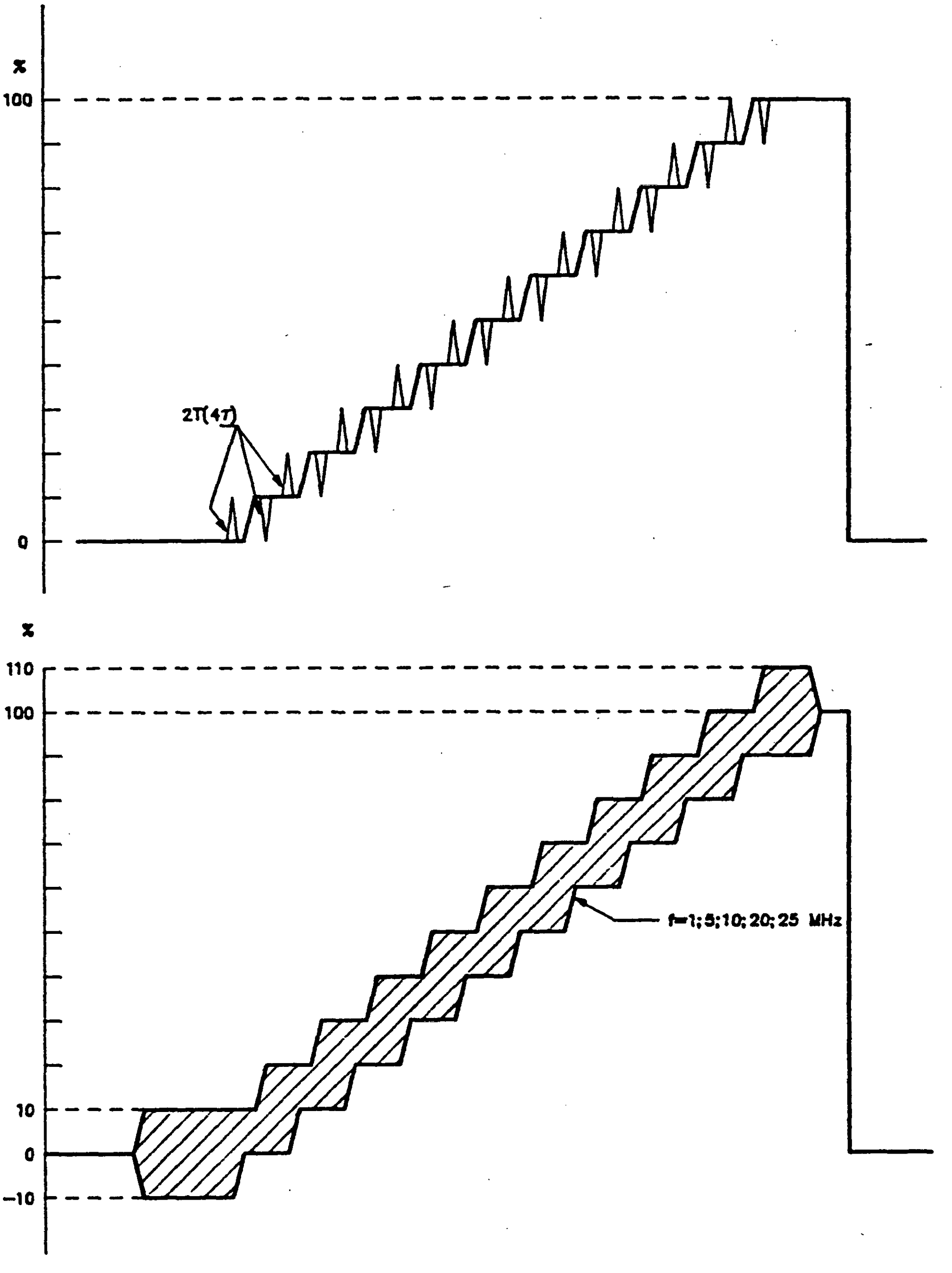

FIGURE 4 - Test signals for the measurement of non-linear distortions

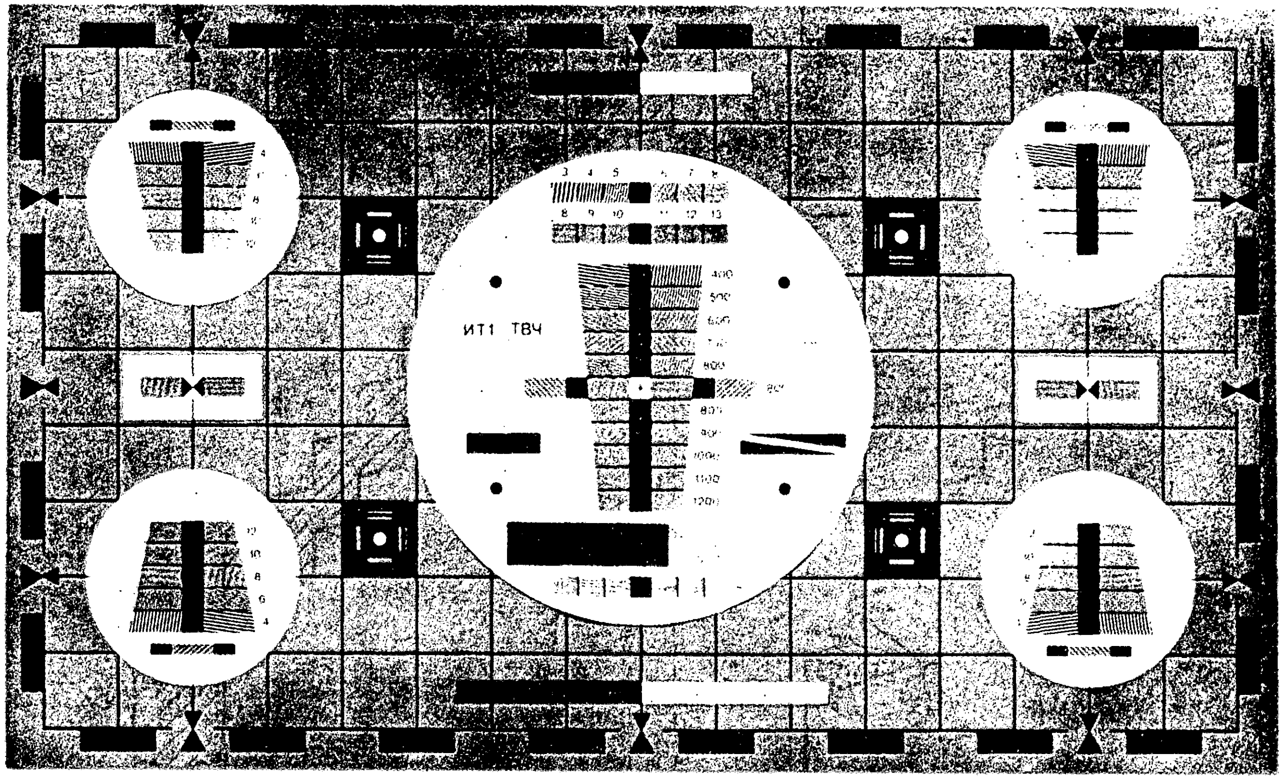

FIGURE 5 - Resolution Test Chart for HDTV

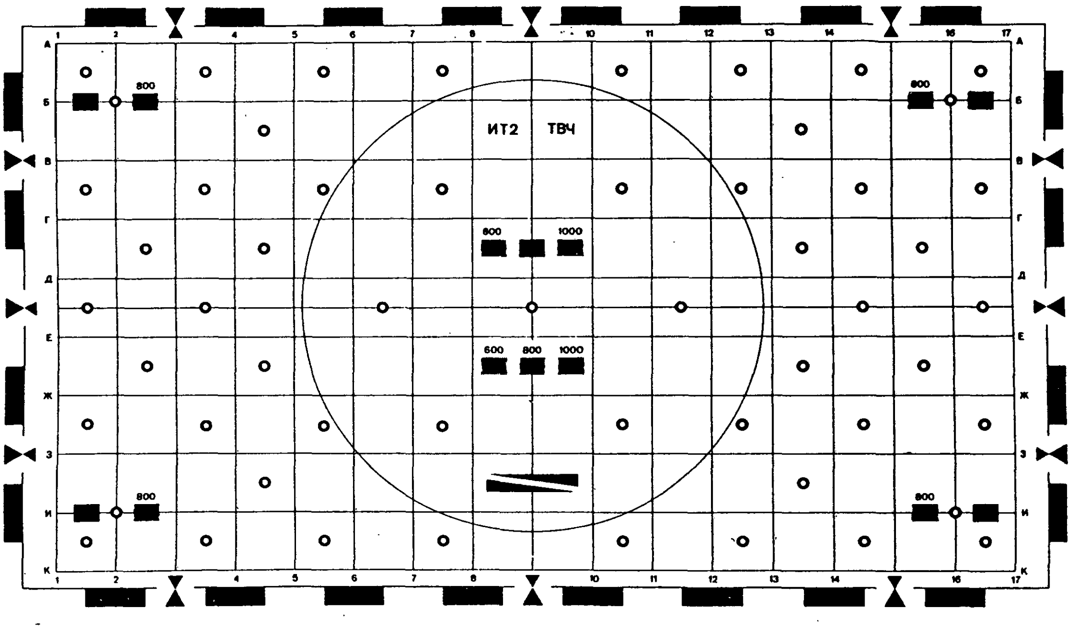

FIGURE 6 - Linearity Test Chart for HDTV

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[1986-90]: a. 11/6-2104 (USSR); b. 11/6-2105 (USSR); c. 11/6-2106 (USSR). d. 11/580 (Japan); e. 11/578 (Japan).

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SECTION 11D: PICTURE QUALITY AND THE PARAMETERS AFFECTING IT

REPORT 1205

ANALYSIS AND PRESENTATION OF THE RESULTS OF TELEVISION SUBJECTIVE TESTS

(Question 3/11, Study Programmes 3A/11 and 3D/11)

(1990)

1. INTRODUCTION

In the course of a subjective experiment to assess the performance of a television system, a large amount of data is collected. These data, in the form of observers' score sheets, or their electronic equivalent, must be condensed by statistical techniques to yield results in graphical and/or numerical form which summarize the performance of the systems under test. Information on various methods of analysis which have been proposed is given in Annexes II and III of Report 405-5 (Dubrovnik, 1986).

In the present Report, a single method of analysis is proposed. It is one which is simple to use and has been studied in depth for many years. Other methods may be more precise in special circumstances but are more difficult to understand and more complex to use. Their use can only be justified when some special circumstances apply.

The proposed method is described in the body of this Report without giving the supporting arguments. Additional information and variants of the method are given in Annexes I to III. Annex IV discusses the errors to be expected in a subjective assessment. Further information on the accuracy of subjective assessment results are given in Annex V. Annex VI describes a further stage of statistical processing which has been found useful in dealing with a family of systems or devices having a wide spread of performance characteristics.

2. Processing test results for a particular value of impairment

The objective magnitude of the impairment is characterized by a particular number according to the convention appropriate to the particular effect; for example, signal/noise ratio in decibels, differential phase distortion in degrees, etc. This numerical value is called D and is defined more precisely in § 3.

The tests carried out with D constant, according to the principles set out in Recommendation 500 lead to a certain distribution of scores on the 5-point scale used. This distribution includes the differences in judgment between observers and the effect of a variety of conditions associated with the experiment, for example the use of several pictures.

In what follows U denotes the quality grade (1 to 5) on the scale used.

The analysis of the distribution gives, for each grade U_i, the proportion of the total opinions p_i (note that $\sum_i p_i = 1$).

The analysis of this distribution can be made by two methods:

2.1 By simply calculating the direct mean score,

$$\bar{U} = \sum_{i=1}^{5} i \times p_i \tag{1}$$

2.2 By finding a mathematical model (or interpolating function) which smooths out the random errors in the measured proportions p_i.

The different solutions to this problem which have been proposed fall under two main classifications. Firstly, models which yield directly the proportions in the five grades. An example of such a model is:

– a modified binomial distribution [Prosser *et al.*, 1964] which is described by its mean score and order (an integer).

Note 1 – In fitting the chosen model to the experimental results for a given impairment condition, an efficient method of adjustment is simply to equate the mean and standard deviation of grades yielded by the model, to those actually found.

Note 2 – In an experiment with a given type of impairment, it is commonly found that a single value of width parameter (or binomial order, etc.) suffices to fit a well-chosen model to all the impairment conditions tested. Differences between the standard deviation actually found for a given impairment condition and that yielded by the model are no greater than can be accounted for by sampling error. Indeed, it has been found that a single width parameter can apply to many different types of impairment. Thus the finding of a distribution model with a width parameter which will apply to all impairment conditions in an experiment, and the establishment of a relationship between central tendency (mean or median) and objective magnitude can be treated as separate operations.

3. Processing to find the relationship between U_m and D

The next step in processing the data is to establish the relationship between the mean score U_m (or $\overline{U}$) and the objective measure of the distortion D as D is varied. The process which follows consists of finding a simple continuous relationship between U_m and D.

3.1 Approximation by a symmetrical logistic function

The approximation of this experimental relationship by a logistic function is particularly interesting.

The processing of the data U_m can be made as follows:

3.1.1 The scale of values U_m is normalized by taking a continuous variable u such that,

$$u = (U_m - 1)/4 \tag{2}$$

when U_m is in the range 1 to 5.

3.1.2 Graphical representation of the relationship between u and D shows that the curve tends to be a skew-symmetrical sigmoid shape provided that the natural limits to the values of D extend far enough from the region in which u varies rapidly.

The function $u = f(D)$ can now be approximated by a judiciously chosen logistic function, as given by the general relation:

$$u = 1/[1/u_0 + \exp(D - D_M)G] \tag{3}$$

where G may be positive or negative.

In this expression the presence of the constant u_0* will be noted. It represents, in the function $u = f(D)$, the asymptotic value of u for the very small impairment.

This peculiarity of the curve $u = f(D)$ is frequently encountered and characterizes the fact that even for a level of impairment which is theoretically zero, the mean quality grade obtained in the course of the tests does not reach the limiting value $U_m = 5$, or $u = 1$. As a result of various imperfections of the picture, the measured value is u_0.

3.1.3 The value u obtained from the optimum logistic function approximation is used to provide a deduced numerical value I according to the relation:

$$I = (1/u) - 1 \tag{4}$$

In the case where the value u_0 is not equal to 1, this transformation provides a limiting value of I, as

$$I_0 = (1/u_0) - 1 \tag{5}$$

3.1.4 If I_{exp} is the raw result obtained from equations (3) and (4) a correction is made to this result by the relation, $I_u = I_{exp} - I_0$.

It is convenient in practice, for the graphical representation of the values of I_u as a function of the impairment D, to use a logarithmic scale for I_u. This convenience results from the fact that the logistic function being used to represent the relationship takes the form of a straight line in this graph. The expression for this relationship is effectively:

$$I_u = \exp(D - D_M)G \tag{6}$$

It will be observed that in such a graph the experimental values, processed to obtain corresponding values of I_u, will be sensibly on a straight line.

Interpolation by a straight line is simple and in some cases of an accuracy which is sufficient for the straight line to be considered as representing the impairment due to the effect measured by D.

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* In the publications this constant is also designated H.

In this representation, the direct measurement of the impairment by the value D is shown on a linear scale. The slope of the characteristic is then expressed by:

$$S = \frac{D_M - D}{\log_e I} = \frac{1}{G}$$

and, for the particular value of D where $I = e$ and $I = 1/e$, we get:

$$|S| = D_M - D = \Delta D$$

Figure 1 shows the representation thus obtained. The values of I are expressed, in accordance with the proposals which have been made by Lewis and Allnatt [1965] in "imp" units.

The straight line may be termed the impairment characteristic associated with the particular impairment being considered. It will be noted that the straight line can be defined by the characteristic values D_M and G of the logistic function.

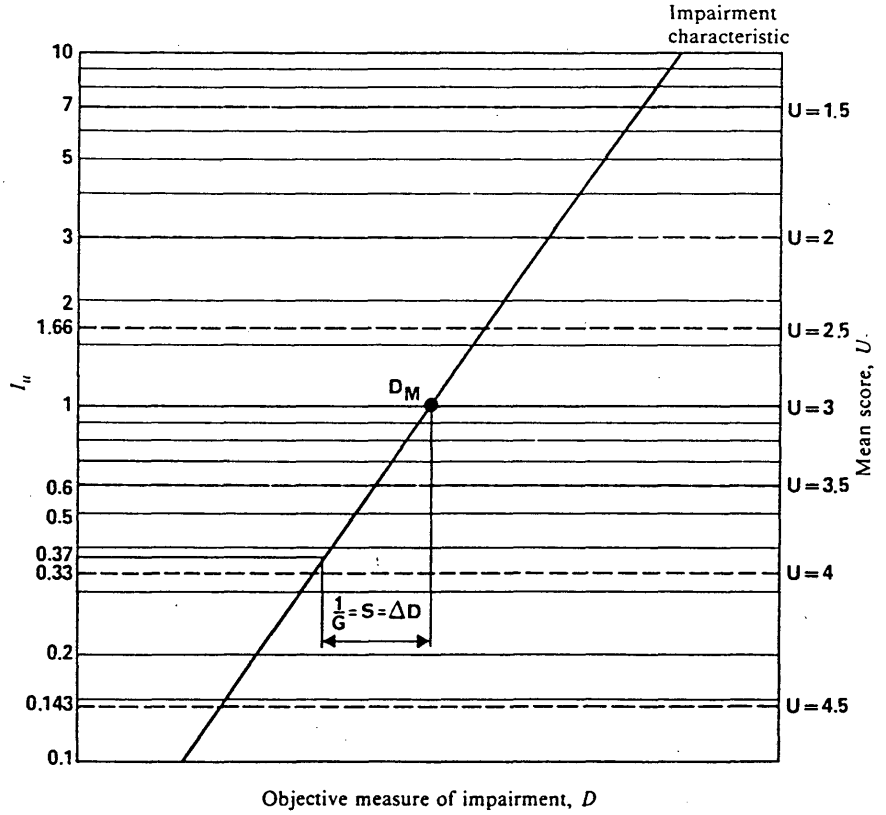

FIGURE 1 – *Representation of the impairment characteristic*
U – Mean score, 5-grade scale

3.1.5 *Arithmetic measure of objective impairment*

Where the conventional objective measure of impairment is arithmetic in nature, the relationship with u will generally not be skew-symmetrical and it will be necessary to employ logarithms. However, the arithmetic measure, which will be designated d, and such that $d < 1$ if d is a ratio (e.g. noise voltage/signal voltage) might be considered the more basic one and it is of interest to examine the function relating u with d.

$$D = \log_e d$$

and,

$$D_M = \log_e d_M$$

Substituting D and D_M in the logistic equation(3) it can be shown that,

$$u = 1/[(1/u_0) + (d/d_M)^G] \tag{7}$$

from which (as in § 3.4equation 6)),

$$I_u = (d/d_M)^G$$

In this case, with the logarithmic scales I and d, the slope is expressed by the relationship between d, I and d_M

$$G = \frac{\log_e I}{\log_e (d/d_M)}$$

and $|G|$ can be found using the particular value of D where $I = e$ or $I = 1/e$.

It may be considered that the corresponding values of G (or equally those arising from values D which are natural logarithms) are of more fundamental significance than those from values of D expressed in decibels, or a logarithmic measure other than natural logarithms. Accordingly, it is proposed to reserve G exclusively for values appropriate to equation(7), as this usage is common in the literature and particularly because an extensive set of results, expressed in these terms, has been published (Report 959).

When, in practice, the value shown on the impairment scale is the expression in *decibels* of the relation, which will then be designated by D and shown on a linear scale, we shall get:

$$D = 20 \log_{10} (1/d), \qquad \text{i.e.} \qquad 1/d = 10^{D/20}$$

For the linear characteristic, the slope is given by

$$G' = \frac{\log_e I}{\log_e (d/d_M)} = \frac{\log_e I}{\left[\frac{D_M - D}{20}\right] \log_e(10)} = 8.686 \frac{\log_e I}{D_M - D}$$

Values of G arising from values of D expressed in decibels may conveniently be designated G'.

Therefore, $G = 8.686\ G'$.

3.2 <u>Approximation by a non-symmetrical function</u>

3.2.1 <u>Description of the function</u>

In practice, the use of a symmetrical logistic function frequently induces strong differences between actual data and approximation. These discrepancies may be due to the end of scale effects or simultaneous presence of several impairments in the test which may influence the statistical model and deform the theoretical logistic function. The issue of these complex artefacts is generally a skewness in the function providing the relationship between the mean scores U_m and the objective measures of the distortion D.

Annex III proposes methods to correct some of these artefacts but the perfect logistic approximation may rarely be obtained, so, [CCIR, 1986-90] proposes another function in order to take into account all the parameters. The purpose of this very simple approximation is reduced to the statistical analysis of the data and not based on an observer's behaviour theory. The function approximates the logistic one in a non-symmetrical way. For a five grade scale, the formula is:

$$U_m = 4/(1 + (D_M/D)^{1/G}) + 1$$

the notation being the same as in section 3.1.

If U_m is normalized as in section 3.1, we obtained:

$$u = (U_m - 1)/4$$

and $u = 1/(1 + (D_m/D)^{1/G})$.

3.2.2 Estimation of the parameters of the approximation

The estimation of the optimal parameters of the function that provides the minimum residual errors between the actual data and the function may be obtained with any recursive estimation algorithm. Figure 2 shows an example of the use of the non-symmetrical function to represent actual subjective data. This representation allows the estimation of specific objective measures corresponding to interesting subjective value: 4.5 on the five grade scale, for instance.

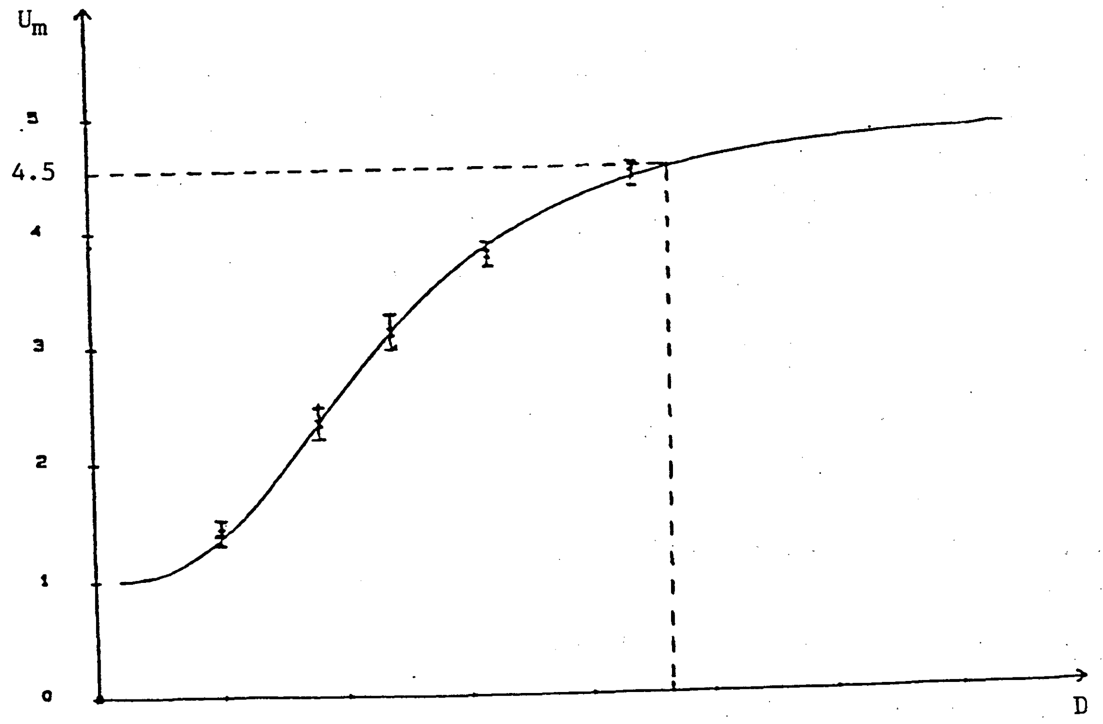

FIGURE 2

Non-symmetrical approximation

4. Reliability of subjective results: confidence region

Even for objective measurements, the reliability of results is generally indicated by means of standard deviation. Knowing the strong standard deviation reported for individual subjective assessments, many observations are needed and the correct information about reliability is not the standard deviation but the confidence interval.

In order to unify the presentation of subjective results, [CCIR, 1986-90] proposes to use the 5% confidence interval which is provided by: $\pm 1.96\ SD/\sqrt{N}$. SD is the standard deviation and N the number of observation.

Then, to incorporate this reliability aspect in the graphic, from the mean grades for each impairment tested and the associated 5% confidence interval, three series of grades are constructed:

- minimum grade series (means - confidence intervals);
- mean grade series;
- maximum grade series (means + confidence intervals).

The estimation parameters for the three series are then estimated independently. The three functions obtained can then be drawn on the same graph, the two from the maximum and minimum series as dotted lines and the mean estimate as a solid line. The experimental values are also plotted on this graph (see Figures 3 and 4). We thus get an estimate of the 5% continuous confidence region.

For the grade 4.5 (threshold of visibility for the method) we can thus read off directly from the graph an estimated 5% confidence interval that can be used to determine a tolerance range.

Limits of the method

The number of scenes and observers must be large enough (at least 30 observations per impairment, adequate number of sequences representing natural scenes).

The space between the maximum and minimum curves is not a 5% interval, but a mean estimate thereof.

The experimental values should all lie within the confidence region; otherwise it may be concluded that there was a problem in carrying out the test or that the function model chosen was not the optimum one.

Figure 3: Case of an impairment characteristic assimilable to a logistic function

U = mean grade
D = objective impairment measurement

Figure 4: Case of a non-symmetrical impairment characteristic

U = mean grade
D = objective impairment measurement

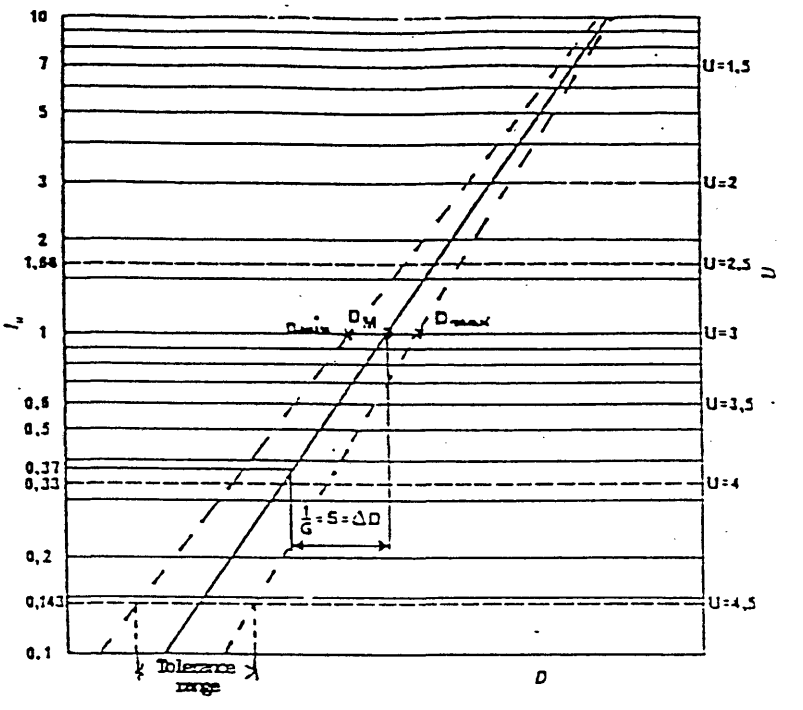

FIGURE 3

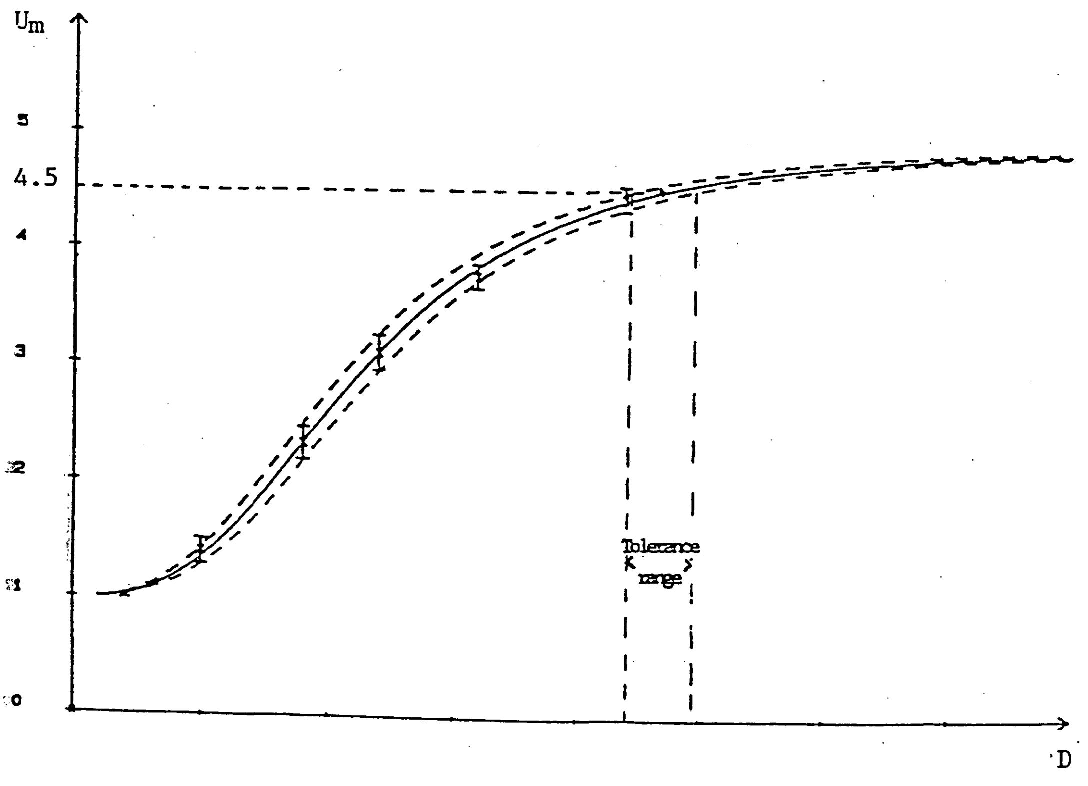

FIGURE 4

5. Conclusions

The processing of subjective test data which is described above has two advantages:

- the impairment characteristic is a straight line;
- in very many cases, the values of I appear to possess the property of summability when several sources of impairment which are not correlated are present simultaneously on the picture.

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PROSSER, R. D., ALLNATT, J. W. and LEWIS, N. W. [March, 1964] Quality grading of impaired television pictures. *Proc. IEE*, Vol. 111, 3, 491-502.

CCIR Documents

[1986-90]: 111/462 (France)

ANNEX I

OPINION DISTRIBUTIONS

1. Introduction

Methods of analyzing and presenting experimental data relating the degradation of a television signal to the consequent picture impairment, assessed subjectively, have up to now varied considerably among experimenters. Such differences add to the difficulty of comparison of results which may already exist due to variations in experimental method. Generally, the techniques that have been used fall into the following categories:

1.1 In what is probably the simplest method, numbers in an arithmetic series are assigned to the grades of the assessment scale, thus making possible the computation of a mean subjective score (from the reactions of all observers) corresponding to a given magnitude of objective impairment. The results are usually presented as a smooth-curve plot of mean score against objective magnitude. Statistically, the mean is the most efficient estimator of central tendency of the data, but it gives no information about the distribution of opinions regarding a given impairment condition.

1.2 In some cases it is only necessary to evaluate the perceptibility threshold of an impairment rather than the complete relationship between subjective evaluations and objective impairment. The "random stimuli" method is proposed [CCIR, 1974-78a]. Two slightly different definitions of the threshold may be used, either corresponding to the maximum standard deviation of assessments or to 50% of the positive observations [CCIR, 1974-78b].

However, it should be remembered that knowledge of the threshold of perceptibility alone is insufficient in the treatment of any but the simplest situations.

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[1974-78]: a. 11/171 (Italy); b. 11/65 (France).

ANNEX II

SUBJECTIVE IMPAIRMENT UNITS

Although the present concern is with analysis of results, it is useful to take a note of a requirement that frequently arises in application.

Under practical viewing conditions, a number of impairments may arise simultaneously. As it is impracticable to test all the possible combinations, a "law of addition" of impairments can be of great benefit.

An empirical law, which has been used [Lewis and Allnatt, 1968; Allnatt, 1979; CCIR, 1970-74], states that if $\bar{u}_1, \bar{u}_2, \ldots, \bar{u}_r, \ldots, \bar{u}_n$ are the respective normalized mean scores for n unrelated impairments taken separately, the normalized mean score $\bar{u}$ for all impairments taken simultaneously is given by:

$$\frac{1}{\bar{u}} - 1 = \sum_{r=1}^{n} \left(\frac{1}{\bar{u}_r} - 1 \right) \tag{1}$$

While a possible psychophysical basis for the law of addition in the above equation remains a matter for speculation [Siocos, 1972; Allnatt, 1979], all the relevant experimental data available at the present time confirms that it appears to be valid to an accuracy sufficient for most, if not all, practical purposes [CCIR, 1974-78]; although the multiple regression analysis quoted below may provide an interesting approach.

Consideration of design objectives is facilitated by expressing subjective impairment magnitudes in the form of directly summable quantities. As equation (1) suggests, this can be done very simply by transforming the mean score $\bar{u}$ into units of subjective impairment, termed "imps", by means of the relation $I = (1/\bar{u} - 1)$ imps. The I scale ranges from zero for the "perfect" picture ($\bar{u} = 1$) to infinity at the other extreme ($\bar{u} = 0$). $I = 1$ imp at the "mid-opinion" point given by $\bar{u} = 0.5$.

In the presentation of results, convenient mark points may be placed on the I scale, for example, 1/8, 1/4, 1/2 and 1 imp. When the term "imp" was originally introduced [Lewis and Allnatt, 1965 and 1968], its proponents intended that it should be related to a particular quality grading scale and narrowly defined test arrangements [Prosser *et al.*, 1964; Corbett, 1970], with a view to providing as near an absolute basis as possible for results. Subsequently it has become clear that some qualification of results will almost always be necessary. For example, scales and observers' standards could vary from place to place, translation of the scale into another language produces an unknown effect, and sometimes it may be desired to apply the test technique to a television system for which broadcast-viewing conditions are unsuitable. It is suggested that details should be given of test arrangements which might affect results.

The following remarks offer some guidance to interpretation of the mark points when a particular set of conditions [Prosser *et al.*, 1964; Corbett, 1970; Allnatt and Bragg, 1968] is used. The 1/8 imp mark point represents a low level of impairment, of the same order as the residual impairment normally found with a laboratory set-up consisting of a high-grade slide scanner and picture monitor. Experience suggests that 0.25 imp may be taken as a practical design objective for each of the major impairments that may occur in a system, such as a national one, of moderate size and complexity. At the present time, 0.5 imp appears to be a reasonable design objective for each major impairment in a complex system involving transmission over a chain of long-distance international links.

One final word of caution is that the use of the "law of addition" to find the overall impairment resulting from the simultaneous presence of component impairments, should not be used to add impairments having the same subjective effect, but resulting from the errors of different objective parameters (e.g., in the PAL system, chrominance phase and chrominance gain errors both give rise to saturation impairments in the image). In this case, the overall impairment should first be calculated in objective terms from each of the errors of the individual objective parameters [CCIR, 1970-74].

Some alternative addition laws have been proposed - see Annex II of Rep. 405-5 (Dubrovnik, 1986) - but information about the supporting subjective tests is not always complete, making comparisons difficult. It is considered that the imp addition law should normally be used as a good approximation to the results which would be achieved in practice, unless there is clear evidence that, in a particular case, some other method is substantially better.

Within the usual impairment level range of PAL system television pictures ($3 \geq I \geq 0.2$), the impairment summation law given by the following formula:

$$I_{\Sigma} = \sum_{r=1}^{n} a_r I_r, \qquad (2)$$

in which the weighting coefficients a_r can be obtained by linear regression of the test data and can then be used for calculating the overall impairment, provides a highly accurate method for the addition of impairments [CCIR, 1986-90]

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[1970-74]: 11/330 (Italy)

[1974-78]: 11/56 (United Kingdom)

[1986-90]: 11/143 (China (People's Republic of)).

ANNEX III

Adjustment for the residual impairments: alternative methods

The relation $I_{exp} = I_u + I_0$ described at the beginning of § 3.1.4 of this Report is used to adjust the results for the residual impairment corresponding to u_0 or I_0. In a comprehensive study [CCIR, 1978-82a, b and c; Kretz, 1981; Sallio and Kretz, 1982], comparisons between an absolute procedure and a procedure using direct anchoring with a reference unimpaired picture provide another basis for the adjustment of the residual impairment. A shift applied to u values ($u' = u + 1 - u_0$) is found to correspond very satisfactorily to the data. According to this analysis equation (3) of this Report would become:

$$u = (u_0 - 1) + 1/[1 + \exp(D - D_M)G] \tag{1}$$

then, an imp value can be calculated from adjusted u' data, by setting:

$$I_u = (1/u') - 1 \tag{2}$$

and equation (6) of this Report is seen to be also applicable, the rest of the analysis remaining unaltered.

The residual impairment considered in the previous sections arises because observers are aware of deficiencies in the "unimpaired" picture due to such effects as flicker, the scanning structure, etc. and consequently, they grade the quality less than "excellent". The appropriate methods of adjustment for this "residual impairment" (§ 3.1.4 and 3.1.5) involve some shift in the scores at the centre of the scale.

A different type of "residual impairment", which may be termed "scale boundary effect", has been indentified [CCIR, 1982-86] which appears to arise from a psychological reluctance by the observers to use the extreme grades of the scale. This can affect both ends of the scale equally leaving the centre (grade 3) unaffected. It is advisable to make an adjustment for "residual impairment" of this type when the impairments being assessed are small ($I < 1$).

An appropriate adjustment, avoiding a shift in the centre of the scale, can be made by applying the following formula to relate the true to the experimental scores [Gofaizen *et al.*, 1983]:

$$U' = 2\,\frac{U - 3}{U_0 - 3} + 3 \tag{3}$$

where:

- U' : true score on the 5-grade scale;
- U : experimental score;
- U_0 : experimental score without distortions.

For the normalized quality scores, the formula is written as follows:

$$u' = \frac{u + u_0 - 1}{2u_0 - 1} \tag{4}$$

where:

$$u' = \frac{1}{1 + I_u} = \frac{1}{1 + \exp(D - D_M)G} \tag{5}$$

Here, equation (1) of this Annex is converted into:

$$u = 1 - u_0 + \frac{2u_0 - 1}{1 + \exp(D - D_M)G} \tag{6b}$$

while equation (6) of this Report and the entire subsequent analysis may be used without any change.

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[1978-82]: a. 11/71 (France); b. 11/257 (France); c. 11/312 (France).
[1982-86]: 11/86 (USSR).

ANNEX IV

Prediction of the error in a subjective assessment test

If the true subjective grade of a test condition is considered to be the average obtained with a very large number of observations, it is possible to calculate the relationship between this true grade and the mean grade obtained by a practical experiment (with a realistic number of observations).

It is possible to calculate the "expected error" associated with the number of observations at a defined confidence level. A 95% confidence level, for example, is a reasonable reference, and with this figure in mind it is possible to delineate the relationship between the number of observations and the maximum expected error (making certain statistical assumptions) [Miceli and Orlando, 1977; CCIR, 1978-82]. This varies with mean grade and is given (for a mean grade of 3) in Fig. 5. Figure 6 shows the correction factor to be applied for mean scores above and below 3.

The "expected error" can be visualized as the half-amplitude of the area of uncertainty within which the result of the test is expected to approximate the true value to be measured at the selected confidence level. From Fig. 5 it can be seen that roughly equal numbers of pictures and observers give the lowest expected error for a given number of observations (see for example, points P and Q).

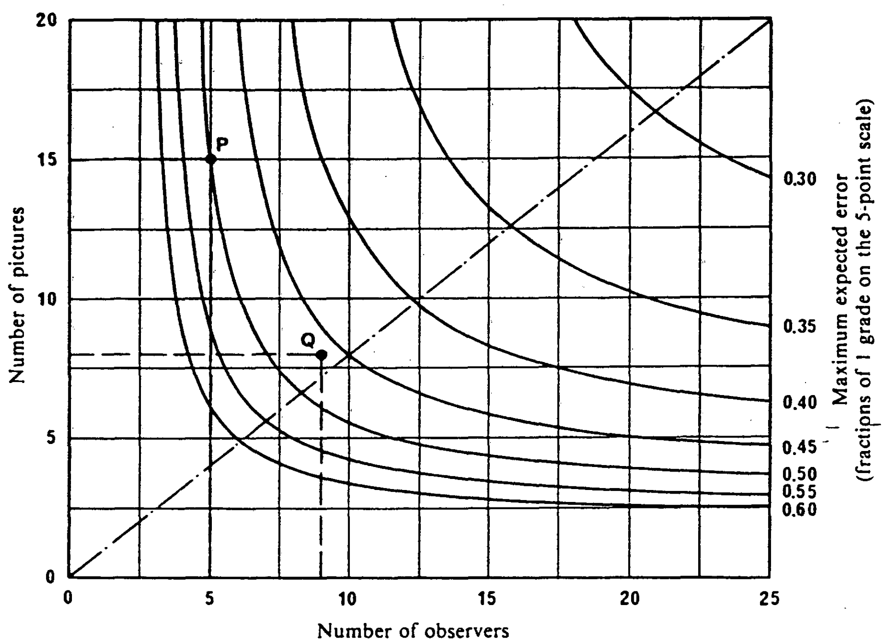

FIGURE 5 – *Curves giving the maximum expected error in a subjective assessment test, as a function of the number of observers and the number of pictures, for a confidence level of 95%*

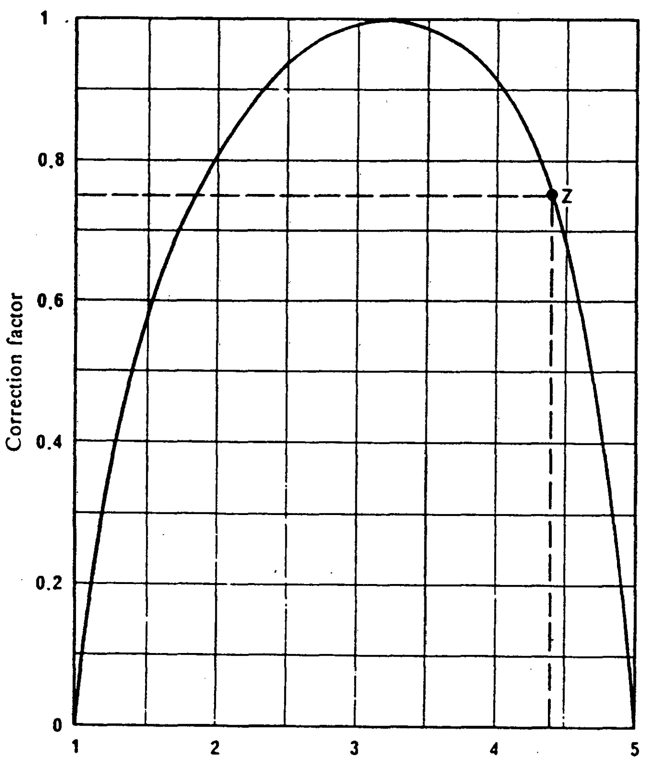

FIGURE 6 – *Curve giving the correction factor to be applied to the maximum expected error computed by means of Fig. 2 if the mean score is not 3*

As an example of the application of the curves, if for instance a subjective test has been made with 9 observers and 8 pictures the maximum expected error is 0.47 (from Fig. 5 point Q). If the mean grade was 4.40, the correction factor (from Fig. 6 point Z) would be 0.75, so the "expected error" at 95% probability would be 0.47 × 0.75 = 0.35. The curves were derived from analogue colour television experiments based on Recommendation 500 and using reasonably critical pictures. They may however serve as a good approximation for other test conditions. It would certainly be helpful if some experiments were carried out to derive exact curves for the other cases.

The general principles given above always apply generally, but the degree to which the errors are in practice below the maximum, when critical pictures are used, is the subject of discussion. Some experiments point to successful application in this case, but other workers believe that the subject should be studied further.

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CCIR Documents

[1978-82]: 11/309 (Italy).

ANNEX V

THE ACCURACY OF SUBJECTIVE ASSESSMENT RESULTS

1. INTRODUCTION

In order to evaluate the accuracy of subjective assessment results, it is necessary, as a first step, to develop a suitable model of the opinion population.

The opinion of the j-th observer about the quality of the i-th picture may be represented by a random variable x_{ij}. The whole collection of such opinions, i.e. the opinions of all the possible observers about the quality of all the possible pictures, is the opinion population.

This population is the one we are dealing with in, for example, the calculation of mean, variance, etc., and should not be confused with the picture and observer population, although both such populations are involved in the process of generation of the opinion set.

The average value of all opinions collected in this population is termed the "mean opinion" Q, and this may be formally expressed as the expected value

$$Q = E\left[x_{ij}\right] \qquad (1)$$

For this value, all possible observers and all possible pictures equally contribute, and therefore it may be considered as a "measure" of the quality of the system under test.

Unfortunately, this quantity cannot be evaluated exactly as this would involve an enormous number of scores, but it may be estimated by one or more subjective assessments. The purpose of the following discussion is the evaluation of the error which affects the experimental estimate of the "mean opinion" Q, i.e. the one obtained by practical subjective tests.

2. SAMPLING

The mean opinion is usually estimated by the assessments given by a group of observers about the quality of a limited number of pictures. This subset of assessments is often referred to as the 'sample'. It should be noted again that we are talking about assessment samples, rather than picture or observer samples.

However, because of the particular way it is generated, the assessment sample is not a usual one, in the sense that each element (opinion) is not obtained independently from the others. In fact, in the assessment sample, each observer gives his opinion about the quality of a set of pictures: hence these opinions are related to each other in some way (they have been generated by the same observer). In addition, the scores collected by each picture from different observers are not mutually independent (they refer to the same picture).

From the above discussion, it clearly appears that because of the cross dependence among the scores, the whole sample should carry less information than an hypothetical one in which the opinions are not related to each other.

Consequently, for this kind of sample, common quantities, such as the standard deviation, no longer hold their usual significance. Hence it becomes necessary to re-define an appropriate set of statistical quantities, with associated formulas, in order to properly process the collected scores.

3. ESTIMATE OF THE MEAN OPINION AND OF ITS CONFIDENCE INTERVAL

The sample mean, i.e. the average value of the collected scores from n observers and m pictures, is given in formula (2) below.

$$\bar{x} = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{x_{ij}}{m \times n} \qquad (2)$$

This is consistent with values given in Section 1. The sample mean still holds the meaning usually associated with it. It may be considered an unbiased estimate of the mean opinion Q. The best estimate of the mean opinion possible with the available data, is the one obtained by simply averaging them.

As this value is sample-dependent, in the sense that different groups of observers and/or pictures will give different scores and eventually different average values, it may be considered again as a random variable, whose variance $\sigma_{\bar{x}}^2$ is related to the accuracy of our subjective test.

In fact, it may be proved that in 95% of cases, the mean opinion Q will be contained within the range

$$\bar{x} - \frac{\delta}{2} < Q < \bar{x} + \frac{\delta}{2} \qquad (3)$$

where δ is the confidence interval which is a measure of the possible error range, and is related to the variance $\sigma^2_{\bar{x}}$ already defined by

$$\delta = 4 \sqrt{\sigma^2_{\bar{x}}} \qquad (4)$$

From the above discussion, it is seen that the estimate of the variance $\sigma^2_{\bar{x}}$ is essential to the evaluation of the accuracy of our subjective assessment results. As explained later, this variance is a function of the size of the sample itself (i.e. number n of observers and number m of pictures involved), and of certain quantities characteristic of the opinion population and not related with the sample itself. In the next section, a step-by-step procedure for the evaluation of such quantities and their relationship with the variance $\sigma^2_{\bar{x}}$ of the sample mean are given.

4. STEP-BY-STEP EXPERIMENTAL ESTIMATE OF THE POPULATION CHARACTERISTICS, AND OF THE VARIANCE OF THE SAMPLE MEAN

This procedure assumes that a number of experiments have been carried out in order to evaluate the behaviour of a system under various conditions or circumstances. Hence it is assumed that the scores of the various experiments ("samples"), are available for processing.

Fig. 7 gives an example. It refers to a set of experiments carried out on still pictures with various types and levels of distortions. The whole number of the samples was 300, each sample being constituted by 40 scores (8 observers by 5 pictures). The plot is given in a normalized format, i.e. with the assessments ranging from 0 to 1, instead of the usual 1 to 5 of the CCIR grading scales. Multiplying the linear quantities (such as the confidence intervals) by a factor of 4, and the squared quantities (such as the variances) by a factor of 16, will properly scale the results to comply with the CCIR scale.

(a) The first step to be performed in the procedure is to calculate, for each sample, the average $\bar{x}$ of the scores, according to equation (2) above.

(b) As a second step, the three quantities s^2, s^2_p, s^2_o, according to equations (5) given below, are computed.

$$s^2 = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{(x_{ij} - \bar{x})^2}{m \times n}$$

$$s_p^2 = \frac{1}{m} \sum_{i=1}^{m} \left(\sum_{j=1}^{n} \frac{x_{ij}}{n} - \bar{x} \right)^2 \qquad (5)$$

$$s_o^2 = \frac{1}{n} \sum_{i=1}^{n} \left(\sum_{j=1}^{m} \frac{x_{ij}}{m} - \bar{x} \right)^2$$

(c) As a third step, the calculation for each sample of the <u>population quantities</u> in square brackets of example (6) given below is performed.

$$\sigma^2 = E \left[\frac{((m-1)(n-1)-1)\ s^2 + ns_p^2 + m\ s_o^2}{(m-1)\ (n-1)} \right]$$

$$\sigma_p^2 = E \left[\frac{m\ n\ s_p^2 - m\ (s^2 - s_o^2)}{(m-1)\ (n-1)} \right] \qquad (6)$$

$$\sigma_o^2 = E \left[\frac{m\ n\ s_o^2 - m\ (s^2 - s_p^2)}{(m-1)\ (n-1)} \right]$$

Some of these quantities might give negative results, which might seem surprising, being estimates of variances. However, these quantities are under the operator E ("Expected value"), so only the final average must be positive and a single estimate has the possibility of negative values.

(d) As a fourth step, a sorting of the samples according to their average increase value $\bar{x}$ is performed.

(e) As a fifth step, the samples are collected in groups, each having the same number of items. <u>Fig.7</u> gives an example of the construction of the histogram for the evaluation of σ^2 (i.e. the first quantity in example (6), and in this case 15 groups of 20 samples each were obtained. For each group, the average value of the mean scores $\bar{x}$ is calculated. The same operation is performed also on the other relevant quantities of the samples belonging to the group (i.e. the quantities in equations (6).

(f) In the sixth step, various histograms, like the one given in Fig.7 , are drawn to show the new situation of the processed data. Each rod in the histogram is representative of an average value performed on a group of very similar samples. Hence it is an approximation of the operation "expected value" which is expressed in example (6). At this stage, any negative values should disappear.

(g) As the seventh step, filtering of the histograms by suitable functions, in order to further smooth the variability among the rods is performed. In the reported example, a function of the mean score $\bar{x}$ was selected.

$$\sigma^2 = A\,[\bar{x}^b\,(1-\bar{x}^b)]^c \qquad (7)$$

This function has the property of having nulls at the minimum and maximum score (0 and 1 in the diagrams).

The estimates of the population variances obtained by example (7) are far more accurate than the ones obtainable by single experiments.

(h) As the last step in the procedure, it is possible to evaluate for each mean score $\bar{x}$, the variance of the sample mean $\sigma^2_{\bar{x}}$ by the following:

$$\sigma^2_{\bar{x}} = \frac{\sigma^2 + (n+1)\,\sigma^2_p + (m-1)\,\sigma^2_o}{m \times n} \qquad (8)$$

where σ^2, σ^2_p, σ^2_o are the population quantities just mentioned, and n,m are the sample dimensions.

CONCLUSIONS

A procedure for the evaluation of the confidence intervals, i.e. the accuracies of a set of subjective assessments tests, have been described.

The procedure also leads to the estimation of mean general quantities that are relevant not only to the particular experiment under consideration, but also to other experiments carried out with the same methodology.

Therefore, such quantities may be used to draw diagrams of the confidence interval behaviour which are helpful for the subjective assessments, as well as for planning future experiments.

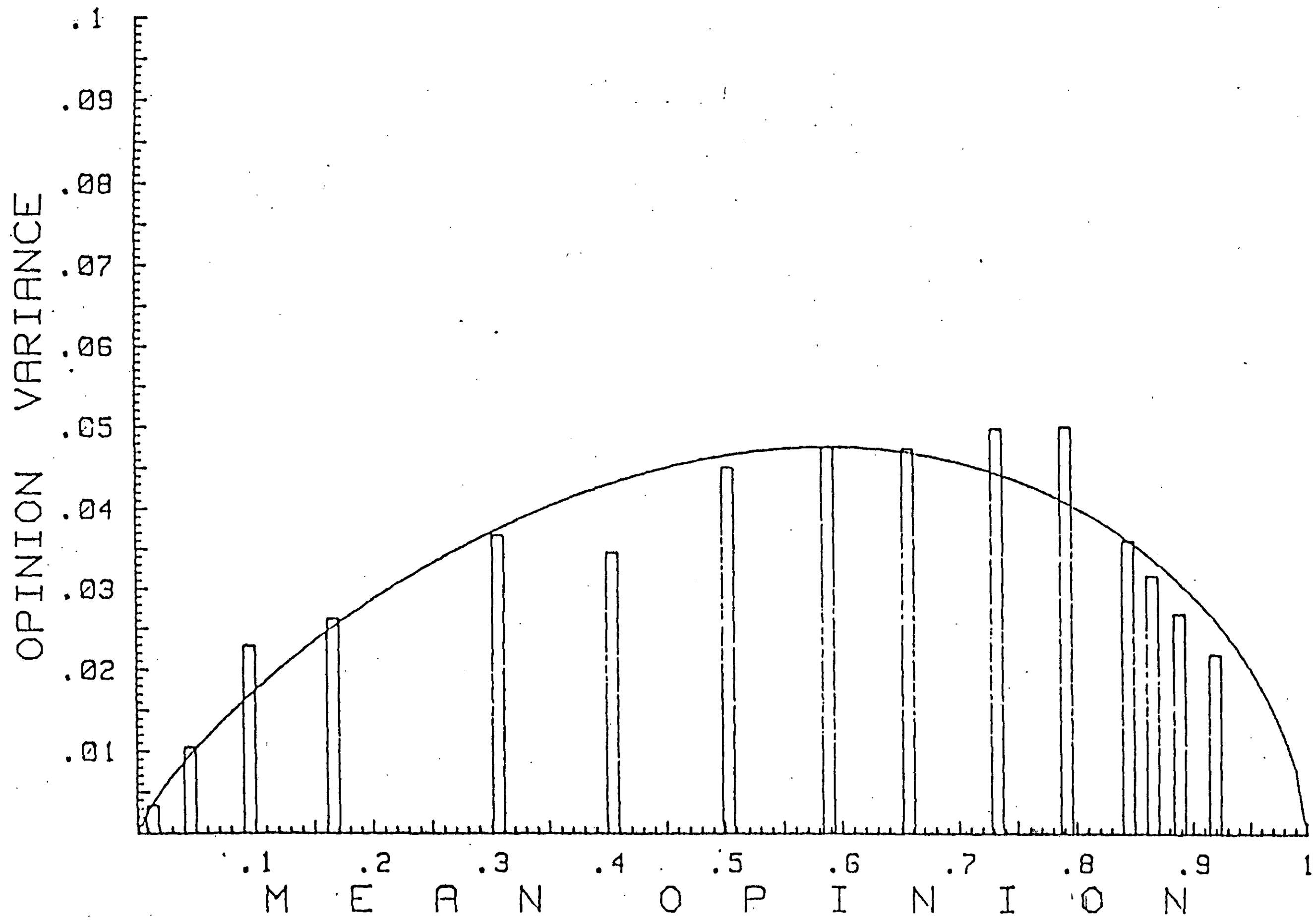


Fig.7 –Estimate of opinion variance as a function of mean opinion and distribution of the experimental data(density of vertical bars)

ANNEX VI

ADVANCED STATISTICAL PROCESSING OF SUBJECTIVE TEST RESULTS

1. Introduction

Recommendation 500 and Report 405 describe preferred methods to be used when conducting subjective tests on the quality or impairment of television signals affected by distortion or interference. Methods are described to assess the performance of a given television system, under a given amount of a specific distortion or interference, leading to a result represented by a single statistical value. Methods are also described to assess the performance of a given television system, under several amounts of a given distortion or interference, leading to a result represented by a statistical curve.

It often happens that an assessment is required on the statistical performance obtained when testing a family of devices, under several conditions of distortion or interference, although the devices in the family exhibit a wide spread in their performance characteristics. This is the case, for example, when tests are made to ascertain the statistical subjective quality, provided by a population of television receivers, for a range of interference levels. An advanced statistical treatment method can be applied to the data obtained in such subjective tests, in order to permit a statistical presentation of the results of the test, in a simple and readily understandable form.

2. Procedure description

This method finds application in the case of subjective tests performed on a sample of the population of a given type of equipment when their susceptibility to an impairment factor is tested.

For each equipment in the sample, the subjective scores for a number of levels of the impairment factor are collected and, for each level, the mean score is calculated.

As a first processing step, a least square fitting of the mean scores is performed, for instance by means of the well-known logistic function (see also § 3 of the present Report). This process generates a family of curves, each describing the behaviour of a particular equipment, with a large spread of characteristics among them (see Fig. 8).

Subsequently, an adjustment for the residual impairment, as described in § 3 of the present Report is applied on each curve, but scaling it from 0 to 100 instead of the usual 0 to 1. This permits the plot to be read in terms of "percentage of full quality" or "relative quality in percent" as in Fig. 9.

It is difficult to draw conclusions by just examining such a complete set of curves, and it is also meaningless merely to take the average of them, even if some additional information about the spread of the curves is available.

However, a statistical synthesis of the experimental results can be plotted in the form of a boundary line that divides the representation plane in two regions (Fig. 9). The first region, located below the boundary line, will contain the curves pertaining to no more than x% of the whole equipment population in the lower quality range; the second region, located above the boundary line, will contain the curves pertaining to the equipment population in the higher quality range. The parameter x can be selected at will.

The procedure to plot this boundary is to compute the limit values for D_M and G (parameters of the logistic function, defined in § 3 of the present Report) so that the boundaries of their joint distribution for a given probability (e.g. 10%) can be identified. Based on the two limit values thus computed, the two limit cases for the logistic function are then plotted.

Then, for each value of the impairment factor under test, the worst case is chosen; it is thus possible to trace a piecewise line, bounding the two regions for the given percentage of equipment population.

The boundary line thus found, is such that no more than x% (e.g. 10% in Fig. 9) of equipment population, can be expected to have characteristic curves falling in the region under the boundary and thus showing a performance worse than the one described by the boundary. The remaining population can be expected to display a better performance and to be described by curves falling above the boundary.

This kind of representation is helpful in the utilization of the results of a subjective test and it is expected to provide more reliable results than those obtainable by other methods.

A more complete description of the method can be found in [CCIR, 1982-86].

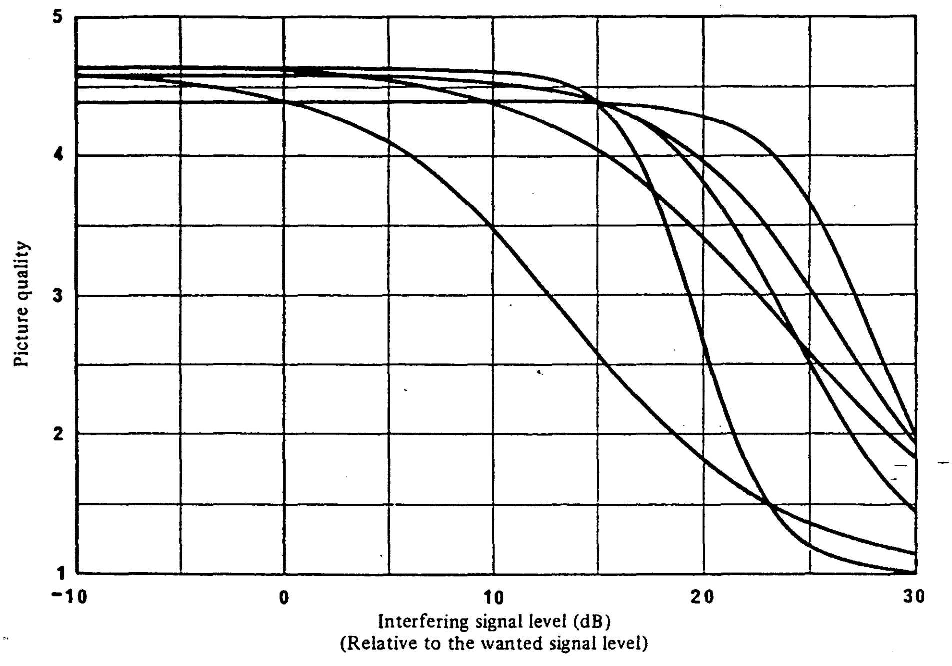


FIGURE 8 – *Behaviour of 6 commercial receivers for continuous interference coming from the adjacent inferior channel*

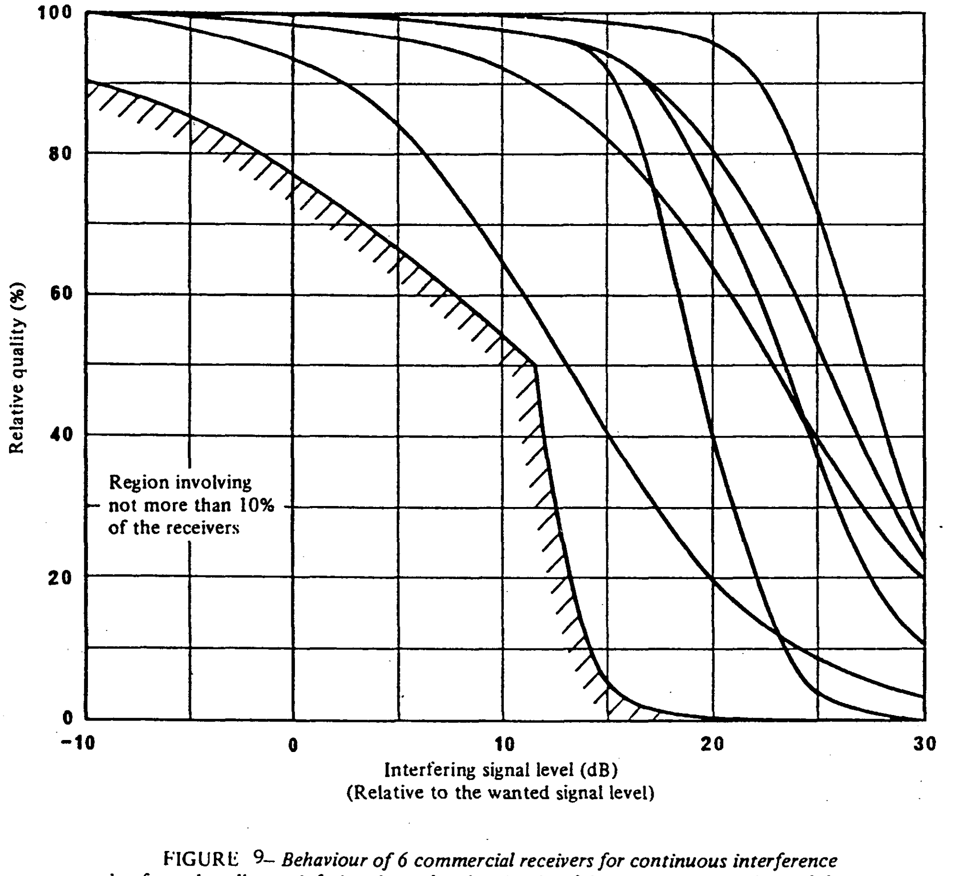


FIGURE 9 – *Behaviour of 6 commercial receivers for continuous interference coming from the adjacent inferior channel and region involving not more than 10% of the receivers*

REFERENCES

CCIR Documents
[1982-86]: 11/115 (Italy).

REPORT 959-2

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).

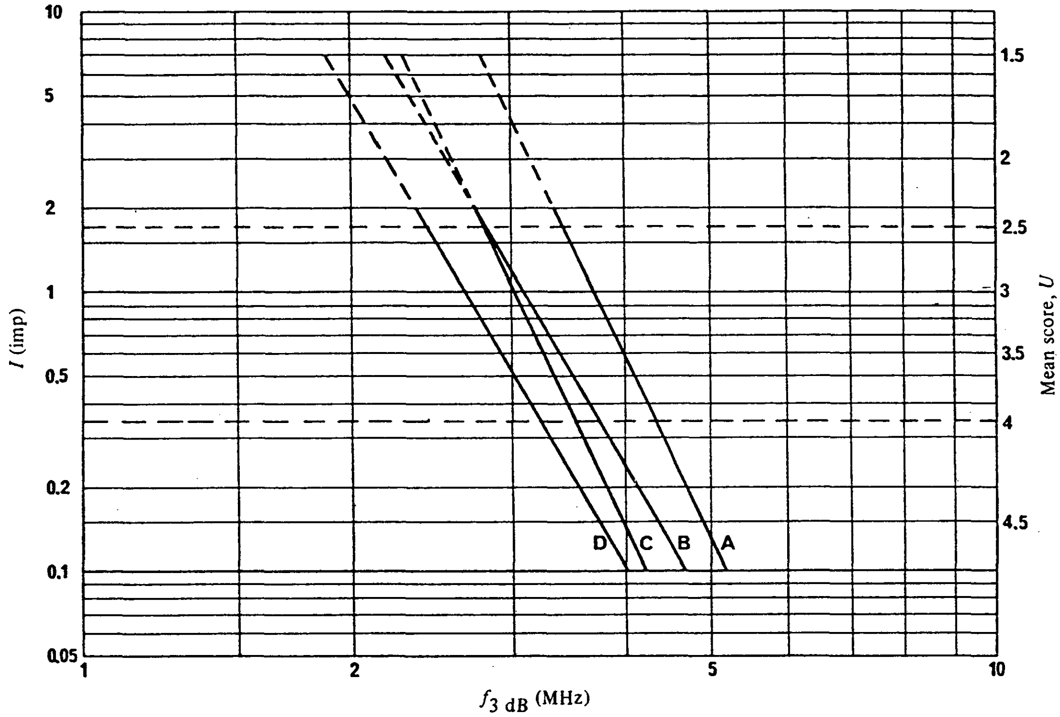


FIGURE 1 – *Impairment characteristics for bandwidth restriction of the luminance signal*

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
	$G = 6.80$	$G = 5.60$

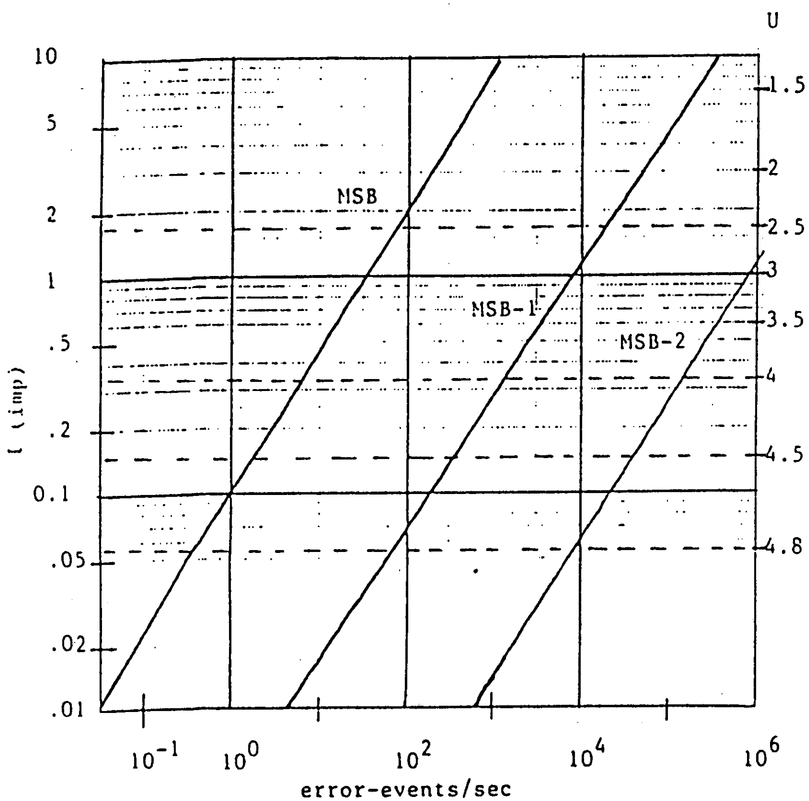
3.3 The subjective effects of random bit errors in YUV digital component video signals

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.



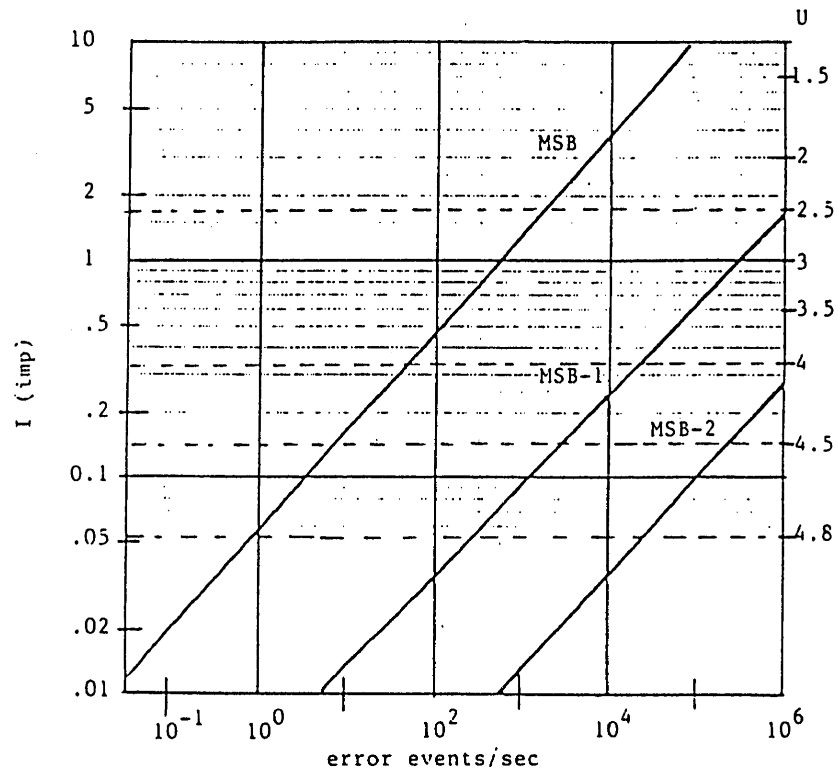


FIGURE 2 - Impairment characteristics for random single-bit errors in bits of various significance

(a) Errors in luminance (Y) component signal

		d_M	G
Y component	MSB	3.60×10	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

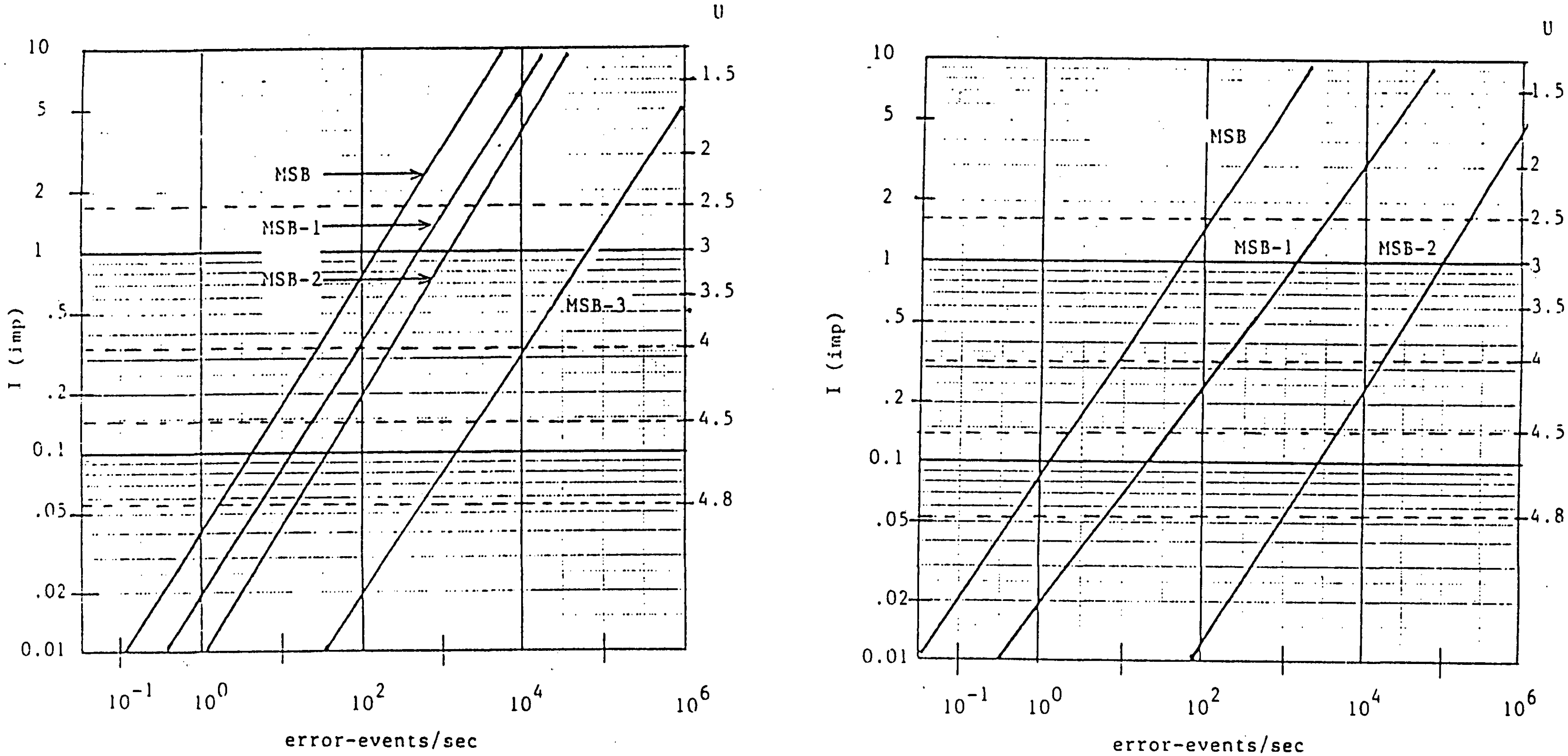


FIGURE 3 - Impairment characteristics for random single-bit errors after chroma-key processing

(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.

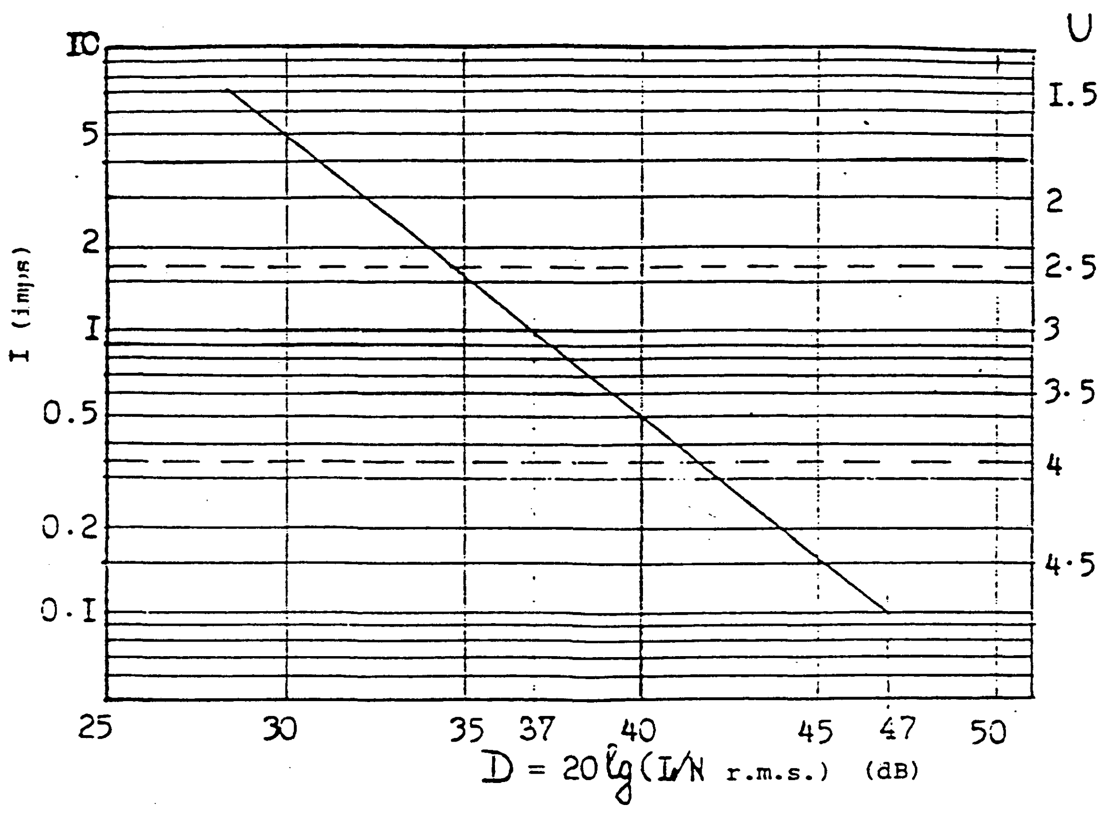


FIGURE 4

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.

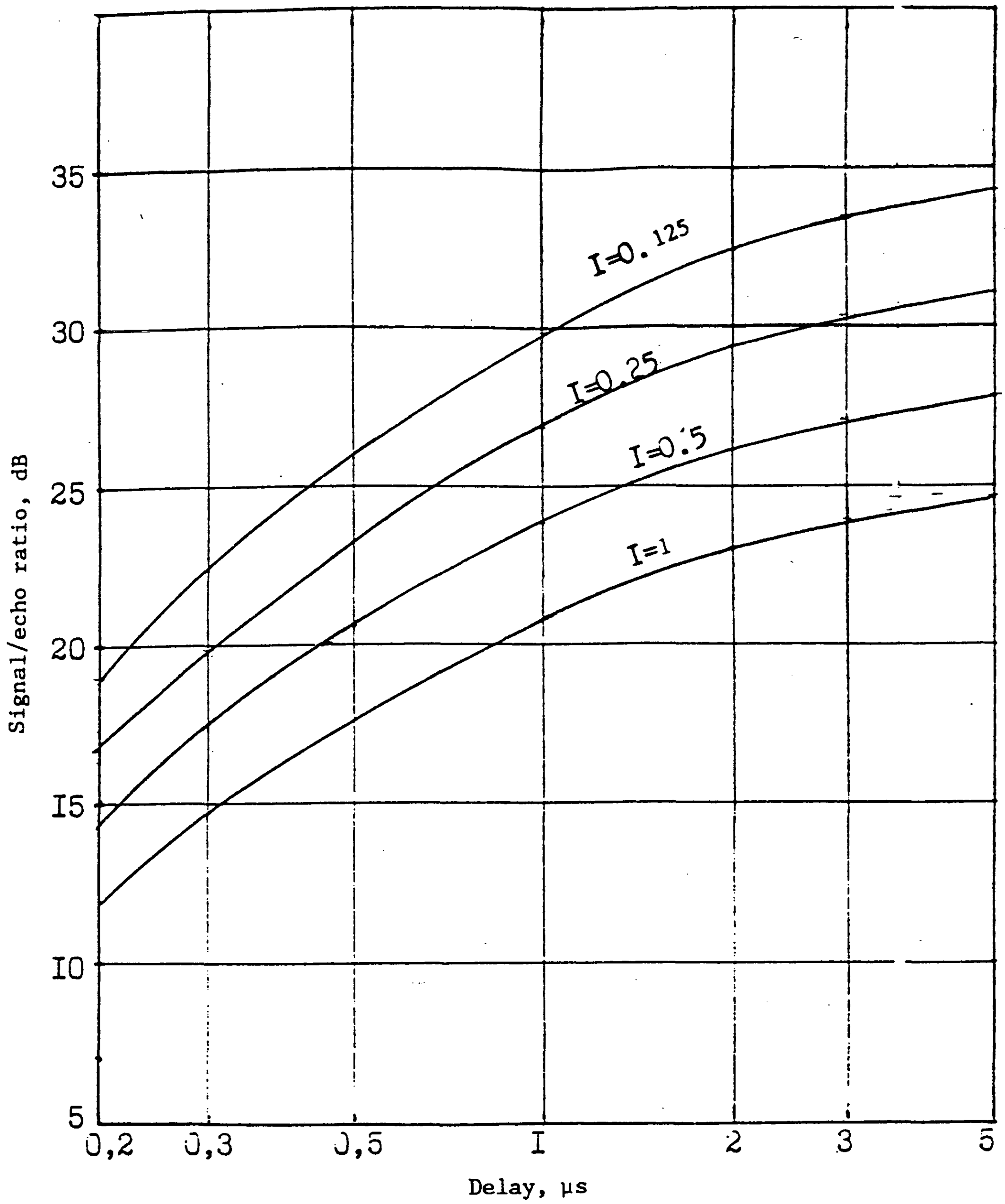


FIGURE 5
Impairment characteristic for echo signals

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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 $\pm 50\%$.

- 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.

This report describes studies related to the development of new methods intended to yield more information and to overcome or circumvent the shortcomings mentioned above. The general areas being studied are as follows:

- ratio scaling (numerical magnitude estimation of quality)
- graphic scaling (evaluation of conceptual differences in descriptors)
- numerical category scaling
- multi-dimensional scaling.
- pair comparing
- visibility threshold measurement.

To become candidates for inclusion in Recommendation 500, methods must be fully developed and provide significant advantages compared to currently recommended methods.

This report also describes recent work intended to examine whether it is possible that impairments such as noise can be assessed using graphic scaling.

2. RATIO SCALING

2.1 Introduction

Because it permits the broadest range and variety of statistical operations, the ratio scale allows the experimenter not only to rank the order of the elements being scaled but also to describe the relative magnitudes of any chosen attribute of those elements. One can determine, for example, not only that picture A is better than picture B, but also **how much better.** A category scale allows only a determination of rank order and not of the intervals in between. The most appropriate psychophysical method for generating ratio scales of picture quality is magnitude estimation.

The method of magnitude estimation has been used throughout the world since the middle 1950s. The scales yield ratio, and therefore equal-interval, data. With ratio-scale data, it is legitimate to calculate geometric or harmonic means, as well as arithmetic means, and to calculate percentage variations as well as standard deviations. This increased precision allows a more complete description of the data. The observers generate their own scales and therefore avoid one important failing of fixed scales, that of imposing potentially uncomfortable or inappropriate verbal labels and numbering systems.

2.2 Experimental test methodology

2.2.1 Procedure

In the method of magnitude estimation, the observers produce their own scales as the experiment progresses. The observer is presented with a series of pictures in random order and is asked to assign a numerical value of quality to each picture presented. The instructions should include the following information and be modelled on this example:

"You will be presented with a series of pictures in random order. Your task is to judge the picture QUALITY of each by assigning numbers to them. Rate the first picture any number that seems appropriate to you. Then assign numbers to successive presentations, in proportion, in such a way that they reflect your subjective impression. There is no limit to the range of numbers you may use. You may use whole numbers, decimals or fractions. Try to make each number match the picture quality as you perceive it. For example, if one picture looks three times better than another, assign a number three times greater: if it looks only one-fifth as good, assign a number one-fifth as great".

The range and number of stimuli should be as large as is reasonable for the particular experiment, so as not to restrict the observer to a small set of conditions and to allow the observer to use all those criteria available for making quality evaluations. Each stimulus is ordinarily presented twice (more presentations have been found to give little or no additional information).

2.2.2 Judgement of "ideal"

In order to establish a reference to make it possible to compare test results obtained in different laboratories with different television systems, test pictures, etc., the observers should be asked, at the end of each test session, to assign the numerical value appropriate to their conception of picture quality which they would consider "ideal". The "ideal" is intended to refer to the single best possible picture quality imaginable produced by any imaging system. In the analysis of the data (see § 2.2.6), the judgement of the "ideal" (i.e. that number) will be normalized to become the number 100, and this value will provide a uniform standard.

2.2.3 Assessors

It has been found that the ratios of the geometric means become stable when fifteen observers are used (of course, more can be used if desired).

2.2.4 Test pictures

The appropriateness of the test pictures depends upon the specific experiment being conducted.

2.2.5 Presentation

The pictures should be presented in random sequence with the proviso that the same picture (i.e. test scene or sequence) should not be presented on two successive occasions at the same quality level. If possible, a different random sequence should be presented to each observer. The initial stimulus picture for each observer should be varied, but the quality level need not be. It is advisable to begin each sequence somewhere in the middle of the range, not at either end point.

A viewing session should last approximately one half-hour, including the explanations and preliminaries. The test sequence could begin with a few pictures indicative of the range of picture quality (but it need not, and the observers, should not be told what the range might be). Judgements of these preliminary presentations would not be taken into account in the final results.

2.2.6 Normalizing and averaging magnitude estimates

The most appropriate and commonly used measure of central tendency with magnitude-estimation data is the geometric mean. It takes into account the distribution of the responses and has the advantage of preventing an extreme judgement from overly influencing the result. It gives an unbiased estimate of the expected value of the logarithms of the magnitude estimates. Despite the different numbers that the different observers may have assigned to the first stimulus, no normalising is necessary prior to averaging. The ratios of the geometric mean remain unaffected even though the observers use different units for their subjective scales. However, normalization will become necessary for certain subsequent statistical operations and for inter-laboratory comparison. To accomplish this, the following calculations for normalizing to the "ideal" should be followed for each observer's data.

The geometric means will be normalized so as to give the "ideal" the standardized value of 100. To accomplish this, the geometric mean of the numerical responses should be calculated. All the geometric means are then multiplied by the common factor $100/R_1$ (where R_1 is the numerical value of the "ideal" response). This simple procedure serves to define the "ideal" as 100 and at the same time to adjust the mean responses to all of the other stimuli in proportion.

2.3 Ratio scale performance studies

2.3.1 A comparison of the use of a single stimulus category rating scale and a ratio scale

2.3.1.1 Introduction

A pair of picture quality experiments was conducted (CCIR, 1982-86a) using the CCIR quality grading scale and, for comparison, the method of magnitude estimation. The purpose was to examine the effect of context on the two test methodologies. The reason for such interest at this time is the emergence of highly improved television pictures and their effect of stretching the range of picture qualities.

2.3.1.2 Procedure

Test method

Each observer was tested individually and two quality assessment methods were used. The category rating scale evaluation used the CCIR quality scale as a method for estimating the quality of the test images. The mean scores for each test picture were calculated. The magnitude estimation evaluation followed the procedures outlined in Section 2.2 of this Report.

Apparatus and arrangement

The observers sat at a viewing distance of three times picture height. Both CRT displays were run at 60 Hz field rate and had 19-inch (48.3 cm) diagonals.

There were four levels of picture quality in one test and five in the other; A, B, C and D respectively stand for 525-line NTSC, notch filter decoder; 525-line NTSC, comb filter decoder; RGB direct from the camera; and high definition. All of these pictures were considered to be of good to excellent quality (narrow range). The X and Y stimulus levels in the extended range test were 525-line NTSC, notch filtered with noise added. The S/N levels for this extended range test were 22 (X) and 32 (Y) dB. In this test there were fewer RGB data points because each observer scaled RGB only once, as the last judgement of each test session.

Approximately five weeks separated the two tests.

Assessors

All 67 observers had normal or corrected-to-normal visual acuity and colour vision. No observer had ever participated in a magnitude estimation experiment but a few had experience with five-grade scales.

Three groups of observers participated.

A group of 9 "experts" was gathered from within the laboratory. They were men who work in the field of television engineering. Their ages ranged from 27 to 65 years.

A group of 47 non-experts was also gathered from within the laboratory. They were women and men whose ages ranged from 33 to 60 years.

A group of 11 high school students was gathered to balance the total group. They were males and females, 16 years of age.

Viewing conditions

The viewing conditions were generally kept in accordance with Recommendation 500 except for the viewing distance which was three times picture height.

Test pictures

The three test pictures were 8 x 10-inch (25.4 cm) colour transparencies of the Stamford, Connecticut area. They were illuminated by a Porta-Pattern. These pictures were selected specifically to ensure the highest quality possible and a reasonable amount of high spatial frequency information.

Two cameras were trained on the Porta-Pattern: a medium quality 525-line camera and an 1125-line HDTV camera. All pictures were fed from the cameras to encoders when appropriate, or else directly to the displays.

2.3.1.3 Results

Five-grade scale tests

The three quality levels which were common to both tests shifted to some degree. The notch-filtered picture shifted most - from 1.88 to 3.56 - a shift of 63% of the total range from minimum to maximum response. In other words, the shift in the rating from the narrow range experiment to the wide range experiment was nearly as great as the entire range of ratings used in the narrow range experiment.

Note also the apparent lack of meaning of the verbal labels: a picture which had been rated "poor" became "good".

Magnitude estimation tests

Similar shifts are present here, but they are quite small compared with those of the five-grade scale. Again, the notch-filtered picture was shifted the most, but in this case, the analogous shift was only 34% (as opposed to 63%).

A point of interest is the fact that when the stimulus range stretched, the observers' numbers stretched. The total range of numbers used in the narrow range test was 43 (19.5 to 62.5) while in the expanded range test it was more than 60 (4.12 to 64.5). This is further evidence that the magnitude scale was more suited to the task and more naturally adaptable. Observers behaved more appropriately by expanding their scales in response to a wider range of stimulus quality. With the quality scale, when the stimulus range stretched, the numbers and labels remained fixed.

Finally it is interesting to note that the results of the relatively "naive" high school students showed very little effect of stimulus range, that is, there was little shift between the narrow and wide range tests.

2.3.1.4 Conclusions

Ratio scales are far less affected by changes in stimulus range than are 5-point category scales.

Ratio scales are free of the need for linguistic interpretation, and only require the assessor to have a knowledge of proportions.

Ratio scales have the virtue of providing meaningful intervals and ratios in the numerical responses, thus providing the additional information of how much better one picture is than another.

2.3.2 A comparison of the use of a double-stimulus quality scale and a ratio scale

2.3.2.1 Introduction

Another pair of picture quality experiments was conducted in France [CCIR, 1986-90b] using a double-stimulus quality scale and, for comparison, a ratio scale method. The reason for interest in such experiments is the same as stated in § 2.3, but in this case the double-stimulus continuous-quality rating method is used rather than the simple quality grading scale method.

2.3.2.2 Procedure

Test method

The test methods were the same as in § 2.3.1 except:

- assessors were tested in groups of 4;
- the same order of presentation was used for each assessor;
- the double-stimulus procedure complied with the second variant of §3 of Rec. 500;
- some examples of the pictures were shown during the instruction period.

Apparatus and arrangement

The assessors sat at a viewing distance of 6H. A 50 Hz field rate was used: monitors had 51 cm diagonals.

There were two ranges of quality (or impairment) which were assessed by means of various codecs which are listed below.

(i) small range of impairments; RGB, DPCM1, DPCM2 and SECAM
(ii) large range of impairments; RGB, DPCM1, SECAM, DPCM1 + noise, SECAM + noise.

Assessors

A minimum of 15 assessors was used in all tests. Each assessor participated in only one test. They were non-experts.

Viewing conditions

The viewing conditions were in accordance with Rec. 500.

Test picture

Four EBU test slides were used.

2.3.2.3 Results

Four parameters were tested:

- three types of stability:
  - intragroup: the same group was used twice for the same experiment;
  - intergroup: a comparison of results of two different groups was made;
  - effect of context (range): a comparison of the two ranges was made.
- and sensitivity: a comparison of ranking order of small impairments.

The students' "t" test was employed to test the significance of differences.

For all experiments, two analyses have been used to provide absolute and relative results. In fact, two types of evaluation are frequently carried out: assessment of degradation as a comparison with a reference and assessment of absolute quality. Therefore, to verify the performance of each method in the two cases, processing of direct ratings and processing of the difference between reference and test ratings are provided.

The intragroup test results show an acceptable stability; the "t" remained within the 90% confidence interval (t = 1.7) and the standard deviations are similar.

It is upon the results of the intergroup test that the ability of measurements to be compared from one laboratory to another depends. The two procedures are equivalent, since the values of t are close to, or smaller than, the value of "t" described above. There is a need for further studies in different laboratories to investigate intergroup stability of judgements using these methods.

The results of small versus large range test show that, in the case of absolute results, the "t" value has greatly exceeded the 90% confidence interval. On the other hand, for relative results, the magnitude estimation method is able to provide a low "t" value indicating that this evaluation is quite stable. This difference between absolute and relative processing indicates that differences in results due to the variation of range of impairments is only a global sliding in case of the magnitude estimation method.

Finally, an analysis of the sensitivity of the two methods was provided by a comparison of classification of impairments which are close in magnitude in each experiment. The two methods seem equally able to provide a rank order of small impairments but this order is different, because the criteria used by assessors is apparently not the same for the two procedures. The double stimulus procedure seems to induce a local analysis and in this case, SECAM was the best. The ratio scale seems to induce a global analysis that made the digital impairments (DPCM1 and DPCM2) preferable.

2.3.2.4 Conclusion

The conclusions brought out by this study of procedures are as follows:

- The practical use of a modified ratio scale method is convenient for the current subjective evaluation of television pictures.
- No procedure can provide reliable absolute ratings without any reference.
- When the range of impairments is the same for each test, both the double stimulus and the ratio scaling methods are stable enough to allow the comparison of results coming from different laboratories.
- In the case of different impairment ranges, only the ratio scale procedure is stable enough to provide reliable relative results that may be compared from one experiment to another, and then only if an identical implicit reference is included in the test. Consequently, a reference is needed for each type of subjective evaluation, for example, conventional television, high definition television.
- The criteria by which assessors arrive at their evaluations may not be identical for the two methods. The procedure based on ratio scaling seems better adapted to the global assessments of subjective picture quality.

3. GRAPHIC SCALING

3.1 Introduction

Graphic scales have been used to determine the perceived intervals between and among descriptive terms. Adjectives and adverbs have been scaled to determine their relative strengths as modifiers of nouns and verbs. The CCIR (Recommendation 500) quality scale consists of five (5) qualitative terms which have been scaled to determine the size of the intervals in English (USA), French, German and Italian. The results were surprisingly similar in the interval spacings (Jones and McManus, 1986).

The results of graphic scaling tests are inherently valuable. Assessors make judgements in their own native languages, free of all constraints and the need for numerical interpretation. These resulting scales have themselves been used to test picture quality by asking assessors to make a mark on the line where the assessor thinks the picture quality best fits on the scale (Jones, 1986).

It is the opinion of IWP 11/4 that this subjective assessment method, due to its extreme simplicity and ease of use, could become a useful test method internationally. It is hoped that other Administrations will repeat these studies, in their own native languages, using the following instructions and guidelines.

3.2 Experimental test methodology

3.2.1 Procedure

3.2.1.1 Prepare papers with long vertical lines (the original study used and 18 cm line on 8 x 11-inch paper) and extreme terms at each end. In a box at the corner write one of the test words (one word only for each page).

3.2.1.2 Arrange papers in as many different random orders as possible.

3.2.1.3 Present one set of papers to each assessor. Ask the assessor to make a mark on the line on each paper where the assessor feels the meaning of the word in the corner fits in relation to the two extremes. Proceed through all pages; impose no time limit; allow assessor to look back or forward. Give no further instructions or explanation except for an example or a repeat of the instruction above. The experimenter should not indicate the placement of any terms. The experimenter should not influence or help the assessor once the session begins. In the original study few people had trouble understanding the task. When this occurs, it is most often best to choose another assessor.

3.2.2 Assessors

Responses should be requested from as many assessors as possible (for example, > 20 in each group), and from as many parts of the linguistic region as possible. The results of each group should first be compared to determine perceived differences within linguistic regions within the country.

3.2.3 Averaging graphic scale results

A value can be given to each response by measuring the distance from one end of the line to the assessor's mark. Geometric or arithmetic means and standard deviations can then be calculated and plotted.

3.3 The results of evaluations made to date of the perceptual intervals between descriptors

[CCIR, 1986-90c] reports studies in Germany following the methodology described in 3.1. The results are included in Fig. 1. In these tests about 55 assessors were involved. An analysis was also made of the results of different age groups (young/old) and regions within Germany (North/South). Relatively insignificant differences were revealed.

[CCIR, 1986-90d] reports studies in France following the methodology described in 3.1. The results are included in Fig. 1. About 50 assessors, who had some familiarity with CCIR quality scale and impairment-scale descriptors were used. The dispersion of the results was rather less in this case than for other linguistic groups.

Results from the USA and Italy have been reported and described previously in 3.1. They are given also in Fig. 1. The most obvious trend can be observed in three of the four qualitative-term graphs (German excepted) which is seen at the lower end. The terms are bunched together with only a small interval between them. The five-point, four-interval scale is really a four-point, three-interval scale of unequal spacing.

The impairment scale terms scaled rather regularly in all three languages, perhaps because annoyance is perceived as an obvious continuum.

3.4 Subjective assessment of protection ratios for UHF broadcast signals

Studies in the United States have been conducted to investigate a number of factors affecting the use of the UHF TV band by land mobile radio services. One such study (Jones, B.L., 1986) attempted to correlate desired to undesired protection ratios with picture quality. Details of the test procedure can be found in the referenced document. Both graphic and ratio scales were successfully used for different and similar picture conditions.

The results of these tests clearly indicated that viewers have higher expectations regarding picture quality today than they had in the past.

Table I shows an example of the test results, the assessors' judgments of the 28 dB picture condition on the two separate tests, ratio and graphic scales and good agreement can be seen. The picture would need a threefold improvement to be considered "acceptable" for day-to-day viewing.

Table I

28 dB D/U with 10 kHz offset (525.24 MHz)

ON RATIO SCALE

where "Acceptable" - conceptually - equals 100

	Geometric Mean	Geometric Standard Deviation
Experts	= 35.5	2.9
Non-experts	= 35.0	2.3
All observers	= 35.3	2.4

ON GRAPHIC SCALE

Experts	= "Poor"
Non experts	= "Not quite passable"
All observers	= "Not quite passable"

3.5 The use of the CCIR quality scale descriptors

The traditional CCIR Rec. 500 quality scale terms have been studied extensively. They have been scaled in several countries and languages (France, Germany, USA, and Italy) to determine their meanings and the size of the intervals between them. The resulting graphic scales have themselves been used quite successfully for the subjective assessment of picture quality.

In an HDTV environment using double-stimulus methods, it has been argued that the traditional terms do not apply. It has been suggested that the terms are no longer used in a manner descriptive of perceived picture quality. For example, since inferior or impaired pictures are not at issue, do "bad" and "poor", or even "fair", belong on the scale? There certainly are no bad or poor pictures shown for assessment.

An experiment was suggested and carried out in which the terms were scaled subsequent to the picture quality judgements [CCIR, 1986-90e] (post-production word scaling). The subjects were instructed to place, on their scales, any or all of those terms which described the pictures just seen. They saw unimpaired studio-quality NTSC and 1125 line pictures.

Without exception, the subjects scaled every term. When queried regarding "bad" or "poor" pictures, they said there had been none; yet they scaled the words anyway. It appeared that, in comparing sets of very good pictures with HDTV pictures, the responses to the good pictures had to slide or be pushed down the scale by the HDTV pictures and thus the term meanings were rendered irrelevant to picture quality.

One object of this study was to see if scaling the words subsequent to performing the picture quality task would make them more relevant to the pictures seen. It did not. The terms scale exactly as they have in the past and do not relate to the picture quality. It can be concluded that the wrong question was being asked and that if subjects are given words to scale, they scale them by semantic meaning, and not in relation to their picture quality scales.

It is proposed to try a binary approach: first, ask if the subject saw pictures that could be described by each word and get a yes or no answer; second, scale any words that receive a yes answer. Perhaps this would force a more honest connection between the meaning of the terms and the picture quality. Another approach would ask the subject to produce a word, or choose from among many, to describe a fixed, known picture quality (unknown to the subject).

4. NUMERICAL CATEGORY SCALE

The numerical category scale is based on the ability of observers to make judgments in categories based on a linear scale. Since the categories are not limited in value by adjectives, the scale can be used for quite different ranges.

The number of points on the scale to be chosen depends on the conditions and the range of the perceptual attributes.

Experience has shown that in some cases 5 points are sufficient, while in other cases half points on a scale of 10 are useful.

It is of some advantage to take a scale, to which observers become used to in daily life. For instance, in some European countries a range of 10 points is a familiar schoolmark range.

A numerical category scale works fast, and is easily automated (e.g. 10 buttons). Tests are available for the equality of the steps along the judgment scale (Edwards, 1957).

If necessary, the numbers can be easily translated into equal sized category steps with available software using Thurstone's models (Torgersen, 1958).

Before starting the real experiment it is advisable to do some trials showing about the entire range, however, without specification. It helps the observers to stabilize their internal scale in the right range. The number of trials per condition depends entirely on the purpose of the assessment. However, at least 3 are advisable to have any statistical control.

5. MULTI-DIMENSIONAL SCALING

5.1 Introduction

[CCIR, 1986-90f] reports experiments in which assessors were asked to assess similarity between pictures with varying degrees of noise, CCI and ACI. Efforts were made to delineate a three dimensional perceptual space from the results. These were only partially successful, and this may be due to end effects. Further analysis is in progress.

5.2 Multi-dimensional scaling methods

Several researchers have used multi-dimensional scaling methods to consider stimulus-comparison judgments of television (Linde et al., 1981; Goodman and Pearson, 1979). A typical multi-dimensional scaling exercice begins with stimulus-comparison judgements (either categorical or non-categorical, see Rec. 500) of the similarity of the members of pairs of conditions. Then, the similarity judgements are taken to reflect the "distances" between conditions in an $\underline{n}$-dimensional perceptual space and one of several well-established procedures is applied to the judgements to solve for, and label, the dimensions of that space (Shiffman et al., 1981).

Such methods can contribute to a three-stage approach to the study of television. First, multi-dimensional scaling can be used to establish the perceptual dimensions upon which design and transmission factors vary. Second, the co-ordinates of the levels of factors in the perceptual space can be used to define relations between objective and perceptual parameters. And, finally, the perceptual dimensions can be related to judgements of quality or viewer satisfaction. At present, however, the multi-dimensional scaling methods have been used in few studies of television picture quality. It remains for further study to determine the value of these methods and of the overall approach. A fuller description of this approach is given in (Lupker and Hearty, 1987). Studies of the usefulness of this approach are being made in Canada.

5.3 Multivariate method

A related method has been used in the ESPRIT 925 Project, and is under study in Spain (CCIR, 1986-90g). Experiments will attempt to identify, group and interpret relevant subjective variables and factors which affect picture quality. The experimental design will include a questionnaire asking a number of opinions about the observed video sequences. The questions will be concerned with such things as: Which are the most and least preferred attributes? Are the sequences the same or different in quality? If there is picture degradation, how could it be corrected? And what are the traits, in order of importance, that make up a high quality image? (See CCIR 1986-90g for more details). The variables found to be the most important or influential might be:

- Loudness of audio

- Picture: edges (soft or hard)
  brightness and lighting
  sharpness
  motion (especially horizontal)
  colour
  video noise
  contrast
  flicker
  global and local content
  pleasantness of composition
  clarity of facial features
  facial expressiveness
  ratio of clarity of faces to background
  continuity of sequence
  positioning of subjects

The variables can then be assigned to overall factors such as:

- Local content and noise
- Content and face: background
- General quality (colour, contrast, etc.)
- Expressiveness of faces
- Clarity of faces
- Motion

or perhaps further to: content, noise and colour

Work is currently underway to improve and extend the questionnaire and to establish the validity of the approach for various assessments of television picture quality.

5.4 Orthogonal test method

In China studies have shown that by applying the orthogonal test method in subjective assessments of picture quality, a group of distortion combinations representing the same main characteristics as in a comprehensive test can be generalized within a certain distortion tolerance through a small number of experiments, and the independence of the distortions in each combination can be verified, thus providing a reasonable group of distortion combinations for subjective assessments of picture quality affected by five simultaneous distortions (CCIR, 1986-90h).

6. GRAPHIC SCALING WITH TRIPLE STIMULUS PRESENTATION

Experimental results have shown that picture assessment with category scales may only yield a rank order scale. Graphic scaling methods could be an alternative. [CCIR, 1986-90i] describes an approach to a graphic scaling method which makes it possible to control the type of the resulting scale (ordinal or interval scale). In a triple stimulus presentation experiment, the assessors were instructed to graphically indicate where the quality of the picture on a central monitor would fall, in relation to the quality of the pictures on two monitors on either side of it. The pictures were impaired by different levels of noise. All possible combinations of a set of noise levels were displayed. This method has been used to show that subjective scaling judgments may not yield an interval scale.

7. A PAIR-COMPARING PROCEDURE

7.1 General description

This method can only yield a rank order of pictures or sequences according to their subjective quality, which is derived from the assessments of all possible pairs. The method has the advantage that the data facilitate an examination of the transitivity of the judgments of individual subjects and of the agreement of the criteria used by different subjects. It is not always obvious that these conditions are met, especially if complex picture degradations are involved. If the results of the examination are negative, a multidimensional method of assessment (Multidimensional Scaling or Factor Analysis) should be considered.

The reliability of the method depends on the number of pictures or sequences (should not be smaller than six) and the number of subjects.

7.2 Test procedure

A rank order of **n pictures or sequences** shall be established by **N subjects.** The subjects are presented with all possible pairs in random order. They decide for each pair which picture or sequence is better. The total number of pairs is

$$z = n\ (n-1)/2$$

The test results are combined to an individual **dominance matrix** (n x n) for each subject. A "one" in column t and line s means that picture or sequence t is better than s, a "zero" means the opposite.

7.3 Examination of individual transitivity (Zeta method)

The results of all subjects should be checked for transitivity. A subject has produced an "intransitive triad" if it was decided that picture A is better than B, B is better than C, but C is better than A. A rank order can only be derived from the test results if the subjects are judged in a systematically transitive way.

The number of intransitive triads in a dominance matrix is:

$$d = (n(n-1)\ (2n-1)/12 - 1/2)\ \sum_i D_i^2$$

where D_i is the sum of the i-th column.

The maximum of d is:

$$d_{max} = n\ (n^2 - 4)/24 \text{ if n is even.}$$

$$= n\ (n^2 - 1)/24 \text{ if n is odd}$$

ζ is a measure of the transitivity:

$$\zeta = 1 - d/d_{max}$$

If ζ is equal to 1, there is absolute transitivity. If ζ is equal to 0, the judgments are completely intransitive.

Transitive results could also be random. By checking the probability of the calculated value of intransitive triads (d) on condition that transitivity is exclusively random, a decision can be made, whether the assessments of the subject can be judged to be **systematically** transitive or not. First a limit α of the probability is fixed, which is small enough, eg. 0.05 (5%). Then the following value is calculated:

$$x = \frac{8}{n-4}\left(1/4 \binom{n}{d} - d + 1/2\right) + DF$$

$DF = n\ (n - 1)\ (n - 2)\ /\ (n - 4)^2$ (degrees of freedom)

On condition that $n > 6$, x (d) is a χ^2 distributed function. χ^2 is a well-known probability distribution function (table 1). For the fixed value of α and the calculated value of DF, the corresponding value of χ^2 is looked up in Table II. if this value is smaller than the calculated value of x, the transitivity is assumed to be systematical.

Table II

χ^2 distribution

Degrees of Freedom	α = .05	α = .01	α = .001
1	3.84	6.63	10.83
2	5.99	9.21	13.82
3	7.81	11.34	16.27
4	9.49	13.28	18.47
5	11.07	15.09	20.52
6	12.59	16.81	22.46
7	14.07	18.48	24.32
8	15.51	20.09	26.13
9	16.92	21.67	27.88
10	18.31	23.21	29.59
11	19.68	24.73	31.26
12	21.03	26.22	32.91
13	22.36	27.69	34.53
14	23.68	29.14	36.12
15	25.00	30.58	37.70
16	26.30	32.00	39.25
17	27.59	33.41	40.79
18	28.87	34.81	42.31
19	30.14	36.19	43.82
20	31.41	37.57	45.32

21	32.67	38.93	46.80
22	32.92	40.29	48.27
23	35.17	41.64	49.73
24	36.42	42.98	51.18
25	37.65	44.31	52.62
26	38.89	45.64	54.05
27	40.11	46.96	55.48
28	41.34	48.28	56.89
29	42.56	49.59	58.30
30	43.77	50.89	59.70
40	55.8	63.7	73.4
50	67.5	76.2	86.7
60	79.1	88.4	99.6
70	90.5	100.4	112.3
80	101.9	112.3	124.8
90	113.1	124.1	137.2
100	124.3	135.8	149.4

7.4 Examination of agreement of the subjects

The calculation of a common rank order is only reasonable, if the subjects use the same criteria for their judgments (i.e. if their agreement is systematical). In order to examine this, the test results are combined to an **aggregated matrix**, as it is called. All pairs of test pictures or sequences are numbered for this purpose. The order is arbitrary. These numbers correspond to the line numbers of the matrix. The column numbers correspond to the (arbitrary) numbers of the subjects. Element X_{ij} of this matrix is equal to 1 (0), if subject j judged the first picture of the pair i to be better (worse) than the second one.

Agreement between the subjects could be systematic or random. It is assumed to be systematic, if the probability of the actual agreement is small enough on condition that agreement is only random. First a limit α of the probability is fixed, which is small enough, e.g. $\alpha = 0.05$ (5%). Then the following value is calculated:

$$Q = \frac{\binom{n}{2}\left[\binom{n}{2}-1\right] \sum_i (L_i - \bar{L})^2}{\binom{n}{2} \sum_j G_j - \sum_j G_j^2}$$

n: number of pictures or sequences
N: number of subjects
L_i: sum of the ith line of the aggregated matrix

$$\bar{L} = \Sigma\ L_i/\binom{n}{2}$$

ΣG_j: sum of the jth column of the aggregated matrix

Additionally the number of the degrees of freedom is calculated:

$$DF = \binom{n}{2} - 1$$

For the fixed value of α and the calculated value of DF, the corresponding value of χ^2 is looked up in Table 1. If Q is bigger than χ^2, the agreement is assumed to be systematical.

7.5 Calculation of a rank order

On condition that the transitivity of all subjects and the agreement between the subjects is systematical, a rank order can be derived from the test results.

An **overall dominance matrix** is calculated by adding up the individual matrices. An element X_{ij} of this matrix is equal to the frequency of the judgement that picture j is better than picture i. Next, the column sums D_i of this matrix are calculated. D_i is the frequency of the judgment that picture i is better than any other picture. A rank order of the pictures or sequences is given by the order of these column sums.

8. Method of assessing thresholds of visibility

For certain measurements, and in particular to achieve the greatest possible accuracy when establishing a correspondence between objective measurements and the assessment of their influence on visual quality, it is helpful to measure the visibility thresholds of "impairment factors". Even though the double-stimulus impairment-scale method can provide relevant data in this regard, it is worth advocating use of a simpler and more efficient method, known as the "forced-choice double-stimulus method". The performance of this method, which is commonly used in psychophysical studies, has been verified during studies by the CCIR, the results of which are reported in [1986-90j].

The procedure usable for natural or synthetic material is based on comparison of an impaired sequence with the corresponding reference. In each pair of sequences constituting a presentation, the position of the reference is random. The observer's task is merely to state which of the two sequences in the presentation is impaired. The choice is said to be forced because the observers always have to give an answer, even if they are in doubt.

The impairment levels presented have to cover an adequately wide range above and below the estimated threshold of visibility.

The procedure for processing the votes is as follows: since the probability of a correct answer varies between 50% (no impairment detected, that is random answers) and 100% (impairment always detected), the standard practice is to estimate the visibility threshold at 75% for each observer. Once the threshold of each observer has been estimated, the mean threshold and its confidence interval are calculated. A different percentage can be chosen to measure a less strict threshold.

The stability of the method and its ability to provide a genuine visibility threshold have been verified by comparison with the double-stimulus impairment-scale method. The results are clearly in favour of the forced-choice double-stimulus method, whatever the range of impairment chosen, but it is preferable to present impairment levels distributed correctly around the estimated threshold.

9. STEPS TOWARD THE INCLUSION OF A NEW METHOD IN REC. 500

On current evidence, if the existing methods given in Rec. 500 in detail are to be superseded or augmented, the most likely candidate is a ratio scaling method along the lines of that given in section 2.1.

The evidence of one trial is that the method is less context sensitive than a single-stimulus quality-scale method and second trial suggested that interlaboratory correlation should be good provided a reference picture quality is scaled together.

This promise needs to be confirmed by a number of laboratories with linguistic differences.

Providing guidance on how results should be interpreted by the broadcasting community is also important. The broadcasting community is used to working with five-grade category scales and an explanation of the relationship between the two environments is needed.

Studies should also continue on numerical category scaling, multi-dimensional scaling and graphic scaling methods (outlined in Section 4 of Rec. 500) with a view to establishing the advantages they would have over alternative methods.

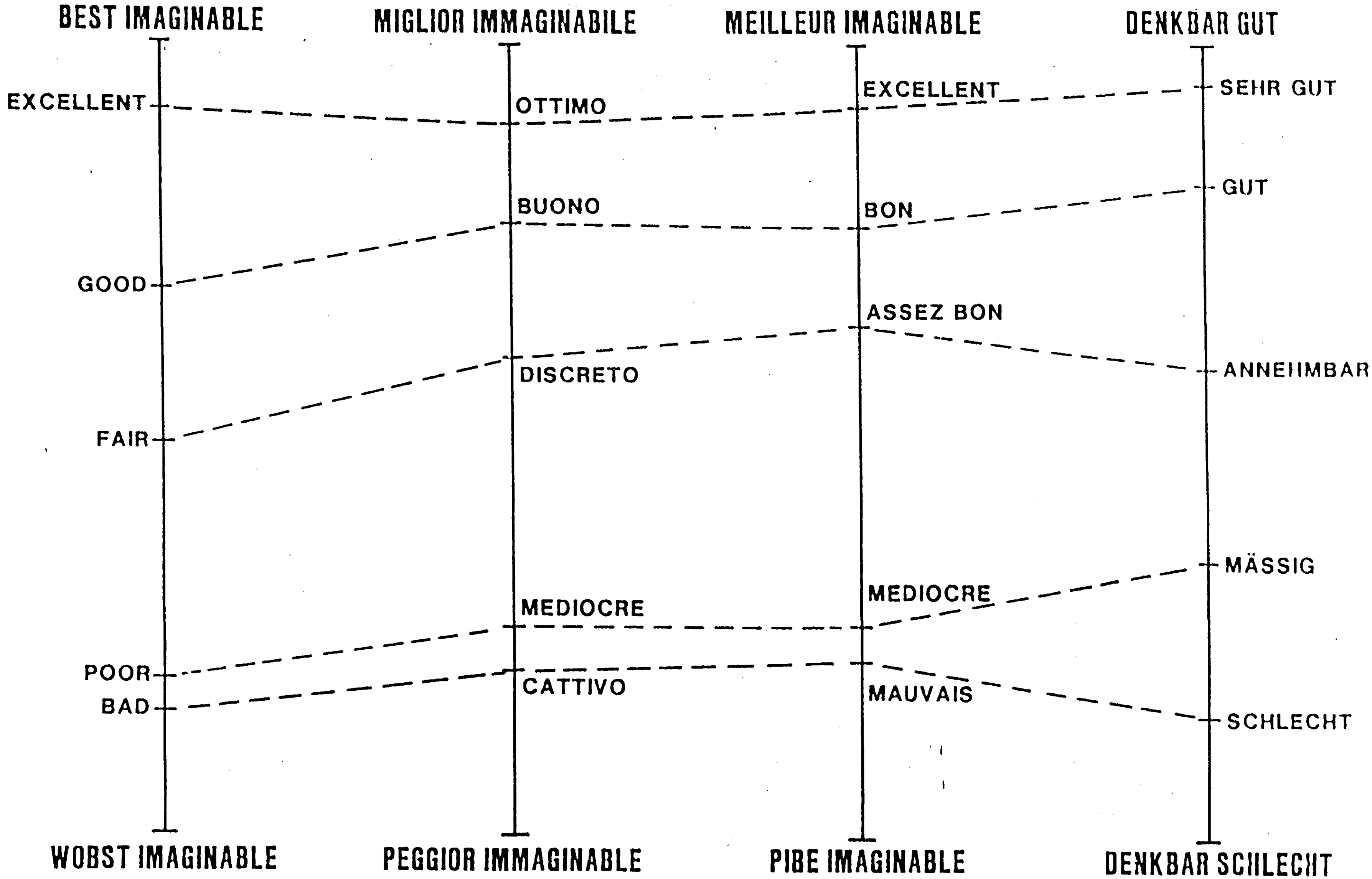

Fig. 1a **GRAPHIC SCALES OF QUALITY TERMS** F-89.1541

Rep. 1082-1

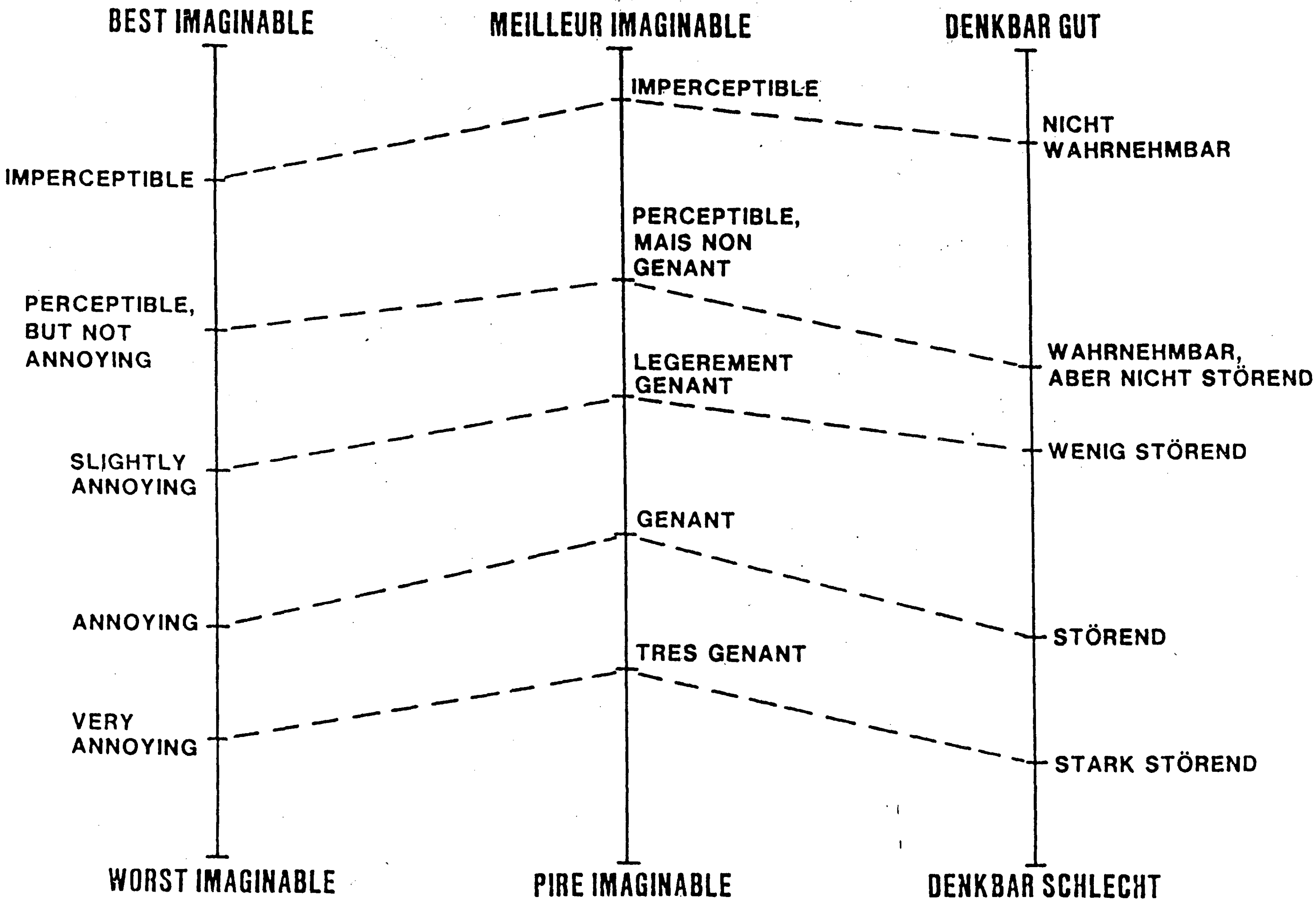

Fig. 1b **GRAPHIC SCALES OF IMPAIRMENT TERMS**

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[1986-90]: a. 11/379 (USA); b. IWP 11/4-123 (France); c. IWP 11/4-137 (Federal Republic of Germany); d. IWP 11/4-147 (France); e. IWP 11/4-160 (Chairman, IWP 11/4); f. IWP 11/4-145 (Canada); g. 11/158 (Spain); h. 11/144 (People's Republic of China); i. IWP 11/4-141 (Federal Republic of Germany); j. 11/463 (France).

ANNEX I

Conditions for assessment during programme transmission

Reference	OIRT [CCIR, 1966-69a]		Canada [CCIR, 1966-69b]
Observers Category Number	Expert 1 or 2		Expert 1 or 2
Grading scale Type Number of grades	Impairment 6 (Note 1)	Quality 6 (Note 2)	Impairment 5 (Note 3)
Pictures Type	Television programmes		Television programmes
Viewing conditions			
Ratio of viewing distance to picture height	4-6		4-6
Angle of view, from a line normal to the face of the monitor			<30°
Luminance, on the screen, at reference white (cd/m²)			70 ± 7
Chromaticity of the screen at reference white			Illuminant *D*
Luminance of the inactive tube screen	Adapted to the ambient illumination		As low as practicable
Luminance of "light surround" (cd/m²)			10.5 ± 3.5 (Note 14)
Chromaticity of "light surround"			Illuminant *D*

<u>Note 1</u> - Six-grade impairment scale – 1 Imperceptible
2 Just perceptible
3 Definitely perceptible but not disturbing
4 Somewhat objectionable
5 Definitely objectionable
6 Unusable

<u>Note 2</u> - Six-grade quality scale – 1 Excellent
2 Good
3 Fairly good
4 Rather poor
5 Poor
6 Very poor

<u>Note 3</u> - Five-grade impairment scale – 1 Imperceptible (implied grade)
2 Detectable
3 Noticeable
4 Objectionable
5 Unsuitable for broadcast

REFERENCES

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[1966-69]: a. XI/46 (OIRT); b. XI/146 (Canada).

ANNEX II

ADDITIONAL INFORMATION ON TEST PROCEDURES

This Annex describes and discusses various test procedures for organizing subjective assessment tests. Recommendation 500 gives much information about subjective assessment and the more commonly used test procedures. Section 1 of this Annex describes additional and new procedures; § 2 describes the virtual sample technique; § 3 gives information on results obtained by some of the procedures in comparable situations; § 4 gives some additional evidence, and § 5 discusses different arguments related to the choice of an appropriate method for various situations.

1. Description of procedures

This section presents descriptions of various procedures additional to those described in Recommendation 500, including new procedures intended to solve new problems. The descriptions cover such items as grading scales, design of the presentation sequence, definition of an impaired condition and so on. The validity of these items is not necessarily restricted to the particular procedure being described.

1.1 *Procedure using the quality scale with direct anchoring**

To study the role of a reference picture, a new method has been designed [Kretz and Sallio, 1981]. In this method, the 5-grade quality scale from Recommendation 500 is used and the procedure is the same as for the procedure of the EBU method (see below § 1.2): a reference picture is displayed before each picture to be assessed and the observers are told to rate the pictures in relation to the reference which is said to correspond to grade 5 ("excellent"). With this procedure, direct anchoring of the rates at the top of the scale is obtained with the quality grading scale.

1.2 *Procedure using sequences of moving pictures*

Recommendation 500 specifies conditions for the subjective assessment of the quality of both still and moving pictures. Nevertheless, there have been few studies reported which deal with some of the basic features of measurement of the subjective quality of moving picture sequences. These features include:

- the elements on which the observer bases his decision are often transitory;
- it may be difficult for the observer to analyse and assess all the elements of the sequence in a single viewing;
- the perception of certain impairments may be different for still and moving pictures.

As a first attempt to define a suitable procedure, a study [CCIR, 1982-86a] using the impairment scale with a reference picture (EBU method) has examined several modes of presentation of moving picture sequences. The impairment used was multiple generations of video tape recordings.

The following preliminary conclusions may be drawn on the basis of the mean scores and standard deviations. Firstly, sequences longer than 10 s seem to be too long and, secondly, repetition of the sequences to give the observers more opportunity to analyse and assess the scenes does not seem to improve the quality of the assessments. The conclusion of this preliminary study appears to be that a single presentation of about 8-10 s is preferred. Additionally, the results show that the assessments of the same impairments on still and moving picture sequences can differ significantly.

The foregoing conclusions are preliminary and are based on results with a single type of impairment; the results with motion-dependent impairments could differ significantly. Further studies in this important area are urgently required.

* Some form of anchoring is always implicit in all the procedures in the sense that it is necessary to standardize the rating process. Here the term "direct anchoring" refers to *explicit* anchoring. "Indirect" anchoring corresponds to standardizing the adaptation phenomena [Corbett, 1970] by means of the range of impairments in a test session.

2. The virtual sample technique

2.1 The main sources of errors in subjective tests are essentially two:

– random (i.e. stochastic) errors, and
– systematic errors.

Provided the objective conditions of the test have been standardized, the nature of the errors is purely related to the parameters used in the design of the tests (number of observers, pictures, procedure used, etc.).

Stochastic errors are very easy to recognize. In the case of a relationship between distortion magnitude and picture-quality, they lead to some dispersion of the experimental mean scores around the fitted curve (e.g. obtained by least squares method). Standardization of test procedures usually tends to reduce stochastic errors but due to their nature they can be further reduced by statistical averaging (the use of a fitted mathematical function is one kind of averaging).

Systematic errors are difficult to recognize because they are almost unrelated to random errors. Usually they act by shifting the previously mentioned curve (biasing) and/or affecting its slope. Once a certain degree of systematic errors have been introduced in the experimental results, they cannot be averaged out by statistical methods.

2.2 The "virtual sample" is constituted by a relatively large number of observers (e.g. 50 or more) and also by a large number of pictures (e.g. 40 or more). It is called the "virtual sample" because it is not used in its entirety for the actual assessment tests; rather, it is used as a population from which small samples of manageable size are repeatedly drawn.

Taking the example in which a relationship between given distortion magnitudes and picture quality is to be found, and having in mind that the aim of the virtual sample technique is to use different samples of observers and pictures for different test conditions, the complete planning of the experiments when following the virtual sample technique should be as follows:

– a number of test conditions (e.g. 8 to 10 values of the distortion magnitude) should be selected;
– a number of groups each made up of no more than 2 or 3 non-contiguous test conditions should be formed;
– for each test condition, a random sample of 5 to 6 test pictures is chosen from the complete set (virtual sample), so each group of test conditions will have 2 or 3 such sets of test pictures. For each group a sample of 8 to 10 observers should be selected from the complete set (virtual sample). In this way we have different test pictures for different test conditions in the same group;
– for each group of test conditions, a session following the procedure given in § 8.4 of the Appendix to Recommendation 500-3, Recommendations and Reports of the CCIR, Vol. XI-1, Dubrovnik, 1986;
– the mean scores should be calculated and then fitted by least squares using a suitable function (e.g. the "logistic function");
– some statistical tests should be carried out for the goodness of fit, and the final output of the experiment will be the fitted curve just obtained.

If more accuracy is required for the fitted curve, the experiment may be repeated as a new experiment, and the corresponding mean scores should be averaged with the past ones before performing the new least squares fit.

There is general agreement that the technique is appropriate for complex impairments at least in relation to observers. However, some administrations believe it may not be economical in the case of a single impairment.

3. Results of directly comparable experiments

This section describes results obtained with different assessment procedures applied to the same experimental material (pictures and impairments). Naturally, when a method is used in a specific situation account must be taken of numerous parameters and the conclusions drawn from such experiments, as described in this section, take only some of these factors into consideration. This is discussed in detail in § 5.

3.1 *Comparison of the results obtained by single stimulus method and EBU method*

The two procedures described in § 8.1 and § 8.2 of the Appendix to Recommendation 500-3, Recommendations and Reports of the CCIR, Vol. XI-1, Dubrovnik, 1986 have been subjected to a series of comparative experiments [CCIR, 1978-82a, b and c; Sallio and Kretz, 1982]. Different types of impairment were used: analogue filtering, additive noise (in two different contexts), cross-modulation transfer noise, edge-busyness, (in two different contexts), accumulation of additive noise and edge-busyness, transmission errors at 34 Mbit/s (in two different impairment ranges). Twenty independent groups of ten non-expert observers (one group for each type of impairment and each procedure) participated in the tests (a total of 46 sessions was necessary for each method). The comparisons of the results obtained were analyzed in terms of average grades and standard deviation, separately for each viewing distance. The following conclusions were drawn:

- the two methods lead to objective-to-subjective relationship curves with very similar curve shapes. There is a shift between the characteristic obtained by each method. The quality rating curve tends to be rather below impairment ratings curve (EBU method). At mid-scale (grade 3), the standard deviations of the scores are at maximum and are very close for both procedures (at $6H$, 0.84 for the single-stimulus method and 0.79 for the EBU method);
- the impairment scale procedure using a reference picture produces an average grade for reference picture very close to the highest grade (4.88 on average), showing good anchoring for the ratings at the top of the scale;
- the quality scale procedure leads to an average grade for reference pictures which varies from almost 0 to one grade below the highest grade (4.56 on average). This seems to be due to the absolute nature of the rating;
- the two methods tested are both sensitive to the context and the range of the impairments presented in a session. These two subjective phenomena have identical effects on the two methods. It would therefore seem important in presenting the results, to describe the precise conditions (range of impairments presented in each session, context within a session); this allows a better understanding of the results;
- in the range between "imperceptible" and "perceptible but not annoying" (around grade 4.5), the procedure using impairment scale and a reference, leads to standard deviations of the scores 1.4 times smaller than with the quality scale procedure; thus the former procedure seems to give better precision, and might allow the number of scores toward the top of the scales to be halved.

These results suggest that it may be possible to obtain a transformation of quality mean grades into impairment mean grades obtained using the EBU procedure by shifting the experimental results by the amount associated with the residual impairment (mean grade for unimpaired pictures). The transformation of impairment mean grades into quality mean grades is suggested by shifting the experimental values by half a grade, although this value is not completely stable. ——————————— Due to the bounded nature of the scale, these transformations cannot apply at the bottom end of the scale.

3.2 *Comparisons of results obtained with other methods*

To study in more detail the role of reference pictures, anchoring and grading scale, several methods have been tested on the same type of impairment [CCIR, 1978-82b]. This study consisted of a comparison of the results obtained with the two previously mentioned methods (§ 3.1) and the results obtained with various other methods. The following aspects were investigated:

- the use of the 5-grade impairment scale and of a continuous impairment scale, of the 5-grade quality scale and of a continuous quality scale, all with a reference picture for direct anchoring (in effect the EBU procedure using different scales);
- the use of a continuous quality scale using a double stimulus procedure close to the one described in § 8.3 of the Appendix to Recommendation 500-3, Recommendations and Reports of the CCIR, Vol. XI-1, Dubrovnik, 1986.

The following conclusions were drawn:

- good anchoring is possible in the upper part of the range with an EBU type of presentation but using a 5-grade quality scale and informing the observers that the reference picture should correspond to the grade "excellent";

- the comparison of results obtained by methods which differ only in the use of a discrete or a continuous rating scale shows that neither the continuous quality scale nor the continuous impairment scale provides more information than the recommended 5-grade scales (comparable means and standard deviations);
- with the double stimulus method which does not provide direct anchoring, the mean score for reference is not close to the top of the score range. The standard deviations obtained by this method are not significantly lower than those obtained by the method recommended by the EBU;
- the implementation of continuous scales gives rise to some problems: certain observers (non-experts) find them difficult to use and analyzing and presenting the results of the experiments becomes more complicated.

3.3 *Comparisons of the results obtained using 5- and 6-grade quality and 6-grade impairment scales*

The comparison of the performance of the 5-grade quality scale and a 6-grade impairment scale have been reported in [Allnatt and Corbett, 1974], and recently re-examined with particular reference to performance near the threshold of visibility [Allnatt, 1980]. The procedure was the same except for the scale used. The 6-grade impairment scale differs from the present Recommendation 500. Two types of impairment were considered, one with 625-line monochrome television using a 2 μs undistorted echo, and the other with opaque photographs impaired by blur. Results were analyzed only in terms of mean score. The main conclusion of this study is that the impairment scale offers no advantage in respect of sensitivity with impairments below the threshold of visibility. However, it should be pointed out that this experiment does not represent results that would be obtained by comparing the single stimulus method and the EBU method.

4. Some other experimental evidence

Experimental evidence from other sources is available, some of it differing from that in § 3. A considerable body of results exists in the case of the single-stimulus quality-grading method, relating to all its important properties.

Results support the applicabilities of the Imp transformation (see for example [Macdiarmid and Allnatt, 1978], also Annex II) as a law of addition of subjective impairments. This law is used to adjust for the effect of residual impairment in analysis, and operates differently from the transformation using shifting of the mean scores, advocated in § 3.1.

As regards the double-stimulus quality grading method, the standard deviations of differences between pairs of scores at the same presentation have been found to be lower than those of the individual scores, when impairments are small. A transformation is required to give the equivalent standard deviations in terms of a 5-grade scale, and at zero impairment values of about 0.13 were found with a fairly wide range of impairment using random noise [White and Allnatt, 1980], and 0.35 in assessment of a high quality digital codec [CCIR, 1978-82d]. In other experiments with digital television [IBA, 1981] the value was 0.22. Comparable values found in similar experiments [Kretz and Sallio, 1981] were 0.25 at $4H$, 0.45 at $6H$ for zero impairment.

Comparison [CCIR, 1978-82d] of measurements of a digital codec using the double stimulus method with those using the single stimulus method with the test impairments embedded among a number of other wide-range impairments, support the finding of White and Allnatt [1980] that adaptation due to indirect anchoring effects are considerably reduced by using double stimulus as compared to the single stimulus method.

Results obtained using an impairment scale show that it is inadvisable, in measuring the visibility of separate impairments, to present them in the same sequence [CCIR, 1982-86b]. Such a procedure might introduce a bias, since the observers will tend to compare the effect of the different impairments. It would therefore seem preferable, when measuring the visibility of separate impairments, to present only a single type of impairment for assessment in each display sequence.

5. Discussion

The aim of specifying a procedure in detail is to minimize the random variation of results that is not due to systematic differences between different populations of observers found when, say, the results of independent tests are compared or combined. This is the common aim of all the procedures described, but there are other factors which are seen as giving strength to particular procedures. These relate to the degree of discrimination of results that is worthwhile, and the degree of complexity and elaborateness of the test procedure. The more complex and elaborate the procedure, the more time-consuming and costly it may be. Central to the discussion on the choice of procedure is the accuracy needed and how much is to be gained in terms of the results achieved.

The procedures described in § 8 of the Appendix to Recommendation 500-3, Recommendations and Reports of the CCIR, Vol. XI-1, Dubrovnik, 1986 —————————— select a combination of quality or impairment scale with the regular use of a reference picture, either signified as such or not, or indirect anchoring by impairment range. Procedure 8.1 is the simplest method for organization; the analysis of results for 8.1 and 8.2 of the Appendix —————————— and § 1.1 of this Annex are about the same complexity; the organization of 8.2 and 8.3 of the Appendix —————————— and § 1.1 of this Annex are about the same, but the analysis of results for 8.3 takes longer. Method 8.4 generally requires more sessions than the other procedures and is designed to reduce systematic errors. A comparison of results obtained by some of the methods for certain impairments is given in § 3, and other experimental evidence in § 4 of this Annex.

It is clear that each method is seen as having certain strengths and that the choice among them is not a simple one. It is impossible to do full justice to the arguments presented in a report of this kind, but essentially the main arguments which have influenced workers in the field are as follows.

The choice of procedure is related to the choice of grading scale, whether it should be continuous or discrete, and the way in which observers should be asked to make the correct use of the scale.

As regards the relative value of the quality scale and the impairment scale, some see the "quality" concept as more closely related to viewers interests, and, furthermore, beneficial because if an "impairment" actually improves the picture, the results reflect this. On the other hand, others see the impairment scale as easier to interpret and as having the advantage of allowing measurement of a threshold of perception (between grade 4 and 5 on the impairment scale). It would appear that there is an equal preference of observers opinion between the two scales but there is evidence that it may be possible, in some or all cases, to relate the two semantic axes by an appropriate formula, and work is continuing in this field.

The arguments for a continuous scale are that sometimes the extra organization and analysis time are justified because fine discrimination is both possible and needed. The arguments for a discrete scale are that no better results can be achieved with a continuous scale, for reasons that include the fact that non-experts are, in practice, no more discriminating than the discrete scale allows.

The need for some form of anchoring is recognized by all, and this can be achieved in various ways. Some workers suggest that for impairments which are of interest over a wide range of values, no specific regular reference picture is needed, because the standardized wide range of impairments itself causes observers to correctly orientate themselves on the scale. For experiments using only very small impairments an anchor picture should be provided, but it should not be signified as such, because this would make the observation environment too artificial. The double stimulus procedure may have an advantage in measurements of impairments of small magnitude such as in future systems. Other workers argue that the regular, signified, use of a reference picture (high-quality) helps observers to orientate themselves on the scale and that the results of experiments demonstrate this, particularly for small impairments. Another approach which is believed to be valuable is to use two unsignified reference pictures (high and low-quality).

As regards the EBU method, a grade for the reference, in one case as low as 4.63 was found. In a work by the Australian Broadcasting Commission [1981] a grade for the reference of 4.42 was noted in one case. In SMPTE assessments, using NTSC and RGB as references with observers taken from the broadcasting industry, reference picture grades of 4.7 were noted. Some workers believe that the reason for low values may include insufficient procedural control or non-consistent reference quality, as related to the necessary direct anchoring. In those cases, correction for residual impairment seems necessary as for single-stimulus procedures. Further studies in relation to other procedures may be relevant.

In a move towards rationalization of methods, it should be possible, in the next CCIR study period, to bring major elements of the procedures together and confine alternatives to only certain parts. It is encouraging to note that in a recent practical situation (the study of the relationship between impairment and different digital sampling frequencies [CCIR, 1978-82e, f and g]), where careful procedural rules were applied, virtually the same mean scores were achieved by entirely independent tests using different procedures (§ 8.2 and 8.3 of the Appendix to Recommendation 500).

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REPORT 1083

ADVANCED STATISTICAL PROCESSING OF SUBJECTIVE TEST RESULTS

(Study Programme 3A/11)

(1986)

1. Introduction

Recommendation 500 and Report 405 describe preferred methods to be used when conducting subjective tests on the quality or impairment of television signals affected by distortion or interference. Methods are described to assess the performance of a given television system, under a given amount of a specific distortion or interference, leading to a result represented by a single statistical value. Methods are also described to assess the performance of a given television system, under several amounts of a given distortion or interference, leading to a result represented by a statistical curve.

It often happens that an assessment is required on the statistical performance obtained when testing a family of devices, under several conditions of distortion or interference, although the devices in the family exhibit a wide spread in their performance characteristics. This is the case, for example, when tests are made to ascertain the statistical subjective quality, provided by a population of television receivers, for a range of interference levels. An advanced statistical treatment method can be applied to the data obtained in such subjective tests, in order to permit a statistical presentation of the results of the test, in a simple and readily understandable form.

2. Procedure description

This method finds application in the case of subjective tests performed on a sample of the population of a given type of equipment when their susceptibility to an impairment factor is tested.

For each equipment in the sample, the subjective scores for a number of levels of the impairment factor are collected and, for each level, the mean score is calculated.

As a first processing step, a least square fitting of the mean scores is performed, for instance by means of the well-known logistic function (see also Report 405, Annex III, § 2). This process generates a family of curves, each describing the behaviour of a particular equipment, with a large spread of characteristics among them (see Fig. 1).

Subsequently, an adjustment for the residual impairment, as described in Annex III to Report 405, is applied on each curve, but scaling it from 0 to 100 instead of the usual 0 to 1. This permits the plot to be read in terms of "percentage of full quality" or "relative quality in percent" as in Fig. 2.

It is difficult to draw conclusions by just examining such a complete set of curves, and it is also meaningless merely to take the average of them, even if some additional information about the spread of the curves is available.

However, a statistical synthesis of the experimental results can be plotted in the form of a boundary line that divides the representation plane in two regions (Fig. 2). The first region, located below the boundary line, will contain the curves pertaining to no more than x% of the whole equipment population in the lower quality range; the second region, located above the boundary line, will contain the curves pertaining to the equipment population in the higher quality range. The parameter x can be selected at will.

The procedure to plot this boundary is to compute the limit values for D_M and G (parameters of the logistic function, defined in Annex III to Report 405) so that the boundaries of their joint distribution for a given probability (e.g. 10%) can be identified. Based on the two limit values thus computed, the two limit cases for the logistic function are then plotted.

Then, for each value of the impairment factor under test, the worst case is chosen; it is thus possible to trace a piecewise line, bounding the two regions for the given percentage of equipment population.

The boundary line thus found, is such that no more than x% (e.g. 10% in Fig. 2) of equipment population, can be expected to have characteristic curves falling in the region under the boundary and thus showing a performance worse than the one described by the boundary. The remaining population can be expected to display a better performance and to be described by curves falling above the boundary.

This kind of representation is helpful in the utilization of the results of a subjective test and it is expected to provide more reliable results than those obtainable by other methods.

A more complete description of the method can be found in [CCIR, 1982-86].

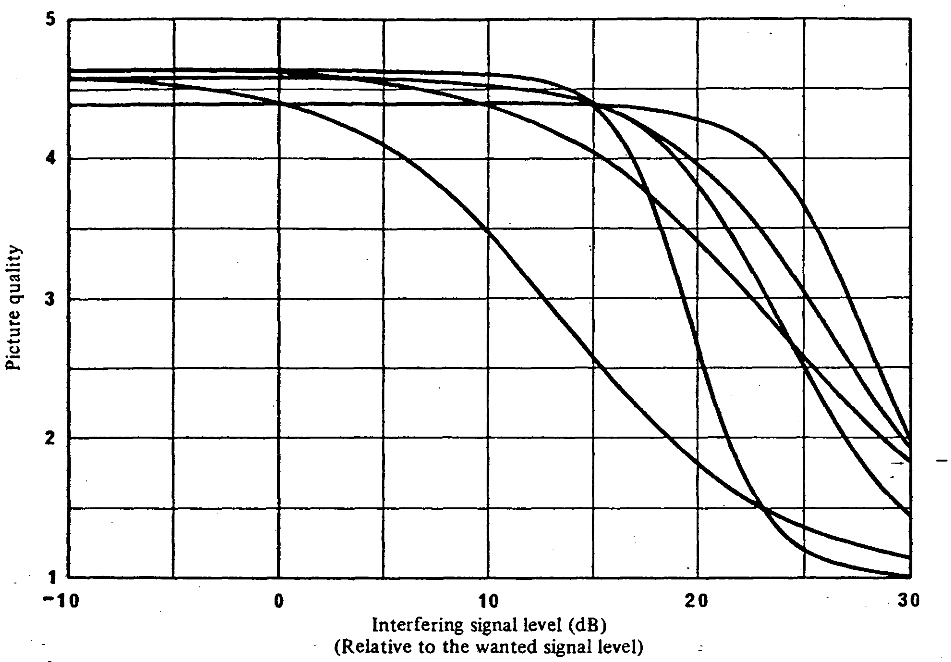

FIGURE 1 – *Behaviour of 6 commercial receivers for continuous interference coming from the adjacent inferior channel*

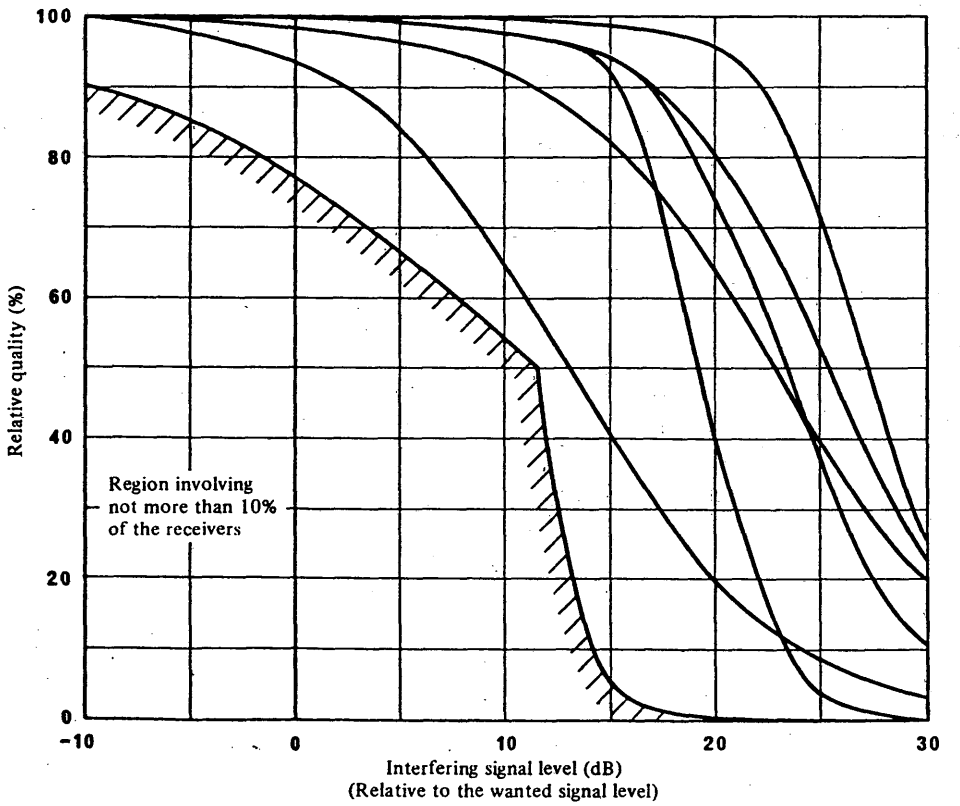

FIGURE 2 – *Behaviour of 6 commercial receivers for continuous interference coming from the adjacent inferior channel and region involving not more than 10% of the receivers*

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REPORT 404-2

DISTORTION OF TELEVISION SIGNALS DUE TO THE USE OF VESTIGIAL SIDEBAND EMISSIONS

(Study Programme 9A/11)

(1966-1970-1974)

This Report provides a synthesis of all information in the documents enumerated in Report 404 (1966) supplemented by new data based on studies carried out by the OIRT, and other contributors (see bibliography).

1. Introduction

Vestigial-sideband emission of television signals and their reception with receivers using demodulation with a Nyquist slope give rise to different kinds of distortion:

- linear distortion due to group-delay differences in the receiver circuits, both along the Nyquist slope and in relation to the necessary attenuation on sound carrier of the lower adjacent channel;
- non-linear distortion due to the envelope demodulation, in the form of quadrature distortion, and to crosstalk between the luminance and the chrominance signals.

These distortions result in the deterioration of the quality of the received television picture.

Theoretical and practical investigations have been recently carried out in many countries with the aim, on one hand, of obtaining a quantitative picture of the distortion of television signals due to the use of vestigial-sideband transmission and, on the other hand, of finding methods of reducing this distortion as well as of determining the degree of the picture quality improvement as perceived by viewers. Such improvement can be ensured by the correction of distortion or the selection of the optimal width of the lower sideband and the steepness of the Nyquist slope.

2. Analysis of the television signal distortion

The distortion of television signals, arising in the vestigial-sideband transmission, depends on several factors such as the steepness of the Nyquist slope (i.e. the relative width of the vestigial sideband), the modulation depth, and the position of the vision carrier on the Nyquist slope. This distortion can be presented either as depending on frequency, i.e. by the amplitude and group-delay characteristics, or as depending on time, by the transient characteristic.

The television signal distortion due to the vestigial-sideband transmission affects the build-up time (10 to 90%) of the transient characteristic, or causes voltage overshoots.

When analyzing the distortion by means of the approximated calculation method [CCIR, 1963-66a; Dobesch, 1966], the following conclusions can be drawn:

- the distortion increases with the modulation depth;
- the build-up time diminishes with the decreasing steepness of the Nyquist slope (i.e. the increasing useful width of the vestigial sideband);
- the influence of the changes of the vision carrier position on the Nyquist slope with regard to the value of distortion depends, to a great extent, on the steepness of the Nyquist slope – it diminishes with the decreasing steepness;
- the shift of the vision carrier on the Nyquist slope within 0 and −1.5 MHz in relation to the nominal position generally tends to decrease the distortion (decreased build-up time and overshoots, improved symmetry of the transient characteristic).

It can be presumed that in industrial receivers the Nyquist slope, within the established tolerances, can be approximated by straight lines. In this case the calculated results are highly accurate in practical conditions. Thus it follows that a further decrease of the steepness of the Nyquist slope will not result in an essential improvement of the video signal form.

Similar results have been obtained by computer calculations. It is noted [CCIR, 1963-66b] that a change of the steepness of the Nyquist slope from 0.75 to 1 MHz does not lead to a perceptible decrease of distortion.

3. Establishment of tolerances for television signal distortion

Measurements of the frequency responses of television transmitters are usually effected between the transmitter input and the Nyquist demodulator output. In this case the measurement results reflect the actual distortion of television signals at the receiving end.

As mentioned above the characteristics can be presented as depending on time, or as depending on frequency. Investigations [CCIR, 1963-66c] have shown that transient characteristics are more useful, because they afford a result closer to the visible effect of the distortion on the received television picture. On the basis of the assessed picture quality, the admissible distortion value can be determined. Under such conditions the amplitude-frequency characteristic is of lesser importance.

Attention should be drawn to the fact that at present no methods are known enabling transformation of tolerances of characteristics in the time domain into tolerances of characteristics in the frequency domain, and vice versa. Even so the danger exists that an equipment may have transient characteristics within the tolerances, while the amplitude-frequency characteristic exceeds the respective tolerances.

Tests have also shown [CCIR, 1963-66c] that transmitter phase correction can be easily effected on the basis of the transient characteristic, the same results being obtained as on the basis of measurement of the group-delay characteristic.

So far sufficient data for the establishment of tolerances of television signal distortion have not been obtained. From theoretical calculations [CCIR, 1963-66b] it follows that the difference between the group-delay on the vision carrier frequency and that on the central video frequency – corresponding to a Nyquist slope of 0.75 MHz – is approximately 150 ns. It has also been proved that the non-uniformity of group-delay higher than 50 ns in the vicinity of the vision carrier frequency causes considerable distortion of the transient characteristics.

For measurements on a television transmitter with the Nyquist demodulator, it is proposed that adequate tolerance masks be used for determining the admissible deviations of the individual characteristics from nominal responses [OIRT, a]. These masks determine separately the parameters of the transmitter and those of the Nyquist demodulator [OIRT, b] as well as the parameters of the entire transmitter-demodulator channel.

Theoretical calculations of T and $2T$ sine-squared pulse distortion in the Nyquist demodulator have shown that the amplitude of $2T$ sine-squared pulse at the demodulator output attains:

– 80% without demodulator phase correction,
– 100% with demodulator phase correction;

and the amplitude of T sine-squared pulse:

– 76% without demodulator phase correction,
– 80% with demodulator phase correction,

in relation to the input pulse amplitude.

It has also been calculated that the distortion of 4.43 MHz sub-carrier pulse with $20T$ sine-squared envelope, originating in the Nyquist demodulator, need not be taken into consideration and that the distortion at the base of the pulse does not exceed 3% when applying phase correction to the demodulator.

4. Investigation of possibilities for improving picture quality

To improve the quality of television pictures, distorted due to the use of vestigial-sideband transmission, several investigations have been carried out along two basic lines:

– pre-correction of distortion while maintaining the existing standards for the width of the vestigial sideband, and
– broadening of the vestigial sideband.

4.1 *Correction of the television signal distortion*

Long-term investigations of the correction of television signal distortion have led to the conclusion that in this way a considerable improvement of the signal form can be obtained [CCIR, 1963-66d]. With this in view, both correction of linear distortion with the aid of phase filters and correction of quadrature distortion were used on the transmitter. Measurements effected under laboratory conditions and on a number of transmitters have shown that television signal distortion can be almost entirely eliminated in this way.

In relation to colour-television signals the quadrature component causes two types of distortion: incorrect reproduction of the brightness of coloured areas, and phase modulation of the vision carrier, depending on the degree of modulation.

It has been shown that the correction of quadrature distortion can entirely eliminate both effects.

With the aim of confirming the measurement results of the correction of linear and quadrature distortion investigations of picture quality have been carried out on the basis of subjective tests [CCIR, 1963-66e]. The results of these measurements make it possible to establish the following:

- the improvement of picture quality obtained by group-delay correction is greater than that obtained by quadrature correction,
- after an optimal correction of both types of distortion no deterioration of the picture quality can be observed;
- in rebroadcasting transmissions with two successive modulation and demodulation processes quadrature correction should be used.

The usefulness of linear-distortion correction has been investigated in system L [CCIR, 1963-66f]. Some improvement of the transient characteristic has been obtained (decreased overshoots from 7% to 4% and decreased streaking). A further improvement of the picture quality can be obtained by quadrature correction.

4.2 *Broadening of the vestigial sideband*

In order to verify the influence of broadening the vestigial sideband on the subjective picture quality assessed by viewers, investigations of the picture quality with 0.75 MHz and 1.25 MHz vestigial-sideband transmissions have been carried out [CCIR, 1963-66g]. Investigations with the aid of various characteristic pictures have confirmed that most viewers note a better picture quality in the case of transmission with a broader vestigial sideband, the degree of improvement depending on the contents of the picture. Differences in quality were almost indiscernible only in pictures with low contrast and a small number of details.

As regards broadening of the vestigial sideband, the opinion has been expressed [OIRT, a] that the reduction of the steepness of the Nyquist slope tends to decrease the non-uniformity of group-delay and the quadrature distortion, as well as the sensitivity of the receiver to heterodyne frequency variations. For channels in Bands IV/V, 1.5 MHz is considered to be the optimum value. At the same time, attention has been drawn to the fact that broadening of the vestigial sideband decreases the protection between adjacent channels and that this is connected with transmitter network planning and the establishment of protection ratios.

5. Effects of quadrature distortion on the insertion test signals described in Recommendation 473, Annex I

A complete theoretical investigation on this subject has been carried out in Italy [CCIR, 1970-74; D'Amato, 1971], and calculations have been made for the case of systems B and G.

A hypothetical "transmitter-demodulator chain" has been considered, with the following characteristics:

- all the circuits have a flat group-delay frequency response;
- the overall amplitude-frequency response of the radio-frequency intermediate-frequency circuits varies linearly from 0 to 1 over the frequency range (f_v – 0.75 MHz) to (f_v + 0.75 MHz) and is equal to 1 for frequencies greater than f_v + 0.75 MHz (f_v being the video-carrier frequency);
- the amplitude-frequency response of all the video-frequency circuits is equal to 1 over the range 0 to 5 MHz and to 0 for frequencies greater than 5 MHz;
- the depth of modulation at white level is 10%;
- the depth of modulation at black level is 73%.

With these assumptions, the distortion which affect the elements of the insertion test signal are those summarized in Table I. As regards distortion of the white bar, $2T$ and $20T$ pulse, the theoretical results of Table I agree with results of an experimental investigation carried out in the Federal Republic of Germany [IRT, 1970].

TABLE I

Signal element	Parameter	Values (1) for system B, G
White bar leading (trailing) edge (shaped by the network generating the $2T$ pulse)	Undershoot amplitude Half-amplitude delay (lead) Rise time (fall time)	3% 69 ns 240 ns
$2T$ pulse (half-amplitude duration: 200 ns)	Amplitude reduction Half-amplitude duration Main negative echoes amplitude	11% 156 ns 6.7%
$20T$ pulse	Base-line depression Amplitude reduction Phase distortion	6% 13.8% 5° 50′
Chrominance bar	Chrominance peak amplitude Chrominance-to-luminance intermodulation	− 92.1% 9.9%
Luminance staircase	Line-time non-linearity distortion	0%
Staircase with chrominance superimposed	Differential gain (2) Differential phase Line-time non-linearity distortion (altered by chrominance-to-luminance intermodulation) (2)	3.7% 0° 4.4%

(1) All values expressed as percentages are referred to the nominal amplitude of the picture signal (0.7V).

(2) As the sub-carrier at the white level gives rise to over modulation, the step at the white level is not considered.

It must be remembered that these characteristics are not representative of normal equipment designs where the response in the frequency range of the colour sub-carrier is reduced to minimize quadrature distortion.

6. Receivers employing synchronous demodulation of the intermediate-frequency signal

The use of an ideal synchronous demodulator for the intermediate-frequency signal eliminates quadrature distortion due to vestigial-sideband transmission and practical circuits show a very considerable advantage over envelope detection in this respect. However, quadrature distortion can arise due to shifts in the phase of the vision carrier relative to the sideband. Such phase shifts may occur at the transmitter or in the receiver circuits.

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REPORT 313-6

ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES

(Question 3/11)

(1959-1963-1966-1970-1974-1978-1982-1986)

During recent years extensive studies have been made in many laboratories on the assessment of the quality of television pictures and the respective methods of measurement, both for monochrome and colour television. Since these studies cannot yet be considered to be concluded, it seems appropriate, with a view to facilitating future work, to give a list of documents and publications bearing on this question.

Such a list would serve both to avoid duplication of work and to enable comparisons to be made with results already found elsewhere. It may be extended to include subsequent publications on this subject and would be a valuable aid, within the scope of Question 3/11, in arriving at suitable standard methods for measuring the various kinds of picture distortion in television.

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REPORT 1206

METHODS FOR PICTURE QUALITY ASSESSMENT IN RELATION TO IMPAIRMENTS FROM DIGITAL CODING OF TELEVISION SIGNALS

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

(1990)

1. Introduction

With the increasing application of digital coding and bit-rate reduced transmission, the assessment of coding impairments are of critical importance. An understanding of these assessment methods is relevant not only to the performance of new coding equipment, but also to an interpretation of measurements made on such equipments and to specifications for target performance. Moreover digital codecs as with all adaptive or non-linear digital processes, cannot be fully characterised with traditional television test signals or patterns.

Studies in connection with Question 3/11 and Study Programme 3B/11 indicate the desirability of establishing relationships between objective measurements of signals impaired by digital coding, and the subjective assessments of the quality of the picture thus obtained. This Report gives progress towards this end, which is proving more difficult to achieve as codec complexity increases.

Subjective methods for conventional resolution television picture quality and impairment assessment are given in Recommendation 500 and for HDTV, are given in Recommendation 710. The application of these methods to television codec assessment is considered in this report.

Recently, considerable experience has been gained in the assessment of the performance of high quality codecs for 4:2:2 component television at 34, 45 and 140 Mbit/s [CCIR, 1986-90a]. In these trials, codec performance was examined in terms of basic decoded picture quality, quality after studio post-processes (chromakey and slow motion) applied to the decoded pictures, and the decoded picture impairment associated with the presence of a range of channel error rates. Parts of this report draw upon these experiences.

For distribution applications quality specifications can be expressed in terms of the subjective judgement of observers. Such codecs can in theory therefore be assessed subjectively or objectively against these specifications. The quality of a codec designed for contribution applications however, could in theory be specified in terms of objective performance parameters because its ouput is destined not for immediate viewing, but for studio post-processing, storing and/or coding for further transmission. Because of the difficulty of defining this performance for a variety of post-processing operations, the approach preferred has been to specify the performance of a chain of equipment, including a post-processing function, which is thought to be representative of a practical contribution application. This chain might typically consist of a codec, followed by a studio post-processing function (or another codec in the case of basic contribution quality assessment), followed by yet another codec before the signal reaches the observer. Adoption of this strategy for the specification of codecs for contribution applications means that the measurement procedures given in this Report can also be used to assess them.

Throughout this Report the importance of choosing critical test picture sequences, mostly of natural scenes, is stressed and some guidelines on how such sequences may be generated or chosen is given.

2. Digital Codec Classification

The function of digital coding is to reduce the bit-rate needed to represent a sequence of images while ensuring minimal loss in picture quality. Coding equipment does this, first by removing as much statistical redundancy from the images as possible (i.e. no loss in quality occurs as a result of this conceptual first stage). Then, if more bit-rate reduction is necessary, some distortion has to be introduced into the picture, although one of the objectives of codec design is to hide this distortion by exploiting certain perceptual insensitivities of the human visual system.

It is convenient to divide codecs into two classes, those using **fixed word-length coding** and those using **variable word-length coding** (see definitions in sections 3.1 and 3.2 respectively). The latter class is more efficient and complex, and includes all recently proposed systems for coding 4:2:2 video to the range 30-45 Mbit/s. The former class is however sufficient to permit 4:2:2 video to be reduced to 140Mbit/s while still preserving the quality demanded for contribution applications. A further sub-division of these classes is also useful, into **intrafield** (or spatial) codecs and **interframe** (including interfield) codecs, which contain frame (or field) stores permitting them to exploit the redundancy which exists between successive picture frames (or fields).

There is emerging a third class of codec which employs variable word-length coding but which is being designed for variable bit-rate networks. These codecs can in principle, preserve a constant decoded image quality subject to the bounds of peak network demand. The quality-testing of such codecs would have to take into account the nature of the network used and the statistics of the data injected by all of its users, and remains to be studied.

3. Objective Assessments of Codecs in Terms of Perceived Picture Impairments

3.1 Fixed Word-length Codecs

With fixed word-length codecs a fixed number of bits is used to represent a fixed number of source picture samples. For example in fixed word-length PCM or DPCM codecs, a fixed number of bits is allocated to each picture sample, and in fixed word-length transform or vector quantisation codecs, a fixed number of bits is allocated to each block of picture samples.

3.1.1 Methods based on the use of synthetic test signals

In these codecs the impairment introduced into each received picture sample of an image is dependent upon the values of those samples in the locality surrounding it, either in the same field (for an intrafield codec) or in the same and previous fields (for an interframe codec). It is therefore possible, using suitably chosen 2 or 3 dimensional digital test signals to artificially provoke the degradations characteristic of digital image coding.

Some of these **degradation factors** have acquired names such as false contouring, granular noise, blur, blocking impairments, etc. relating to their interpretation by observers. Having provoked these distortions, their magnitudes can be objectively measured and, using experience gained from subjective assessments these measurements could then be related to some quantification of codec quality. Examples of these measurements are given in [Kobayashi, 1977] for intrafield codecs and [Hishiyama & Inoue, 1984] for interframe codecs. Relating the degradation factors to their interpretation by observers may prove difficult in interframe coding systems or systems employing some adaptive processing because they can vary at any moment, with motion or adaptation of the coding algorithm. A method for classification in such cases is presented in [CCIR, 1982-86]. In that method the subjective assessment test first uses scales derived from pairs of opposite adjectives (the Semantic Differential Method), and then the results are analysed by principal component analysis to extract the picture quality degradation factors. The classification results can be tested by applying multiple regression analysis which relates the factors to subjective judgements. A list of picture quality degradation factors is presented in Table I.

While these methods appear to have conveniences for codec assessment and also to offer a tool to the codec designer, they are difficult to relate to the performance of a codec for real pictures for the following reasons:

- the complex composition of real picture sequences cannot be satisfactorily modelled by a practical number of synthetic test signals;

- degradations can be numerous in character and difficult to classify because of their subtle nature (for example, a particular distortion may be visible only in textured parts of an image moving in a particular way);

meaningful objective measurements of degradations can be difficult to define (for example, for motion portrayal). It should be noted that the duration of the period in which objective measures are taken should correspond to the observation window provided by the duration of the presentation in subjective tests.

TABLE I

Examples of picture quality degradation factors for digital system, and corresponding physical measures (units)

Picture quality degradation factor	**Physical measure**
- Image blur	- Step response rise time
- Edge busyness	- Step response jitter width
- False contouring	- S_{p-p} to minimum quantizing error p-p
- Granular noise	- Equivalent analogue signal-to-noise ratio expressed in terms of S_{p-p}Nrms
- "Dirty window" effect	- Maximum noise amplitude
- Temporary image blur	- Rise time of a moving edge
- Jerkiness	- Field or frame difference in terms of moving edge position
- Mosaic-like impairment	- To be studied
- Bit error	- To be studied

3.1.2 Methods based on natural picture material and coding error

Natural picture sequences can be thought of as being composed of a number of different regions, each with different local content and each exercising different fixed word-length codecs in different ways. Therefore the content of an image sequence will have a significant impact on the quality perceived by a viewer [Roufs et al., 1989]. It is also possible, where a comparison is to be made between two codecs for the image sequence content to determine which appears the better. Not only does this underline the importance of the choice of test images for subjective assessments (see section 9) but also that an objective measure of the performance of a particular codec must consider image content, if there is to be a correlation between subjective and objective assessment results.

The most common forms of objective quality measurement are based on the **coding error** of a codec; that is, the difference between an input picture sequence and its decoded output. This difference signal (often amplified) can itself be displayed as an image sequence and this can provide a useful development aid to the codec specialist. It should not however be used as material for subjective assessments.

3.1.3 Methods based on normalised mean square error

A frequently used objective measure of decoded image quality is mean square coding error. This is the average, over every picture sample in a sequence, of the square of the coding error and is usually normalised with respect to (the square of) the full amplitude range of the picture samples. Sometimes the normalised mean square error (NMSE) is quoted as a coding noise figure evaluated as -10 log(NMSE). The popularity of the NMSE measure stems from its mathematical convenience but it must be regarded with caution as a measure of decoded quality. It cannot distinguish, for example, between a few large coding errors (which may be annoying to an observer) and a large number of small coding errors (which may be imperceptible). Weighting of the coding error signal (performed after a log operation) prior to the NMSE evaluation, with a filter derived from a visual model, has been attempted and has achieved improved correlation with subjective assessment results. The NMSE is a useful practical tool in codec development where it is often required to compare coding methods which are very similar (ie those which use minor variants of the same algorithm and where impairment processes can be assumed to be identical).

3.1.4 Methods based on visual models

The sensitivity of the human visual system to coding error in a particular region of an image is strongly influenced by the characteristics of the image material itself in that region. The inability to recognise this fact is the major failing of the NMSE measure. To give just one example of this influence: it is known that an observer`s sensitivity to coding error noise is reduced when the spectrum of that noise approximately coincides with the spectrum of the "background" image. These properties of the visual system are those which are being exploited in codec design when subjective experiments or psychovisual data are used to optimise system parameters.

In order to further the correlation between objective measures of picture quality and that judged by human observers it is necessary to develop a visual model which can interpret local coding error in the context of the background image and which can combine all these local assessments to form a global quality rating. This approach is applicable to both fixed and variable word-length codecs and is considered in section 3.2.3.

3.2 Variable Word-length Codecs

Television codecs which require to reduce their source image data by more than a factor of about two, use methods based upon variable word-length coding. These codecs have increased efficiency because they possess the flexibility to allocate dynamically coding bits to the parts of an image sequence where they are most effective in maintaining decoded image quality. There are several ways in which codecs can do this, the use of variable length entropy codes is not necessarily implied.

3.2.1 Methods based on the use of synthetic test signals

Because of the flexibility of these codecs, the impairment which they introduce into each coded sample is dependent not only on the values of samples in the same locality, but also on the history of previous samples extending a frame or more into the past. This means that for either intrafield or interframe variable word-length codecs it is not meaningful to attempt codec characterisation by trying to provoke local distortions with local test signals and making objective measurements on them. If however the adaptation modes of a variable word-length codec can be artificially held (requiring access to its internal workings), each mode may be characterized separately. Knowledge of the codec's adaptation switching, when it is presented with natural scenes, could then be used to objectively determine its performance.

It is possible to contrive moving synthetic test sequences which take a codec to the point where it produces visible distortion, but even if objective measurements could be defined to characterise these distortions (see reservations in section 3.1.1), their interpretation could only be made in the context of that entire test sequence. This raises questions about how typical of natural scenes it is, and whether a codec designer would have the opportunity to optimise its performance to suit known test material.

3.2.2 Methods based on natural picture material and coding error

It is important in any assessment of variable word-length codecs that natural picture sequences be used. Bearing in mind the ability of these codecs to direct the utilisation of coding bits throughout the image, careful consideration should be given to the content of every part of the image sequence when judging its criticality (see section 9). It is recommended that any objective assessments be based on the coding error of a codec where the inputs are a number of natural test pictures. The normalised mean square error method discussed in section 3.1.3 may also be applied to the coding error from variable word-length codecs but such results should be for specialist interpretation only and even then, only as a supplement to subjective assessments. Similarly objective comparisons between codecs based on the NMSE should only be undertaken by specialists in codec design and only where techniques to be compared have very minor differences (ie are variants of the same algorithm) and where impairment processes can be assumed to be identical.

3.2.3 Methods based on visual models

The major disadvantage of measures based upon the NMSE is that they do not recognise the strong influence which the image content itself has on the sensitivity of an observer to impairments. As was mentioned in section 3.1.4, codec design optimisation involves the use of subjective experiments and psychovisual data to match the distortion-tolerance of the human observer to the characteristics of local image regions. This ensures that when a variable word-length codec apportions coding bit-capacity (and therefore also apportions the magnitudes of coding errors) throughout an image it can do so in a manner which is also matched to visual characteristics. Any objective assessment method must therefore encompass properties of the human visual system if it is to yield results which correlate well with subjectively-determined quality ratings. It is the function of a visual model to interpret coding error in the context of the source image in which it occurs.

The assumption in the following text assumes that access to the internal workings of a codec is not available. If information on adaptation modes can be obtained, variable word-length codecs can also be assessed using the method of degradation factors (section 3.1.1) along the lines discussed in [Inoue and Hishiyama, 1984].

In the development of a visual model, two levels of knowledge must be incorporated. The first concerns how visible any arbitrary impairment is, given its location in the image and the second determines how the visibility of all the impairments should be combined to yield an overall quality rating. It is however only necessary to concentrate on models which account for the impairments characteristic of digital coding methods; distortions of a geometric or semantic nature, for example, need not be considered. Models of the response of the human visual system to distortions arising from image transmissions have concentrated on phenomena at or near the threshold of visibility, which is adequate for high quality television applications (see for example, [Sakrison, 1977]). Little is known about the modelling of the response to larger distortions.

A significant study detailing the design of a visual model for picture quality prediction was made by [Lukas & Budrikis, 1982]. Their paper examines the development of this model and its performance as a predictor of subjective quality, from a simple estimator based on raw error measures, through one which models (non-linear) visual filtering, to one which can account for the spatial and temporal masking properties of vision. As vehicles for this study, the distortion processes of uniform quantisation, DPCM coding, additive Gaussian noise, and low-pass filtering were used. Particularly noteworthy in the derivation of an overall quality measure for an image sequence, was the modelling of the observation that viewers tend to grade pictures according to the level of distortion present in the most impaired locality of the image and not as an average over all the image. More recently another visual model has been developed [Girod, 1988] for application to digital picture coding and [Zetzsche & Hauske, 1989].

The use of visual models for the objective determination of picture quality in the presence of, not only digital coding impairments but also impairments arising from other non-linear or adaptive processes, is an area of great promise. Unfortunately it has received little attention and more contributions to this topic are encouraged.

4. Objective Assessment of Codec Picture Quality in the Presence of Transmission Errors

In a practical transmission environment the link between coder and decoder will be subject to influences which can corrupt the data being conveyed, so an important characteristic of a decoder is its response to the presence of these transmission errors. In a carefully designed codec this response will be of the form of local transient distortions within the decoded image, where the number of these transients is related to the channel error statistics, and their nature is related to the picture coding algorithm employed and the criticality of the image sequence being displayed. Typically, the aim of assessments involving transmission errors is to derive, for a codec, a graphical representation of the impairment perceived by the viewer over a range of error rates.

There are several levels of processing within a decoder which determine its response to transmission errors, some of which may be analysed mathematically (or simulated by computer), while others require either some degree of subjective assessment or an objective model of the viewer`s response to transient distortions.

The first stage in an objective analysis is to describe as accurately as possible, the way in which errors occur in a practical link, this is usually expressed as a statistical model. In its simplest form such a model assumes that errors occur randomly and independently (Poisson distribution), however it has long been known through practical observation that in reality errors appear in clusters or bursts. Several models have been proposed to account for this behaviour, the most popular being based on the Neyman type A distribution (see for example [Jones & Pullum, 1981]). Whereas the simple Poisson distribution is completely defined by a single parameter, the mean bit-error ratio, the Neyman A model requires a further two parameters to be quantified relating to the degree of clustering and the error density within each cluster. No recommendation is yet available for realistic choices of these parameters.

Aware of the bursty nature of transmission errors, codec designers often incorporate a process of time-reordering of the transmitted bits before they enter the channel. This ensures that bursty channel error occurrences are spread by the inverse reordering mechanism in the decoder and are thus rendered in a form which is more amenable to processing by the subsequent error correction system. This error correcting system will be capable of completely correcting a number of errors using a redundant overhead of transmitted data capacity but there will remain some distribution of "residual" errors which will enter the picture decoding algorithm. The distribution of residual errors may be calculated for a particular codec and channel model but it remains to assess the effect that these errors will have on the on the decoded image.

[CCIR, 1986-90b] suggests that the performance of a particular codec in transmission errors be judged in two parts first subjectively, in order to determine the impairment due to the distortion transient characteristic of that codec, and second objectively, taking into account the rate of residual errors obtained by computation from the above considerations. At present no experimental evidence is available to support this approach, it could however be the first step in a wholly objective measure, if the response of the viewer to different codec transients can be characterised. It is important to note that some transmitted bits are more sensitive to corruption than others, meaning that a codec's response to a single bit residual error can vary greatly and can also depend on the criticality of the source image sequence. In interframe codecs for example, the transient resulting from residual errors can remain in static parts of a picture sequence until provision is made to remove them by **refreshing**. Finally, a feature of some codecs employing variable word-length coding is that they can detect some violations of coding caused by transmission errors and use this knowledge to attempt to conceal the distorting transients. While not successful for every error, this concealment process generally improves the subjective quality of the resulting image, a fact which must be accounted for in any objective codec assessment.

5. Subjective Assessment of Codec Picture Quality

Although progress is being made, there is currently insufficient experience to give details of objective picture quality assessment methods for codecs. In the area of subjective assessment, where much experience exists, test conditions and methodologies can be recommended. It must be remembered however when specifying quality or impairment targets, that existing methods cannot give absolute subjective ratings but rather results which are influenced to some extent by the choice of the reference and/or anchor conditions. The same methodologies may be adopted for both fixed and variable word-length codecs, and for intrafield and interframe codecs although the choice of test images sequences may be influenced (see section 9).

At the present time, the most completely reliable method of evaluating the ranking order of high-quality codecs is to assess all the candidate systems at the same time under identical conditions. Tests made independently, where fine differences of quality are involved, should be used for guidance rather than as indisputable evidence of superiority.

5.1 Basic Quality Assessment

Where a codec is being assessed for distribution applications this quality refers to pictures decoded after a single pass through a codec pair. For contribution codecs, basic quality may be assessed after several codecs in series, in order to simulate a typical contribution application.

5.1.1 Viewing conditions and choice of observers

It is recommended that these should be as in section 2.4 of Recommendation 500 for conventional resolution television and as in Recommendation 710 for HDTV codecs.

5.1.2 Use of test picture sequences

It is recommended that at least six picture sequences be used in the assessment, plus an additional one to be used for demonstration purposes prior to the start of the trial. The sequences should be of the order of 10s in duration but it should be noted that test viewers may prefer a duration of 15-30s [Inoue, 1988] [CCIR, 1986-90c]. They should range between moderately critical and critical in the context of the bit-rate reduction application being considered (see section 9).

5.1.3 Test methodology

Where the range of quality to be assessed is small, as will normally be the case for television codecs, the testing methodology to be used is the double-stimulus continuous quality-scale described in Recommendation 500. The original source sequence will be used as the reference condition. Discussion on the duration of presentation sequences is continuing in IWP 11/4 [CCIR, 1986-90 d,e]. In the recent tests by IWP 11/7 on codecs for 4:2:2 component video [CCIR, 1986-90a, f] with the results given in [CCIR, 1986-90g], it was considered advantageous to modify the presentation from that given in Rec. 500. Composite pictures were used as an additional reference to provide a lower quality level against which to judge the codec performance.

5.2 Post-processed Quality Assessment

This assessment is intended to permit judgement to be made on the suitability of a codec for contribution applications with respect to a particular post-process eg chromakey, slow motion, electronic zoom. The minimum arrangement of equipment for such an assessment is a single pass through the codec under test, followed by the post-process of interest, followed by the viewer. It may however be more respresentative of a contribution application to employ further codecs after the post-process.

5.2.1 Viewing conditions and choice of observers

See section 5.1.1.

5.2.2 Use of test picture sequences

Because of the practical constraints of possibly having to assess a codec with several post-processes, the number of test picture sequences used may be a minimum of three with an additional one available for demonstration purposes. The nature of the sequences will be dependent upon the post-processing task being studied but should range between moderately critical and critical in the context of television bit rate reduction and for the process under consideration. The sequences should be of the order of 10s in duration but it should be noted that test viewers may prefer a duration of 15-30s [Inoue, 1988] [CCIR, 1986-90c]. For slow motion assessment a display rate of 1/10th of the source rate may be suitable.

5.2.3 Test methodology

The test methodology to be used is the double-stimulus continuous quality-scale method described in Recommendation 500. Here however the reference condition will be the source subjected to the same post-processing as the decoded pictures. If inclusion of a lower quality reference is considered to be advantageous then it too should be subjected to the same post-process. In the tests described in [CCIR, 1986-90f] slight modification was made to the presentation given in Rec. 500.

6. Subjective Assessment of Codec Picture Impairment due to Transmission Errors

Section 4 presented some discussion of the way in which transmission errors are handled by a digital decoder, with a view to considering how objective picture quality analysis could be approached. A useful subjective measure may be impairment determined as a function of the rate at which transmission errors occur in the link between coder and decoder. At present there is insufficient experimental knowledge of true transmission error statistics to recommend parameters for a model which accounts for error clustering or bursts. Until this information becomes available Poisson-distributed errors may be used. Some details of data corruptors for application to the 34, 45 and 140Mbit/s hierachical transmission levels are given in [CCIR, 1986-90f].

6.1 Use of test picture sequences

Because of the need to explore codec performance over a range of transmission error rates, practical constraints suggest that 3 test picture sequences with an additional demonstration sequence will probably be adequate. Each sequence should be of the order of 10s in duration but it should be noted that test viewers may prefer a duration of 15-30s [Inoue, 1988] [CCIR, 1986-90c]. It should range between moderately critical and critical in the context of television bit rate reduction (see section 9).

6.2 Choice of error rates

A minimum of 5, but preferably more, error rates should be chosen, approximately logarithmically spaced and spanning the range which gives rise to codec impairments from "imperceptible" to "very annoying".

6.3 Test methodology

As the tests will span the full range of impairment, the double-stimulus impairment scale (EBU) method is appropriate and should be used. The method is described in Recommendation 500.

6.4 A note on the use of very low error rates

It is possible that codec assessments could be required at transmission error rates which result in visible transients so infrequent that they may not be expected to occur during a 10s test sequence period. The presentation timing suggested here is clearly not suitable for such tests.

If recordings of a codec output under fairly low error rate conditions (resulting in a small number of visible transients within a 10s period) are to be made for later editing into subjective assessment presentations, care should be taken to ensure that the recording used is typical of the codec output viewed over a longer time-span.

7. Subjective Comparisons Between Codecs

Where a judgement of absolute codec quality or impairment is not required, but only the ranking order, or where confirmation of the ranking order found from double-stimulus results is desired, the method of paired-stimulus comparisons should be used. This is given in section 4.2 of Recommendation 500.

As it is described, the method provides a sensitive comparison and a means of determining a measure of the relation between pairs of systems. An extension of this method, to ranking the quality or impairment of more than two systems, is given in [CCIR, 1986-90h]. In this approach overall ranking order is derived from the ranking of all possible pairs of picture sequences by the observers.

The analysis is complicated by the fact that an observer can rank, for example, picture A better than picture B, and picture B better than picture C, but also picture C better than picture A. This is termed an "intransitive triad". The statistical treatment of transitivity for each observer is dealt with in [CCIR, 1986-90h, i] as is the important aspect that statistically significant systematic agreement between observers exists.

A problem with the method is that the number of presentations required increases as the square of the number of test picture sequences and codecs, and can become impractical.

8. Distortions in Mixed Analogue and Digital Transmission

Until the present time, picture quality specification problems have been considered individually for analogue or digital systems. If the psychological independence of picture quality degradation phenomena mentioned in section 3.1 can be assumed, then the approach described in that section may also be applicable to mixed systems. That is, they can be classified into one of the following three groups from the viewpoint of psychological independence.

a) impairments caused only be the analogue section;

b) impairments caused only by the digital section;

c) impairments caused by both analogue and digital sections (which might be independent factors in each individual system).

Impairments belonging to group a) or b) will be dealt with as independent factors and a function has already been proposed to the CCIR for estimating the overall picture quality in this case. This estimation function is applicable when certain mutually independent psychological factors exist at the same instance.

On the other hand, in group c), where picture quality degradation phenomena from both sections are so similar that they cannot be regarded as independent, it will be necessary to find a new way to allocate picture quality degradation to both the analogue and digital sections before applying the estimation equation mentioned above.

An example of the investigation results for such a case is reported in [Inoue, 1987]. In this paper a combination of random noise from the analogue system and granular noise from a fixed word-length intraframe DPCM coding system was investigated to show that it is possible to replace a physical measure in the analogue system with a corrected value based on visual sensitivity differences.

9. The Choice of Test Picture Material for Digital Codec Assessment

Throughout this Report, the importance has been stressed of testing digital codecs with picture sequences which are critical in the context of television bit-rate reduction. It is therefore reasonable to ask how critical a particular image sequence is for a particular bit-rate reduction task, or whether one sequence is more critical than another. A simple but not especially helpful answer is that "criticality" means very different things to different codecs. For example, to an intrafield codec a still picture containing much detail could well be critical, while to an interframe codec which is capable of exploiting frame-to-frame similarities, this same scene would present no difficulty at all. Some sequences employing moving texture and complex motion will be critical to all classes of codec so these are most useful to generate or identify. Complex motion may take the form of movements which are predictable to an oberver but not to coding algorithms, such as tortuous periodic motion.

A consideration of possible statistical measures of image criticality [CCIR, 1986-90j] ——— such as by correlative methods, spectral methods, conditional entropy methods etc. has revealed a simple but useful measure based on an intrafield/interframe adative entropy measurement. This method was used to "calibrate" picture sequences proposed for use in the IWP 11/7 trials of codecs for 34, 45 and 140Mbit/s and proved useful for the selection of the sequences used. The making of such measurements on picture sequences is most easily accomplished by transferring them to image processing computers and subjecting them to analysis by software.

Where access to these techniques is not available, the following presents some general guidelines on how to choose critical material.

Fixed word-length intrafield codecs: while it is possible and valid to assess these codecs on still images, the use of moving sequences is recommended since coding noise processes are easier to observe and this is more realistic of television applications. If still images are used in computer simulations of codecs, processing should be performed over the entire assessment sequence in order to preserve temporal aspects of any source noise, for example. The scenes chosen should contain as many as possible of the following details: static and moving textured areas (some with coloured texture); static and moving objects with sharp high contrast edges at various orientation (some with colour); static plain mid-grey areas. At least one sequence in the ensemble should exhibit just perceptible source noise and at least one sequence should be synthetic (ie computer generated) so that it is free from camera imperfections such as scanning aperture and lag.

Fixed word-length interframe codecs: the test scenes chosen should all contain movement and as many as possible of the following details: moving textured areas (some coloured); objects with sharp, high contrast edges moving in a direction perpendicular to these edges and at various orientations (some coloured). At least one sequence in the ensemble should exhibit just perceptible source noise and at least one sequence should be synthetic.

Variable word-length intrafield codecs: it is recommended that these codecs be tested with moving image sequence material for the same reasons as the fixed word-length codecs. It should be noted that by virtue of its variable word-length coding and associated buffer store, these codecs can dynamically distribute coding bit-capacity throughout the image. Thus, for example, if half of a picture consists of a featureless sky which does not require many bits to code, capacity is saved for the other parts of the picture which can therefore be reproduced with high quality even if they are critical. The important conclusion from this is that if a picture sequence is to be critical for such a codec, the content of every part of the screen should be detailed. It should be filled with moving and static texture, as much colour variation as possible and objects with sharp, high contrast edges. At least one sequence in the text ensemble should exhibit just perceptible source noise and at least one sequence should be synthetic.

Variable word-length interframe codecs: this is the most sophisticated class of codec and the kind which requires the most demanding material to stress it. Not only should every part of the scene be filled with detail as in the intrafield variable word-length case, but this detail should also exhibit motion. Furthermore, since many codecs employ motion compensation methods, the motion throughout the sequence should be complex. Examples of complex motion are: scenes employing simultaneous zooming and panning of a camera; a scene which has as a background a textured or detailed curtain blowing in the wind; a scene containing objects which are rotating in the three dimensional world; scenes containing detailed objects which accelerate across the screen. All scenes should contain substantial motion of objects with different velocities, textures and high contrast edges as well as a varied colour content. At least one sequence in the test ensemble should exhibit just perceptible source noise, at least one sequence should have complex computer generated camera motion from a natural still picture (so that it is free from noise and camera lag), and at least one sequence should be entirely computer generated.

Test sequences required for post-processing assessments are subject to exactly the same criticality criteria. This may be difficult to achieve however in chromakey foreground sequences because they usually have a significant proportion of featureless blue background.

A comprehensive library of test sequence material has been prepared by IWP 11/7 in 4:2:2 component format and is held on D1 tape. Details of these sequences, together with the criteria by which they were prepared (which may apply to other imaging standards), are given in Report 1213.

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REPORT 1216

THE SUBJECTIVE ASSESSMENT OF HDTV PICTURES

(Question 3/11; Study Programme 3E/11)

(1990)

1. Introduction

Methods used in subjective texts of conventional television systems are described in Recommendation 500 and in Report 1082. The main concepts of assessment methodology apply equally to all forms of television, but the way in which the detailed specifications of the methods for conventional television apply to HDTV requires careful study.

According to Decision 95, JIWP 10-11/6 is to examine developments in HDTV and to determine what changes, if any, to subjective test methods are required to accommodate these developments. The IWP has yet to complete its studies in this regard.

Before proceeding, it is important to stress the following points:

- Picture quality is not the only factor which needs to be considered in the selection of standards. Other factors such as system complexity, availability, future possibilities, etc., must be part of the overall equation.

- The results of subjective assessment experiments are not in themselves laws of physics. They offer guidance for a given set of test conditions, and are not absolute facts about a system.

- The conceptual differences between the quality and impairment scale terms currently used are not uniform; but, traditionally, processing of results uses the approximation that they are so. Studies on alternative assessment methods with fewer shortcomings are being made, but interpretation of the results of current methods must take account of the shortcomings. More information is available in Report 1082.

- The key element in subjective assessments is often the selection of test material. Guidelines call for material which is critical but not unduly so. Deciding what could be critical needs a full understanding of how HDTV systems work. Systems-oriented IWPs (IWPs 11/6 and 11/7) therefore must also be part of the methodological discussion.

An HDTV environment evaluation by Krivocheev, related in Part 1 of Report 801 ―――――― was used to delineate elements of the HDTV environment likely to be the subject of assessments.

2. Picture quality evaluations in an HDTV environment

2.1 Areas for picture quality evaluations

2.1.1 Evaluations of HDTV studio formats

There will be a need to evaluate:

- basic picture quality;
- picture quality after downstream processing such as colour-matte, slow-motion and picture manipulation, and possible conversion to other formats, including film.

2.1.2 Evaluations of conventional studio formats (and film) derived from HDTV studio sources

There will be a need to evaluate the adequacy, in terms of picture quality, of conventional studio formats and of film derived from HDTV studio sources.

2.1.3 Evaluations of HDTV emission formats

There will be a need to evaluate:

- basic picture quality;
- failure characteristics;
- echo behaviour; and
- susceptibility to interference.

2.1.4 Evaluations of conventional television pictures embedded in HDTV emissions

Some of the HDTV emission formats currently under consideration include an embedded conventional television format ("backwards compatibility"). Thus, there will be a need to evaluate, in terms of picture quality, the adequacy of conventional television pictures embedded in HDTV emissions.

2.2 Issues for picture quality evaluations

2.2.1 Evaluation methods

2.2.1.1 Evaluations of picture quality

The five-grade quality terms currently used in subjective assessments are not uniformly spaced conceptually and difficulties have been noted in comparing results obtained in different laboratories, particularly when language translation of terms is required (CCIR Report 1082). Further, due to the sensitivity of quality evaluations using conceptual quality terms to the range of conditions used i test, it is unwise to interpret terms in an absolute fashion or to compare results from tests conducted using different ranges of quality (e.g. HDTV and conventional television).

A seven-grade quality scale has been used successfully in [Fujio, et al., 1982] to establish the meaning of HDTV quality and such techniques may be useful in future. Further, alternatives to the five-grade quality methods are presented in § 4 of Recommendation 500 and in Report 1082. Nevertheless, on balance, IWP 11/4 suggests that the double-stimulus continuous quality method given in § 2 of Recommendation 500 generally be used for quality evaluations in an HDTV environment.

2.2.1.2 Evaluations of picture impairments

To an extent, the same problems have been noted for the five-grade impairment scale as for the five-grade quality scale. On balance, however, IWP 11/4 recommends that, when picture quality impairments are to be evaluated, the double-stimulus, impairment method given in § 3 of Recommendation 500, generally be used.

2.2.2 Viewing conditions for subjective evaluations in an HDTV environment

2.2.2.1 Evaluations of HDTV studio formats

Report 801-2 (Dubrovnik, 1986) gives picture presentation objectives for HDTV studio formats.

2.2.2.2 Evaluations of conventional studio formats derived from HDTV studio sources

As these evaluations concern TV systems already considered in CCIR texts, evaluations of conventional studio formats should use the viewing conditions already agreed and presented in Recommendation 500.

2.2.2.3 Evaluations of HDTV emission formats

It is unclear how well the picture presentation objectives given in Report 801-2 (Dubrovnik, 1986) for HDTV studio pictures relate to conditions likely in home viewing. However, subjective evaluations of HDTV emission formats should take account in some way of the higher performance objectives of the HDTV studio.

It is likely that, due to constraints on emission, HDTV emission formats will be unable to fully reproduce the level of picture quality possible in the HDTV studio. However, in recognition of the objective in emission formats to reproduce, as nearly as possible, the original studio image and in order to preserve consistency of subjective tests throughout the HDTV studio-emission chain, it is suggested that the viewing conditions given in Recommendation 710 be used equally for tests of HDTV emission formats, and for tests of HDTV studio formats.

2.2.2.4 Evaluations of conventional television pictures embedded in HDTV emissions

As these involve conventional television pictures, the viewing conditions given in Recommendation 500 apply.

3. Assessment of the picture quality of HDTV studio formats

3.1 Assessment of basic picture quality

At issue here is the picture quality of the HDTV studio format prior to downstream processing. Factors likely to affect basic picture quality include, but are not confined to, spatial resolution, temporal resolution, colour-gamut, and linearity characteristics. Annex I of this Report summarizes work on evaluation factors for assessing HDTV picture quality.

There is general agreement that an increase in colour-gamut and the inclusion of constant luminance coding are desirable goals for the HDTV studio system. However, these features carry with them the need for more complex signal processing at the camera and display, and it may become necessary to evaluate trade-offs between the benefits of these goals and the possible disadvantages due to the complex signal processing.

Evaluation of the value of increased colour-gamut and the impact of additional processing requires the availability of a display having a significantly larger gamut than current CRT displays and a source signal properly processed for that large gamut display. In addition, a current CRT-type display is required with the non-linear processing to transform the large gamut source signal into an appropriate signal for this smaller gamut display. Still pictures containing a range of normal colours plus a few colours that lie outside the smaller gamut should be evaluated by comparing the two displays. One source for high purity colours are balls of yarn containing saturated colours. Materials of this sort can provide very saturated colours that lie outside the gamut of current CRT displays and still lend themselves to reasonable scene composition. Subjective evaluation of such a scene on normal CRT displays and on high purity displays should provide an estimate of the quality gain.

The evaluation of constant-luminance coding methods in comparison to non-constant luminance coding methods should be carried out by comparing a full bandwidth RGB display to a display on which either constant-luminance or non-constant-luminance signals can be displayed. The scene subject matter should include detail in saturated colours along with normal scene elements. Shadows formed on balls of saturated red, green and blue yarns are one means for providing the detail in saturated colours [CCIR, 1986-90a].

The methods normally used to assess picture quality (i.e., double-stimulus methods) typically require a reference condition that provides quality superior to that of the system under test. The high quality of an HDTV studio system, however, makes it difficult to find appropriate reference conditions. For this reason, it may be appropriate to use directly-viewed scenes (still and moving) to provide the reference condition for assessments of HDTV studio systems [CCIR, 1986-90b].

3.1.1 Methodology

The double-stimulus, continuous-quality method could be used. The reference for picture quality assessments could be the scene viewed directly (subject to appropriate framing). The test could be the same scene viewed via the system under test. Methodological issues associated with the use of directly-viewed scenes as reference conditions are summarized in Document [CCIR, 1986-90b].

3.1.2 Viewing conditions

See ——— Recommendation 710.

3.1.3 Assessment material

The test material could comprise a number of still pictures and moving sequences. Sources for the still pictures could be either transparencies (rear-illuminated) or photographic prints (directly illuminated). Sources for the moving sequences could be motion dioramas. The reference condition would be provided when a source is viewed directly, while the test condition would be provided when the same source is viewed via a camera and monitor. Identical framing for the two conditions could be maintained by reflecting the test materials for both onto the same 16:9 viewing mirror. Switching between conditions could be done by shutters in the optical paths. Switching is to be done under experimenter control.

The tests involve implied comparisons of test material from a video camera with the same material viewed directly. To minimize possible contamination of the results by differences implicit to television vs. the "real world", it will be necessary to control a number of factors. These include:

- parallax differences: while viewing, the observer should not be able to move appreciably as this would result in a degree of motion parallax in the directly viewed scene but not in the scene shown on the monitor;

- visible depth: the viewing mirror will display alternately the television image and the source scene. The composition and lighting of source scenes should be set to ensure that differences in depth between the television image and the directly viewed scene are minimized;

- scene lighting: the viewing mirror will display alternately the television image and the source scene. The lighting in the source scene will have to be adjusted when the display path is changed to hold intensity and colour temperature (D_{65}) constant in both of the images. The colour temperature may have to be set on scene-by-scene.

Document [CCIR, 1986-90a] provides a number of criteria for the composition of source scenes. These include:

- static spatial resolution;
- dynamic spatial resolution;
- luminance rendition;
- colour rendition; and
- motion rendition.

In addition, it might be useful to supplement these with other, special-purpose scenes. These might assess:

- apparent depth effects (e.g., in panoramic scenes);
- rendition of familiar tones (e.g., skin tones);
- feeling of presence (e.g., in a rapid pan); and
- flicker performance (e.g., with large, white sub-fields).

It may be useful to establish the standard set of test materials to be used for various subjective assessments of HDTV picture quality, as it has been done in Report 1213 for 4:2:2 materials.

Still pictures available

[CCIR 1986-90c] reports that nine still pictures described in Table I have been selected in Japan for the standard test pictures to be used in assessments of HDTV picture quality. Some demonstrations to the public were carried out and much interest was expressed in the excellent pictures. These are already being used for various tests in Japan.

Table 1. Major assessment factors in the standard pictures

Pictures / Assessment Factors		SET A				SET B				
		1	2	3	4	5	6	7	8	9
Resolution	(Luminance)				◎				◎	
	(Chrominance)								◎	
Wave-form distortion	(Ringing)		◎		○					
	(Smear)							◎		
	(Ghost)	◎	◎		○		○	◎		
Tone reproduction	(Bright area)	○			○	◎	◎			
	(Dark area)	○	○			◎	◎			
Colour reproduction						○			○	
Y/C phase difference		◎						○	○	
Registration			○					◎		
Uniformity		○		○	○		◎			
Aliasing			◎		○	◎				
False contouring		◎		○						◎
Subjective factors										
	Legibility			○				◎		
	Memory colour	◎								○
	Sharpness		◎		◎			◎	○	
	Texture	◎		◎						
	Sensation of reality				○					

◎ : Very Effective
○ : Effective

The pictures have the following titles:

1) A lady;
2) Yacht harbour;
3) Sweaters and a bag;
4) Eiffel tower;
5) A hat shop;
6) A couple in the snow;
7) Guide board;
8) Tulip garden;
9) "Chromakey".

A large transparency (10" x 8") of Kiel Harbour is available, and could be used to generate a test still picture.

Moving sequences available

The following assessment sequences have been prepared in an 1125/60/2:1 format to evaluate the quality of HDTV-to-YUV/PAL conversion. They may also, in some cases, be candidates for assessment of other HDTV systems.

Drum
BBC disc*
Red car*
Merry-go-round*
Newbury racing
Rollers
NHK disc
Football
Pendulum*
Interview
White car*

It has been suggested that if test materials could be prepared and distributed in digital media (Recommendation 657 is used for conventional moving sequences), the performance variations of analogue media could be eliminated. Digital recorders for HDTV are currently under development.

3.1.4 Interpretation of results

The system tested should approximate as closely as possible the level of quality provided by the directly-viewed reference. In considering the results, two issues should be kept in mind:

1. An HDTV studio system is likely to make compromises among the various features that relate to quality. In addition to considering quality averaged over the various pieces of test material, it would be wise to examine reactions to the individual source scenes in order to identify features that could be improved.

2. In interpreting results, it is necessary to identify and, to the extent possible, adjust for possible contamination of the results by technical maturity (state of implementation).

3.2 The assessment of HDTV picture quality following downstream processing

Two areas are considered: post-production processing and standards conversion.

3.2.1 Post-production processing

The major areas of post-production processing are colour-matte, slow-motion and picture manipulation. Assessments made at the time the Recommendation 601 4:2:2 standards were developed suggested that colour-matte is the most demanding post-production operation. For a given field-rate and scan system, this is likely to apply to HDTV.

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* These are probably the most critical for temporal processing systems.

3.2.1.1 Colour-matte assessments

a) Methodology

The double-stimulus impairment scale method should be used provided a full range of picture quality is available. The reference for colour-matte assessments could be a matted picture, using a full-bandwidth RGB signal as a foreground. The test could be a matted picture using the reduced colour-difference bandwidth signal as foreground. The matted test and reference pictures should be optimized for quality on a shot-by-shot basis, as this would be the situation in practice. The methodology appropriate, if a full range of picture quality cannot be provided, is still being considered.

b) Viewing conditions

See Recommendation 710.

c) Assessment material

The test material should be critical for the types of impairment likely for colour-matte processing. The material which is likely to be most demanding would contain moving fine detail. No specific test sequences for colour-matting in HDTV are known to be available, but moving combs, twisted ribbons, and glass (transparent) as in Report 1211 may be appropriate for colour-matte evaluations. One still picture (number 9 "Chromakey" in Table 1) is however available. Colour-matte performance depends highly on scene lighting, and care must be taken to ensure this is optimized and consistent.

d) Interpretation of results

The test material should not be appreciably impaired relative to the reference material.

3.2.1.2 Slow-motion assessments and picture manipulation assessments

Methodology, viewing conditions, assessment material, interpretation of results

The assessments in this category pose problems in that a high quality reference signal is not likely to be available. It is the inclusion of a reference signal which gives the double-stimulus methods their properties. A ratio scaling method is being studied which may be adequately stable and reproducible without a reference. Alternatively, there may, in some cases, be a means of generating high quality reference sequences. For example, high quality slow motion may be possible by a separate shooting of the source sequence at a higher picture rate.

3.2.2 Picture quality following HDTV-to-HDTV standards conversion

a) Methodology

As noted in Decision 58, the declared objective of all administrations is to achieve a single world-wide HDTV studio standard, and one of the reasons is to permit international programme exchange without standards conversion. Situations, no doubt, will arise, however, where conversion from other HDTV formats or film will be required. In addition, similar conversions might be needed prior to the generation of an emission format with a different field-rate to the source. In such a case, an investigation of an emission format should consider this.

Field-rate standards conversion can give rise to transient temporal artifacts, and in order to provide a better overall system evaluation, a two-tier assessment method is proposed here.

Primary assessments

These are considered to be the main and most useful assessments. A double-stimulus continuous quality scale method should be used. The reference signal should ideally be the same picture or sequence used as an input to the standards converter, but shot using the scanning parameters of the converter output signal. If this is not possible, or if such tests were of interest for other reasons, the reference signal should be the input signal to the converter.

Auxiliary assessments

A number of expert viewers should be asked, using the single stimulus method (see Recommendation 500, § 4), to assign an overall quality grade to several representative converted programmes. It may also be possible to assess the frequency of detection of artifacts, but this requires further study.

b) Viewing conditions

As given in Recommendation 710.

c) Test material

Primary assessments

A relatively large number of still pictures and moving pictures should be used. Possible candidates for HDTV-HDTV assessments are those listed in § 3.1.3.

Auxiliary assessment

A number of expert viewers may be asked to scale the overall quality of several programmes of 5-20 minutes duration, which include examples of different types of movement and scenes with high detail. An example would be the "This is HDTV" programme by NHK.

Characteristics of test material

Critical test material for standards conversion is likely to include areas of high detail which have different movement speeds and directions.

d) Interpretation of results

Care must be taken in the interpretation of results, that any inherent quality differences in the two HDTV studio standards are not attributed to the conversion process. The use of reference sequences shot directly in the output standard would assist this.

According to Report 801-2 (Dubrovnik, 1986), the subjective quality of the converted picture should be "virtually equivalent" to the input picture, unless it is limited by the parameters of either standard.

4. Assessments of the quality of conventional studio pictures derived from HDTV pictures in the studio environment

4.1 Areas for assessments

The interface between HDTV and conventional TV may imply conversions of line number, frame rate and aspect ratio, although cases without frame rate conversion are also possible. According to CCIR Report 801-2 (Dubrovnik, 1986), the quality of the conventional picture should be the same as for direct production in the conventional standard.

4.2 Impairments by standards conversion

4.2.1 Impairments due to line number conversions

Conversions involving changes in the number of active lines may result in perceptible disturbances at edges moving vertically. These disturbances may be more pronounced for conversions which increase the number of lines than for those which decrease the number of lines.

4.2.2 Impairments due to frame rate conversions

Conversions involving changes in frame rate will introduce artifacts, such as judder, confined to the moving areas of the picture. The level of these impairments is related to the ratio of the frame rates involved and to the complexity of the conversion algorithm. Some techniques, such as motion adaptive compensation, can reduce these artifacts to very low levels.

4.2.3 Impairments due to aspect ratio conversions

Conversions from the wider aspect ratio of HDTV to the 4:3 aspect ratio of conventional formats may result in the loss of significant picture content or resolution. This is not an area, however, in which subjective evaluation is likely to provide useful guidance.

4.3 Assessment of the quality of conventional quality television derived from an HDTV signal

4.3.1 Methodology

It is evident that the performance of HDTV to conventional television converters can only be completely assessed with moving picture sequences. For the evaluation of the small impairments of the limited range to be expected, the use of the double-stimulus, continuous-quality-scale method is thought to be most useful. The assessors should be asked to view a pair of sequences, one direct in the conventional studio format and the other in the appropriate conventional format but derived from HDTV.

4.3.2 Viewing conditions

The viewing conditions should be as in Recommendation 500.

4.3.3 Assessment material

A wide range of relatively critical programme material should be used as assessment material. The picture sequences listed in § 3.1.3 were recommended by NHK and EBU experts for the assessment of the NHK converter. The test sequences could become even more revealing if some of those sequences were replaced by similar ones with higher maximum velocities. The use of still pictures as given in § 3.1.3 may also be appropriate.

Two other kinds of sequences, likely to be more critical, could be included as well:

- scenes with zoom motion;
- scenes with movements in contrary directions like a market place.

Tests should also be conducted with downstream processed material.

4.3.4 Interpretation

Ideally, an HDTV to conventional television interface should yield the same quality as conventional television direct. Because this demand will probably not be met completely for motion portrayal, the frequency of the assessed picture degradations in television programmes should be investigated. This may imply a two-tier approach as in HDTV-HDTV conversion.

5. Assessment of the quality of HDTV emission systems derived from an HDTV studio standard

5.1 Areas for assessment

The system characteristics which are of interest are as follows:

5.1.1 Basic quality: This is the picture quality under perfect reception conditions, i.e. when the SNR or CNR is high.

5.1.2 Failure characteristics: This is the relationship between picture quality and noise (which has a characteristic appropriate to the modulation system to be used). The range over which assessments should be made needs to be reviewed in the light of a preliminary run, and should be arranged to give 5-8 points covering the scale range. The range of interest for AM systems is usually a S/N of 25-55 dB, and for FM systems a C/N of 0-30 dB.

5.1.3 Echo behaviour: This is the relationship between picture quality and echo amplitude and delay. It is usually more relevant to AM systems. The range over which assessments need to be made should be reviewed in the light of preliminary runs, but a suitable approach might be to obtain information on three curves, having a delayed signal added to an undelayed signal with 150 ns, 1 μs, 5 μs delay respectively, and with echo amplitudes from -5 to -25 dB, compared to the wanted signal.

5.1.4 Interference behaviour: Co-channel and adjacent channel interference characteristics need to be assessed.

It may well be appropriate to assess items 2, 3 and 4 above both with and without scrambling.

5.2 Methodology

Basic quality

The basic design problem in HDTV emission is to meet, as nearly as possible, the visual requirements for HDTV within the bandwidth available. To do this, either or both of spatial and temporal subsampling may be used.

Such techniques may introduce detectable impairments, or losses in quality, beyond those attributable to the studio format. Spatial subsampling may result in detectable losses in one or more of horizontal, vertical or diagonal resolution. Temporal subsampling may result in detectable reductions in the quality of motion portrayal. Spatio-temporal subsampling may result in detectable losses in spatial resolution for moving picture sequences.

Clearly, high resolution pictures and moving picture sequences are needed to evaluate HDTV emission formats. However, in order to provide an adequate and representative overall evaluation, a two-tier assessment method is proposed here for basic quality.

- Primary assessments

These are considered to be the main and most useful assessments. A double-stimulus continuous-quality-scale method should be used. The reference should be the studio source signal and the test signal should be the emission signal.

- Auxiliary assessments

A number of expert viewers may be asked to scale the overall quality associated with several representative programmes in the emission format. It may also be possible to assess the frequency of detection of artifacts, but this requires further study.

Failure characteristics, echo behaviour and interference behaviour

A double-stimulus impairment scale method should be used following Recommendation 500, § 2.

Two approaches can be taken:

- cumulative failure characteristics - for these, the points at which objectionable losses occur relative to the unimpaired high-quality reference are considered;

- non-cumulative failure characteristics - for these, the points at which objectionable losses occur relative to the unimpaired emission format are considered.

5.3 Viewing conditions

See ——— Recommendation 710.

5.4 Test material

Basic quality

The test material should be chosen from a range of high resolution still pictures and moving picture sequences which are critical but not unduly so.

The Critical picture material given in § 3.1.3 is available and may be useful for appropriate HDTV emission systems.

A possible source for the auxiliary assessments could be the NHK programme "This is HDTV". Certain sequences from this programme have detailed crowd scenes, and 10-20 s segments from this part may be useful for the primary assessments.

Material which is likely to be critical would require high detail with simultaneous movement at varying speeds and varying directions.

Failure characteristics, echo behaviour and interference behaviour

Adequate results should be achieved by using only a small range of still and moving pictures. The overall mean grade can usually meaningfully be calculated and used.

5.5 Interpretation of results

a) Basic quality

It seems reasonable to argue that to be effective, the quality of the HDTV emission signal must be closer to the HDTV studio quality than to the RGB quality of conventional television.

As a generality, and for most material, there must be sufficient additional quality, compared to a conventional television. Further, any temporal artifacts must be sufficiently unobtrusive not to detract from the HDTV quality.

b) Failure characteristics, echo behaviour and interference behaviour

(Subject to further study.)

6. Assessment of the quality of compatible pictures embedded in HDTV emission formats

6.1 Areas for assessment

Some HDTV emission systems are intended to allow simultaneous reception on HDTV and conventional receivers. Section 5 concerns the assessment of the HDTV emission quality itself. This section concerns the quality of the simultaneously received conventional signal.

In general, a design tradeoff must be made between the quality achieved on the HDTV display and the quality achieved on the conventional display, leading to a degree of compatibility based on the level of impairment introduced. This may imply an investigation of the same factors as are listed in section 5, but this time for the compatible picture.

The proposed HDTV emission systems involve temporal processing, and other mechanisms, which might cause impairments to the compatible pictures.

6.2 Methodology

For basic quality, the double-stimulus, continuous-quality method might be used with material prepared directly in the conventional emission format and/or material converted directly from the HDTV studio format as reference. For failure characteristics, echo behaviour, and interference, the double-stimulus, impairment method might be used, with material prepared directly in the conventional emission format (but not otherwise impaired) and/or material converted directly from the HDTV studio format (but not otherwise impaired) as reference. In all cases, the test signal should be the compatibly received picture.

6.3 Viewing conditions

As given in Recommendation 500 for conventional television.

6.4 Test material

A range of still and moving pictures should be used. For compatible reception, the material given in the list in § 3.1.3 may be candidates.

Characteristics of test material should be generally as given for assessments in § 5 (i.e., critical, but not unduly so).

6.5 Interpretation of results

Interpreting what the quality of "compatible" pictures should be in quantitative terms presents problems, not least because of the non-interval nature of the scales.

Results for each test picture or sequence should be presented separately.

The quality of the embedded picture should, in principle, be "equivalent" to that of the reference signal. In practice, an agreed "degree of compatibility" must be achieved.

7. Assessment of the quality of motion-picture film derived from HDTV source material

(To be investigated.)

8. Comparisons of candidate HDTV formats

On occasions, it may be necessary to compare candidate HDTV formats for purposes of selection. It is the opinion of IWP 11/4 that such comparisons can be used most advantageously to identify the best features of the various formats under test.

8.1 Comparisons of HDTV studio systems

Three ways have been identified in which candidate studio formats can be compared:

- directly, by side-by-side comparison;

- indirectly, by implied comparisons to a common reference condition in a single experiment, and

- theoretically, by establishing relative placements in terms of psychophysically determined optima.

8.2 Direct comparisons ([CCIR, 1986-90a,d] discuss issues related to direct comparisons, further study is required)

8.3 Indirect comparisons

An indirect comparison requires a common reference condition with which each system under test is evaluated. The subjective methods normally used for indirect comparisons (i.e., the double-stimulus methods) use reference conditions that, typically, provide quality superior to that of any of the conditions under test.

However, the high quality of candidate HDTV studio systems makes it difficult to find such reference conditions. For this reason, it may be appropriate to use directly-viewed scenes to provide the reference condition.

For a valid indirect test, the directly-viewed reference must be held constant across all systems tested. For still pictures, of course, this can be accomplished by means of transparencies or photographs. For moving images, however, it is necessary to use fully reproducible motion sequences for the reference. This may be done using mechanically controlled scenes (e.g. dioramas).

It is equally important to ensure that, except for differences implicit to the formats themselves, the test materials are held constant across all systems under test. This would be accomplished if the video camera for the system-under-test is used to capture the reference still or sequence, as long as the reference is held constant.

It should be noted that all systems under consideration should be tested in a single experimental context (i.e. that viewers should see, over the course of the experiment, a random sequence of the systems under test). This may be done by alternating the cameras used to reflect the systems under test. The monitor which should be held constant, should be selected to be adequate for all system under test. It might not always be possible to extrapolate the general data applicable to the conditions set up by Recommendation 710 from the results obtained with the viewing conditions allowed by present equipment. Care should be taken in interpreting the results of the tests to distinguish system-standard-related values from those relevant to the practical implementation.

Directly-viewed scenes may provide a reference whose quality is considerably superior to that of the systems under test. This may lead to two issues:

1) differences in subjective reactions to the systems under test may be minimized artificially. When viewers judge, they tend to be influenced by the range and distribution of quality seen. When quality (including that shown by the reference) spans a wide range, cases somewhat similar in quality tend to be judged more similar than they would be if evaluated in a more constrained context or compared directly, and

2) the preferred test method may change. If conditions (including reference and test) cover a wide range of quality, the double-stimulus, impairment method may be used for indirect comparisons. However, if conditions span a smaller quality range, the double-stimulus,continuous-quality method is preferred.

Thus, depending upon the purpose of the test, two options arise. If tests are intended to place systems in relation to a "perfect" standard, they may use a superior reference and the double-stimulus, impairment method. In this case, however, fine differences among systems may not be detected. On the other hand, if tests are to make fine discriminations among systems, a superior reference should be avoided and the double-stimulus, continuous quality method used. In the latter case, it may be necessary to limit the quality of the directly-viewed scene by means of composition, lighting, optical filtering, etc.

8.3.1 Methodology

Depending upon the quality range involved in the test, either the double-stimulus, continuous-quality method or the double-stimulus, impairment method could be used.

If the double-stimulus, continuous-quality method is used, it may be appropriate to consider the variant of this method given in [CCIR, 1986-90d]. In this variant, relatively lengthy exposures are used to encourage the detection of subtle effects, particularly in moving sequences.

If the double-stimulus, continuous-quality method is used, each trial will involve multiple, alternating displays of the reference and test conditions. For half the trials (randomly determined), the reference condition is to be presented first; for the remaining trials, the test condition is to be presented first. If the double-stimulus, impairment method is used, each trial will involve a single alternation between reference and test, with the reference presented first.

The test material will comprise a number of still pictures and moving sequences. Sources for the still pictures could be either transparencies (rear-illuminated) or photographic prints (directly-illuminated). Sources for the moving sequences could be motion dioramas. The reference condition would be provided when a source is viewed directly, while the test condition would be provided when the same source is viewed via a camera and monitor. Identical framing for the two conditions could be maintained by reflecting the test materials for both on to the same 16:9 viewing mirror. Switching between conditions could be done by shutters in the optical paths. Switching is to be done under experimenter control.

Each viewer should see the viewing mirror through a viewing aperture that permits binocular viewing, but little or no head movement. Viewers can be run individually or in small groups. However, if more than one viewer is run at a time, the angle of view (to the scene) must be held constant for all viewers.

The tests involve implied comparisons of test material from a video camera with the same material viewed directly. To minimize possible contamination of the results by differences implicit to television vs. the "real-world", it will be necessary to control a number of factors. These include:

- parallax differences: while viewing, the observer should not be able to move appreciably as this would result in a degree of motion parallax in the directly viewed scene but not in the scene shown on the monitor;
- visible depth: the viewing mirror will display alternately the television image and the source scene. The composition and lighting of source scenes should be set to ensure that differences in depth between the television image and the directly viewed scene are minimized;
- scene lighting: the viewing mirror will display alternately the television image and the source scene. The lighting in the source scene will have to be adjusted when the display path is changed to hold intensity and colour temperature (D_{65}) constant for all the alternating displays. The colour temperature may have to be set on scene-by-scene.

As different linguistic groups are known to use quality and impairment scaling terms differently, all tests should be done in a single language with observers fluent in that language.

8.3.2 Viewing conditions

See Recommendation 710.

8.3.3 Assessment materials

See § 3.1.3.

8.3.4 Interpretation of results

Interpretation of results is made on the basis of relative placements of candidate systems relative to the common directly-viewed reference. The issues noted in § 3.1.4 should be kept in mind.

8.4 Theoretical comparisons

The basis of this approach is to consider, parameter-by-parameter, the placements of candidate systems in terms of the relevant psychophysical ideals. This approach is proposed in [CCIR, 1986-90d]; examples of its use (with generalizations) are given in Documents [CCIR, 1986-90f,g].

9. Comparisons of candidate HDTV emission formats

As with HDTV studio systems, comparisons may be direct, indirect, or theoretical. Here, only indirect comparisons are considered. Examples of this approach are given in [CCIR, 1986-90h].

9.1 Basic quality

This generally is as for HDTV studio formats (§ 8.3). Here the double-stimulus, continuous-quality method may be used with a single high-quality reference.

9.2 Failure characteristics

These tests generally are as given in § 5. However, the intent is to compare failure characteristics of all candidate systems.

10. Further issues

In [CCIR, 1986-90a] related issues are considered: evaluation methods for conversion from HDTV to 35 mm cine film, the use of the CCIR quality scale descriptors, interpretation of quality targets in terms of numerical results of assessment, subjective quality and signal-to-noise ratio characteristics of HDTV signals, relationships between picture and sound aspects of HDTV.

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ANNEX I

EVALUATION FACTORS APPROPRIATE TO GLOBAL HDTV ASSESSMENT

In a recent large scale study in North America, viewers evaluated HDTV (MUSE-E via satellite) both in absolute terms and in comparison to studio quality NTSC [Lupker et al., 1988a and b; CCIR, 1986-90]. Evaluations considered both overall picture quality and specific evaluation factors, including image sharpness, colour quality, motion portrayal, depth portrayal, image brightness, screen size, and screen shape (aspect ratio). The results showed that:

1. Absolute judgments of HDTV alone concentrate at the end of the quality scale, suggesting possible problems if the results of separate tests with different HDTV systems were to be compared on the basis of absolute quality judgments.

2. Viewers were able to respond differentially to the different evaluation factors, suggesting that the specific factors approach may be useful in future evaluations.

3. Judgments of overall picture quality were strongly related to most, but not all, of the evaluation factors on which HDTV was perceived to differ from NTSC, suggesting that overall picture quality may fail to fully capture viewer reactions.

4. Judgments on specific factors were, to an extent, related, suggesting possible hierarchies amongst the factors used in the evaluations and the possible existence of lower order basic quality factors.

5. Judgments of overall picture quality were to an extent, affected by different evaluation factors, as a function of viewing distance, suggesting a need for careful consideration of the viewing distances to be used in evaluations.

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REPORT 1221*

SPECIFICATIONS AND ALIGNMENT PROCEDURES TO PICTURE SIGNAL SOURCES AND DISPLAYS

(Study Programme 3A/11) (1990)

Differences in the alignment procedures and performance of the picture signal sources and the picture displays used in subjective tests may contribute to differences between the results obtained in such tests in different laboratories. Study Programme 3A/11, recognizing this problem, invites studies on the minimum performance specifications and on the alignment procedures that can be recommended for picture signal sources and for picture displays to be used in subjective tests.

The EBU has recommended to its member organizations [CCIR, 1978-82] a detailed alignment procedure for grade 1 colour monitors used in television production centres. Although referring to monitors used for a different purpose, this contribution is nevertheless relevant to the monitors used in subjective tests because both these applications require high-quality and reproducible performance standards. The document is therefore noted as a valuable preliminary input to the studies on picture sources and displays.

Broadcasting organizations throughout the world need some means of achieving accurate and consistent line-up of their picture monitors on a routine operational basis. A survey carried out in 1984 [CCIR, 1982-86] showed that many broadcasters are using a type of test waveform know as PLUGE, an acronym derived from picture line-up generating equipment. This type of waveform was introduced in 1960, and since that time different broadcasting organizations have made slight modifications to suit their own circumstances. The current situation is that most broadcasters use variations of the PLUGE signal and their methods of alignment vary slightly.

In these days when the exchange of programme material both within countries and internationally is the norm, it would be helpful if all picture monitors could be aligned to a consistent standard, and it is therefore recommended that all PLUGE generators should be adjusted to produce the same waveform, as far as is sensibly possible, and that monitors should be set up using a consistent procedure.

1. Details of the PLUGE waveform

All PLUGE generators produce a waveform which gives two closely-spaced narrow vertical strips on the left-hand side of the picture, one slightly darker and one slightly lighter than the background, together with a broad bar on the right (see Fig. 1). These signals occupy approximately three-quarters of the picture height while the remaining area is at blanking or pedestal level. In more recent generators the broad bar is divided into four equal areas, one at white level and the other three at descending grey levels. In older generators, the broad bar is divided into two equal areas, one at white level and the other at a grey level.

* The contents of this report have been taken from Annex VII of Report 405-5 (Dubrovnik, 1986).

2. Variations in PLUGE waveform parameters

The 1984 servey revealed the following differences (see Table I) between the PLUGE-type signals used in different countries.

TABLE I

Country	Pedestal amplitude (mV)	Narrow pulses signal amplitude (mV)		White level luminance for 700 mV bar amplitude (cd/m^2)
Austria (ORF)	20	+28	−28	–
Canada (CBC)	52.5	+14	−14	
Federal Republic of Germany (IRT)	0 or 49	+14	−14	80
Netherlands (NOS)	−21	+14	−14	([1])
New Zealand (TVNZ)	20	+20	−20	70
Sweden (Swedish Television)	0	+14	−14	([2])
United Kingdom	0	+14	−14	70/100

([1]) Separate full-field signal used – 70 cd/m^2.

([2]) 100 cd/m^2 white-level bar on all lines.

Note. – In North America, SMPTE Engineering Recommendation ER-1 includes a PLUGE signal as part of the colour bar test signal for monitor alignment.

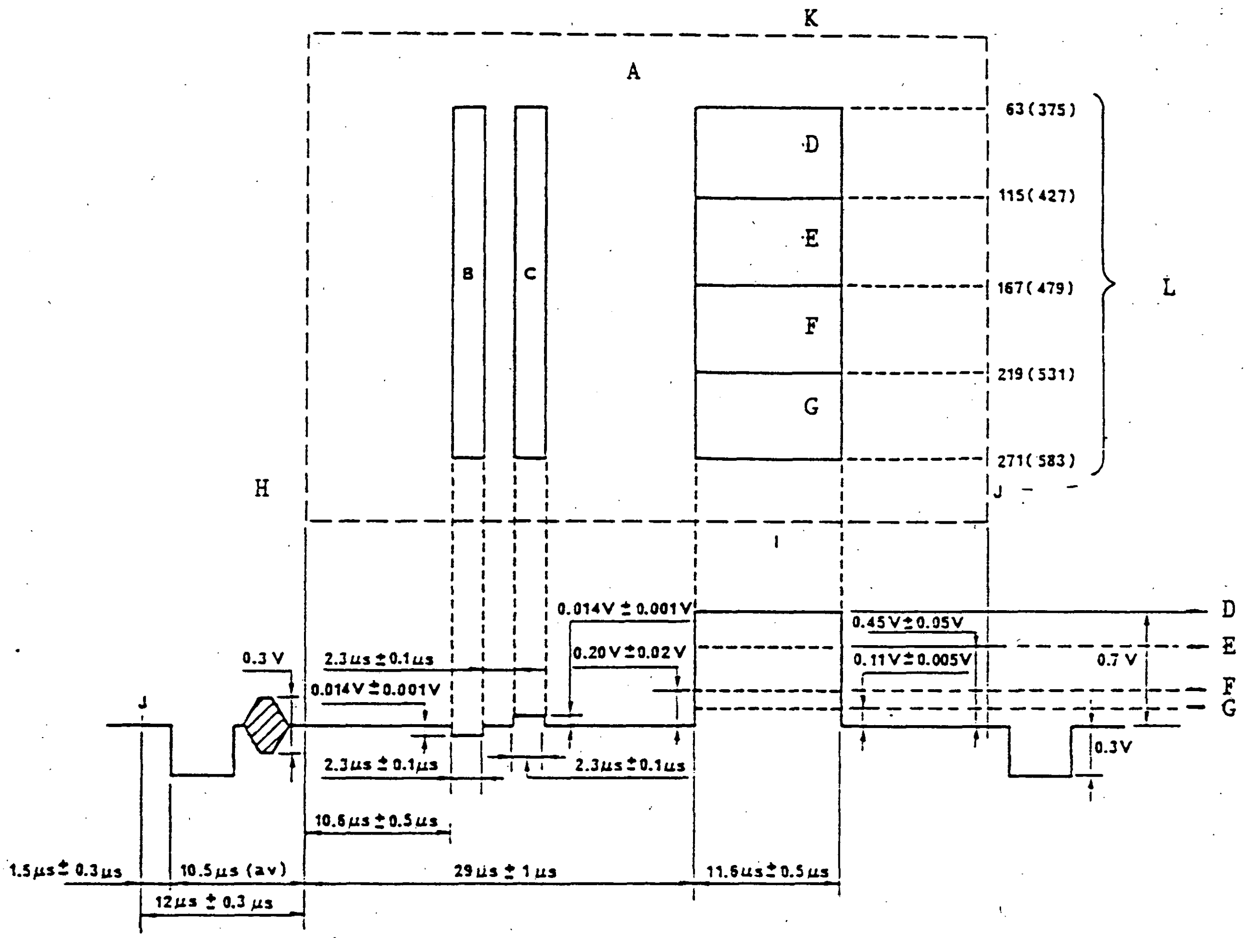

Figure 1 - Example of PLUGE waveform (625-line PAL)

A: blanking or pedestal level background
B: just blacker than background
C: just brighter than background
D: peak white
E: 1st grey bar
F: 2nd grey bar
G: 3rd grey bar
H: line-blanking finish
I: field-blanking start
J: line-blanking start
K: field-blanking finish
L: line numbers where transition occurs (first and second fields)

3. Proposed procedure for use of the PLUGE waveform

The usual recommended operational procedure is to adjust the brightness control so that the background and the darker strip are both invisible while the lighter strip can still be distinguished. Alternatively, the brightness control is set so that the darker strip is just, but only just, indistinguishable from the background. Provided that a narrow pulse amplitude of about 2% of the black and white excursion (about 14 mV) is used, either procedure will give virtually the same brightness control setting, at which the background level corresponds with the effective tube cut-off point.

The white level luminance is adjusted, by menas of the contrast control, to a luminance level which varies with different organizations, but Recommendation 500 gives 70 ± 10 cd/m^2.

To achieve a refined setting of the brightness control, it is recommended that all PLUGE generators should be adjusted to produce narrow pulses of $\pm$ 2% amplitude, with reference to a black-to-white transition. It is also recommended that the width of the narrow pulses, and the interval between the two should each have nominal durations of 2.3 µs, to provide areas of adequate size.

To ensure that all signals between black level and white level will produce a visible image on the screen, it is essential that black level should be not greater than blanking level. Consequently, it is recommended that the PLUGE signal should contain no pedestal if the normal video signal contains no pedestal. If the normal video signal contains a pedestal the PLUGE waveform should contain the same pedestal level (i.e. the background level should be blanking level).

It is recommended that the preferred signal should incorporate a broad bar containing a white area and three equal areas of descending brightness, to facilitate the examination of grey-scale tracking. However, it is considered that this feature is of secondary importance, and the PLUGE generators providing only one grey area are suitable for use as standard sources, provided that the other recommendations are satisfied.

It is found useful if the white bar is of sufficient area such that the luminance of this bar can be measured by an instrument. This results in the other grey-scale bars being of smaller areas than the white bar.

To avoid edge flare on the monitor the PLUGE signal should occupy the centre of the picture area [CCIR, 1986-90a]. In order to ensure that the colour decoder of a monitor is working in its colour mode, it is recommended that a standard colour burst is included in the waveform.

One of the most completely specified waveforms of a PLUGE unit available is that of the United Kingdom, shown in Figure 4.

Using this waveform, the monitor brightness control should be adjusted under standard viewing conditions to the maximum value for which the transition between the darker narrow strip and the background is indistinguishable, while the lighter narrow strip is clearly visible.

It is considered that the white level luminance should be determined by the user's requirements, although it is recommended that similar levels should be used for specific purposes.

For the time being, it is suggested that laboratory assessments should be made using a white level luminance of 70 cd/m^2, in accordance with Recommendation 500, but that a luminance level of about 100 cd/m^2 is more appropriate for control-room applications.

4. Conclusion

An ideal picture monitor alignment procedure would completely standardize the light transfer characteristic (video signal level to light reaching the observer's eyes) of the monitor. The light transfer characteristic resulting from monitor alignment with PLUGE may be dependent on room ambient light level. At present, the interaction of monitor faceplate characteristics (CRT surface and light absorption in CRT faceplate) with veiling illumination (room light falling on the CRT faceplate) is not completely understood. Thus the PLUGE signal should be considered as a means to match monitors of identical optical characteristics used in a common viewing environment.

On the use of the PLUGE signal for adjusting monitors for subjective evaluations, preliminary investigations have indicated non-stable results for different conditions.

An alternative approach for calibrating monitors for subjective testing using a telephoto meter has been found to give more consistent results [CCIR, 1986-90b].

At present the PLUGE signal is specified only in analogue composite form. Further work is needed to specify an equivalent digital version.

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REPORT 1222

THE SUBJECTIVE QUALITY OF ALPHANUMERIC AND GRAPHIC PICTURES IN TELETEXT AND SIMILAR SERVICES

(Study Programme 3C/11)

(1990)

Recommendation 500 proposes methods to evaluate the subjective quality of pictures as proposed in current television programs. But the Study Programme 3C/11 asks for studies on the quality of alphanumeric and graphic pictures which are used for several new services transmitted in the television channel. They use digital codes to describe alphanumeric and graphic pictures (see Report 802). Some transmission parameters have an effect on the quality of displayed pictures: page resolution (number of rows per page and number of characters per row) in the case of alphamosaic coding of teletext, character cell resolution (number of pixels and lines per cell) in the case of DRCS coding, picture resolution in the case of broadcast audiography, facsimile or teletext. Further, the effects of transmission errors which may effect the codes should also be considered. Thus, measurements of quality and determinations of objective-to-subjective relationships for these parameters are necessary (see also Rep. 956).

Several contributions give details of different aspects of quality assessment for these pictures which are characteristics distinct from those of conventional television pictures. Parameters such as pixel format, character cell resolution, spacings, colours and layout have effects on various quality attributes: legibility, quality, comfort, annoyance, effort of reading, fatigue and aesthetic considerations. Three main aspects are considered here: the viewing conditions, the assessment methods and the assessment context.

1. Viewing conditions

Recommendation 500 defines viewing conditions for television pictures corresponding to low illumination levels in the room. It is likely that alphanumeric and graphic pictures would be viewed also in normal lighting conditions. Thus, a complementary set of viewing conditions is suggested for study: illumination of 500 lux, screen maximum luminance from 70 to 200 cd/m^2, screen contrast ratio from 30 to 50 and a value of 1/4 for the ratio of background luminance (from the walls of the room) to maximum screen luminance. Viewing distance is also discussed (from 4 to 8 times picture height).

2. Assessment methods

A considerable number of studies have been made on typographical aspects. Most of them have used what might be called "performance measures" like detection or recognition thresholds, recognition ratio, speed of reading, etc. Very few have used "subjective measures" which are of a conventional use in television. It is felt that new systems transmitted in television channels should have good performance (for example, percentage of good recognition of letters higher than 95%). Quality scale and impairment scale from Recommendation 500 could thus be used efficiently although studies are needed to establish the way in which these scales can be related to legibility. A comparison with speech quality assessment methods (CCITT) was tried and a 5-grade scale of "effort of reading" is suggested for studies.

The contribution [CCIR, 1978-82] compares results of subjective assessments made using two different 5-grade scales given below:

– excellent legibility	– no reading effort
– good legibility	– attention necessary, but no appreciable reading effort
– fair legibility	– moderate reading effort
– poor legibility	– substantial reading effort
– bad legibility	– very substantial reading effort
(Quality of legibility scale)	(Reading effort scale)

The scale on the left concerns legibility, the one on the right, the reading effort (it was found important to make each wording of grades explicit). The mean values of the scores obtained with the reading effort scale are generally higher than those obtained with the legibility scale and the range actually used by the observers is higher in the case of the reading effort scale.

Another experiment [White, 1980 and White, 1981] used the quality scale described in section 4.1.5.1 of Rec. 500 to assess opinion of both overall quality and overall legibility of typescript transmitted by a television system of variable line standard and bandwidth. For each condition, two models, one of greater complexity and accuracy, but both invoking the concept of "Imp-scale" addition were discovered to describe the combined effects of limited horizontal and vertical definition. Legibility was also measured in terms of proportion of correctly identified characters. However, legibility in such terms remained high when quality was low, and it is evident that, usually, the former criterion is less useful.

Another study [Sallio and Morin, 1981] carried out comparisons of performance and subjective methods on printed text material using fixed-width and variable-width characters. Subjective methods were shown to be the more sensitive. The same type of study was repeated using a cathode-ray tube display, applying this time only subjective methods. The use of these subjective methods produced results concerning the visually optimum sizes of fixed and variable matrices.

At the moment, too few experiments have been made on the subjective quality of alphanumeric and graphic pictures in the television field; it would be very useful if administrations could make contributions on the subject.

3. Assessment context

A recent contribution [CCIR, 1982-86] describes a new approach to service assessment. When user activities in the service under study can be defined accurately, assessments are not made according to the conventional method of presenting images and simply asking viewers for standard subjective assessments (e.g., Recommendation 500). Instead, viewers use the images presented as if they were using the service under study and all evaluations are performed in this context [e.g. Hearty and Treurniet, 1985].

Service-use emulation does not preclude the use of conventional subjective measures. Instead, it establishes a context for subjective evaluations that is more appropriate to the service under study. Moreover, it may permit the use of objective measures of viewer performance and the development of new subjective measures that are particularly appropriate to the service and parameters under study e.g. [Hearty and Treurniet, 1985]. Finally, it establishes a more secure basis for generalizing assessments from the laboratory to the service under study.

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SECTION 11E: PLANNING OF TELEVISION NETWORKS, PROTECTION RATIOS, TELEVISION RECEIVERS AND ANTENNAS

REPORT 481

RATIO OF WANTED-TO-UNWANTED SIGNAL IN TELEVISION

Subjective assessment of multiple co-channel interference

(Question 4/11, Study Programme 4A/11)

(1970)

1. This Report summarizes work in the United Kingdom on the subjective effect of a combination of several co-channel interfering signals of constant, but not necessarily equal, levels. The document does not consider the situation in which the signals vary appreciably with time. It includes consideration of transmissions with very high carrier-frequency stability (precision offset) but not special cases where carrier frequencies might be phase-locked.

The interferences are considered to be in one of two classes, viz., "related" and "unrelated" interferences. The related class only arises in cases involving transmitters with precision control of the carrier frequency, i.e., control with a precision of the order of 1 Hz. The laws proposed for related interferences apply to a group of interferences for which either:

- the frequency offsets relative to the wanted signal are close to ($n \pm 1/3$) times line-frequency, where n is a small integer, but precisely adjusted for minimum visibility of interference;
- the interfering signal frequencies, apart from those covered above, are equal to one another within a few hertz.

For example, two-thirds and five-thirds line-frequency precision offsets can be considered as being in the related class, and it is unimportant whether the offset frequency is above or below the wanted signal. Similarly, all precision zero offset interferences can be regarded as in the related class.

On the other hand, all non-precision offset interferences are to be regarded as unrelated. In the cases where both related and unrelated interferences are present, the related interferences should first be added in accordance with the appropriate law; the two classes can then be added together as if they were single unrelated interfering signals. For the purpose of dealing with co-channel signals with different offsets it is convenient to measure the interfering signals in terms of protected field strength defined below:

If R_r: protection ratio (dB) applicable to the rth interfering signal for a given subjective impairment

and I_r: level (dB(μV/m)) of the rth interfering signal,

then $P_r = R_r + I_r$ is the protected field strength (dB(μV/m)) applicable to the rth interfering signal.

2. Unrelated interferences appear to combine according to a simple power-addition law:

$$0.1\,P = \log_{10} \sum_{r=1}^{r=n} 10^{0.1\,P_r} \tag{1}$$

3. For impairment grades near grade 3.5 (using the scale given in Note 2, Annex I, to Report 405) related interferences tend to follow a different law. From the limited experimental work, it appeared that a (voltage)$^{1.5}$ law represented the method of combination at least as well as any other law. Such a law may be written:

$$0.075\,P = \log_{10} \sum_{r=1}^{r=n} 10^{0.075\,P_r} \tag{2}$$

4. For certain types of calculation it may be easier to use the following law which was equally accurate for the cases covered by the experiments (up to seven interfering signals):

$$0.1\,P = \log_{10}\left[10^{0.1}\,P_1 + 2\sum_{r=2}^{r=n} 10^{0.1}\,P_r\right] \qquad (3)$$

where P_1 is the protected field strength applicable to the largest interfering signal alone.

5. For low interference levels (corresponding to grade 2.5 or less on the six-point impairment scale) there was a trend for all types of interfering signals (related or unrelated) to combine by the simple power-addition law given in § 2.

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REPORT 1214

RADIO-FREQUENCY PROTECTION RATIOS FOR AM VESTIGIAL SIDEBAND TELEVISION SYSTEMS

(Question 4/11)

(1990)

1. Introduction

Studies are still needed to allow completion of the information on protection ratios given in Recommendation 655. Additional data are also required to fully cover protection ratios applicable to digital two-channel sound with television. It is the intention that relevant parts of the Recommendation will be supplemented or completed for the following five important cases:

- digital sound carriers,
- analogue AM/FM sound protection ratios,
- out-of-channel range,
- unwanted vision signal affecting sound,
- synchronized carrier operation.

The protection ratios given in this report are supplementary to those in Recommendation 655. However, some require further study, particularly in relation to different television systems.

2. Digital sound system

2.1 Transmission characteristics

Characteristics relevant to protection ratios are given in Table I. Fuller details are given in Report 795.

TABLE I

Characteristics of digital sound system

Characteristics of digital sound signal	Television system	
	I	B, G
Digital sound carrier frequency relative to vision carrier (MHz)	+6.552	+5.85
Unmodulated power referred to peak vision (dB)	-20	-20
Modulation	QPSK	QPSK
Bit rate (kbit/sec)	728	728
Overall data shaping (% cosine roll-off)	100	40

2.2 Sound protection ratios

Protection ratios applicable to co-frequency sound signals are given in Table II. The figures given for analogue sound are from Recommendation 655. Those for digital sound are based on the results of calculations and laboratory tests carried out in the United Kingdom [CCIR, 1986-90a]. The reference sound quality is grade 3 for tropospheric interference and grade 4 for continuous interference. Bit error ratios of 10^{-4} and 10^{-5} respectively approximate to these two planning limits. More information is required to confirm and complete the table.

TABLE II

Sound carrier protection ratios (dB)

Wanted \ Unwanted		FM/CW	AM	Digital
FM	T	32	36*	
	C	39	43*	
AM	T	40	44*	28
	C	50	54*	38
Digital	T		12	12
	C		13	13

* Values are 4 dB higher than those in the first column (see section 6 of Recommendation 655.)

2.3 Adjacent and overlapping channel protection ratios

2.3.1 Interference from the lower channel adjacent digital sound carrier into the upper vision channel

Tests in the United Kingdom /CCIR, 1986-90a/ have shown that reception of a system I television signal is adequately protected against the effect of a digital sound signal in the lower adjacent channel. Field tests, on cable systems, and laboratory tests in Sweden /CCIR, 1986b, c and d/ for systems B and G indicate that the situation for these systems would be similar to that for system I. However, some studies of receivers, e.g. with LC-type IF filters are needed to finally verify this conclusion for system B.

2.3.2 Interference from the upper adjacent vision signal into the lower digital sound channel

The United Kingdom tests established that, at the normal planning limits, reception of the digital sound signal is not significantly affected by the presence of an upper adjacent system I television signal. The laboratory investigations in Sweden show a similar situation for system G. A situation yet to be fully studied exists for system B, where the investigation of adjacent channel operation in cable networks indicate that any interference will very much depend on the vestigial sideband attenuation at the transmitter.

2.3.3 Overlapping channels in the VHF range

Calculations based on Recommendation 655, and laboratory assessments made on receivers available in Finland [CCIR; 1986-90e] have shown that the introduction of digital sound on system B, at level of -20 dB relative to vision carrier, does not increase interference to D/SECAM provided that the level of the existing FM sound carrier is reduced from -10 dB to -13 dB relative to vision carrier. In fact, the required protection ratio values are about 2 dB lower than for an existing single interfering FM sound carrier at a level of -10 dB relative to vision carrier. Further studies by other administrations are needed.

3. Out-of-channel protection ratios

CCIR Recommendation 655 does not provide complete information about interference to television signals caused by unwanted signals outside the channel. The protection ratios for overlapping channel interference given in section 5 are limited to the range from -1.25 to +6 MHz. In section 3, regarding adjacent-channel interference, only special cases of interference caused by interfering television signals are considered.

The effect of a CW signal on the wanted vision signal (system B/PAL) has been investigated for frequency differences between the unwanted and wanted carriers from -9 MHz to +13 MHz. In these tests 14 domestic receivers manufactured in 1987 in the Federal Republic of Germany were used. [CCIR; 1986-90f]

Figure 1 gives the results of the measurements for the continuous interference case. The circles indicate the measured values for worst case, non-precision offset. The bold lines show the proposed protection ratio when the wanted signal is affected by a CW signal.

The proposed protection ratio values for tropospheric and continuous CW interference are given in Table III.

TABLE III

Out-of-channel protection ratio for CW interference signal

Frequency difference (MHz)	Protection ratio (dB)		
	Continuous	Tropospheric	TV systems
-14.0	-10	-15	B,D,G,H,I,K,K1,L,
-6.0	-10	-15	B,D,G,H,I,K,K1,L,
-2.5	+11	+1	B,D,G,H,I,K,K1,L,
-1.5	+11	+1	B,D,G,H,I,K,K1,L,
-1.25	+40	+32	H,I,K1,L
-1.25	+32	+23	B,D,G,L
+4.8	+53	+45	B,D,G,H,I,K/PAL
+6.2	-2	-12	B,G,H/PAL
+7.3	-2	-12	B,D,G,H,I,K/PAL
+15.0	-2	-12	B,D,G,H,I,K/PAL

Studies [CCIR, 1986-90g] carried out in the Peoples Republic of China gave the out-of-channel protection ratios shown in Table IV The tests concerned FM sound broadcast signal interference to television reception using a D/PAL receiver (without SAW-filters) with the unwanted signal falling in the range above the television channel. The values were based on impairment grade 3 and a wanted television signal level of -25 dBm. From these figures it was decided that for the case of co-siting at same transmitting station, the carrier of the FM broadcasting transmitter should be separated from the upper edge of the wanted television channel more than 3.2 MHz.

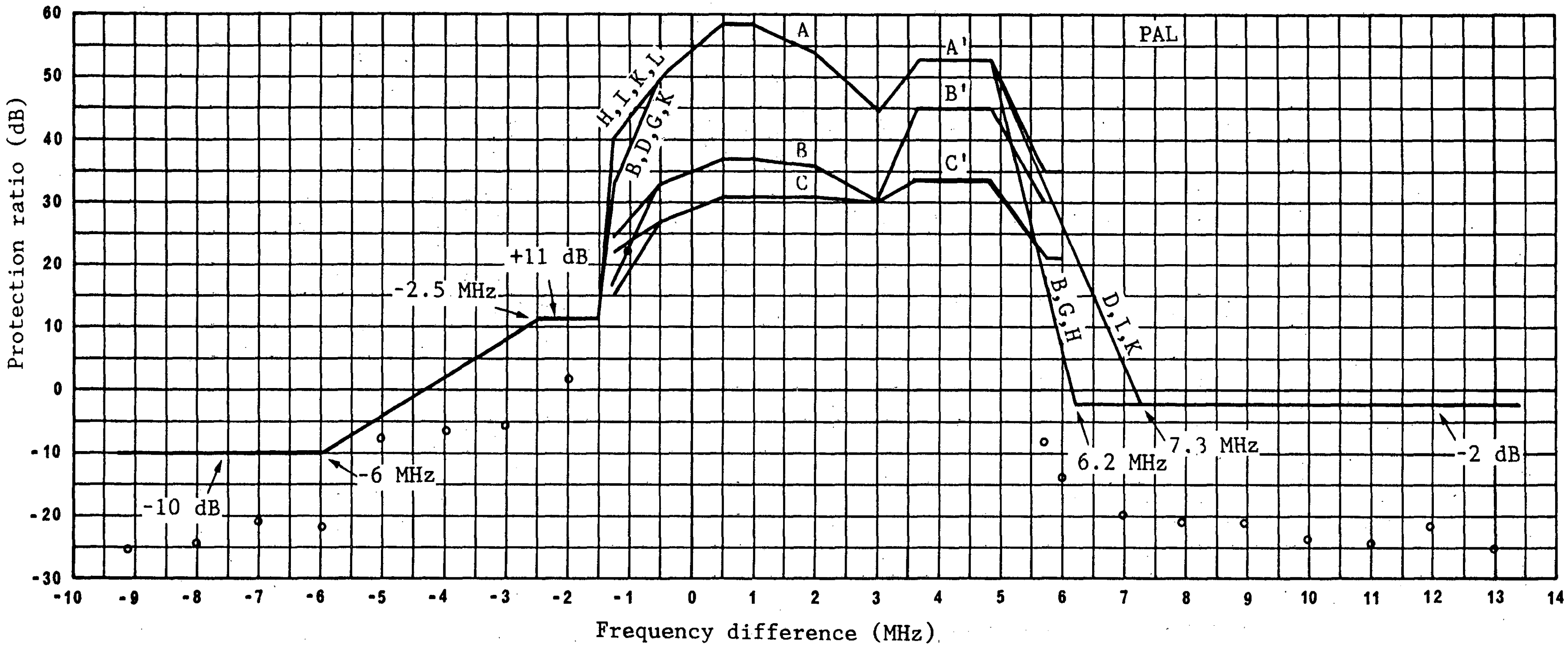

FIGURE 1

Out-of-channel interference from CW signal - Continuous interference

TABLE IV

Out-of-channel protection ratio for D/PAL

Frequency difference to channel edge (MHz)	0	0.6	1.25	2.1	3.0
Protection ratio (dB)	+7	0	-10	+6	-5

Similar measurements have been carried out for system L in France [CCIR; 1986-90h and i]; but these measurements were made with a TV modulated interfering signal and the wanted carrier at 8 MHz multiples (8 MHz channel spacing). These results for system L are given in Table V.

TABLE V

Out-of-channel protection ratio for system L tropospheric, 10 dB vision-to-sound power ratio

Channel	Protection Ratio (dB) (Tropospheric)
N-9 (image)	- 9
N-8 (image)	-26
N-5 (IF spacing)	-13
N-4 (1) (IF spacing)	-6
N-2	-21
N-1	-8
N+1 (2)	-6
N+2	-22
N+4	-27

(1) Affected by non-linearities of the input and mixer stages. The resulting higher protection ratio must be taken into account when planning. For the critical case of IF spacing, a new section should be established in Recommendation 655.

(2) The required protection ratio may be increased if the interfering transmission carries a teletext signal.

Further studies on out-of-channel protection ratios are necessary for a variety of unwanted signals (AM, FM, TV, CW and data) for different television systems in different countries. Interfering signals with modulation can cause greater interference than unmodulated carriers. Substantially lower figures can be obtained with receivers having IF SAW filters.

4. FM - Intercarrier sound reception

Table XI of Recommendation 655 gives values of protection ratio where the television sound is affected by a single unwanted signal within the range ± 250 kHz of the wanted sound carrier. In a co-channel situation the unwanted sound directly affects the wanted sound. In addition, the unwanted vision carrier produces phase modulation of the wanted vision carrier resulting in some sound distortion in receivers using intercarrier demodulation techniques. In many cases, particularly with precision offsets, the required sound protection ratio can be higher than the ratio required between the vision signals. In such instances increasing the frequency offset by a suitable multiple of one, two or three lines frequency will decrease the required sound protection ratio by more than 10 dB, the vision protection ratio remaining unchanged.

Further work is required covering different types of receiver of modern design. To allow comparison of results, the following test conditions should be used:

4.1 Wanted and unwanted television signals

- 10:1 vision-to-sound power ratio
- ± 500 Hz carrier stability

4.2 Modulation of wanted signal

- vision: black level
- sound: no modulation

4.3 Modulation of unwanted signal

- vision: grey level
- sound: coloured noise

4.4 Reference signal-to-noise ratios (S/N) for sound signals

- 40 dB (approximates to impairment grade 3 (T))
- 48 dB (approximates to impairment grade 4 (C))

where S/N is peak-to-peak weighted (Recommendation 468).

Measurements should initially be made to determine if the basic S/N is higher than these figures.

The required measurements are:

a) S/N of wanted sound in absence of unwanted signal;

b) protection ratios for the following frequency offsets between the wanted and unwanted vision carriers: 0, 1/3, 2/3, 4/3, 5/3, 7/3, 8/3, 10/3 and 11/3 of the line frequency.

5. Synchronized carrier operation

Field and laboratory tests carried out in Japan [CCIR; 1986-90j] and have demonstrated that synchronized carrier television systems allow a similar reduction in co-channel interference to that achieved by use of precision offset techniques, when the same television programme is transmitted. Ratios of wanted-to-unwanted signals of 28 dB and 38 dB were respectively found to correspond to impairment grades of 3.5 and 4.5.

Co-channel interference between synchronized carrier transmitters appear as ghost image. During the tests no degradation of picture quality was observed when the frequency difference between both vision carriers was less than 0.2 Hz and/or the phase fluctuation was less than 20 degrees. The use of synchronized carrier techniques simplifies the introduction of new television transmitters and transposers into existing networks.

Some degradation may be observed when phase fluctuation arise, e.g. the swing of the antenna by strong winds. However field tests show that it is technically feasible to keep the phase and frequency difference within the range of 0.2 Hz and 20 degrees. Synchronized carrier television has been operational in Japan since 1987. Further studies in this field are required, especially for the case of different television programmes.

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[1986-90]: a. 11/42 (United Kingdom); b. 11/47 (Sweden); c. 11/53 (Sweden); d. 11/45 (Sweden); e. 11/415 (Finland); f. 11/619 (IWP 11/5); g. 11/131 (People's Republic of China); h. 11/464 (France); i. 11/465 (France); j. 11/424 (Japan).

REPORT 478-2

GHOST IMAGES IN TELEVISION

(Question 6/11, Study Programme 6A/11)

(1970-1986-1990)

1. Secondary radiation from masts in the neighbourhood of transmitting antennas

When a television radiator is sited too close to another antenna structure "ghost" images displaced from the wanted picture can occur over a large proportion of the service area due to re-radiation of the transmissions from the other mast. These "ghosts" can be termed "permanent ghosts" since they cannot generally be reduced by the use of receiving antenna directivity except in the vicinity of the transmitting station. In this way, they are distinguished from "local ghosts" which may be seen only by viewers situated close to large re-radiating structures and which can sometimes be reduced by suitable orientation of a directional receiving antenna.

It has been suggested that under good viewing conditions, "ghost images" will produce negligible impairment for a ratio of 32 dB or more between the direct and re-radiated signals. This figure applies where the time separation is 2 μs or more and may be less for smaller time separations [CCIR, 1966-69; Mertz, 1953].

It has been established, as the result of theoretical studies and experimental work [Allnatt and Prosser, 1965; Hill, 1964] that, where the reflecting structure is at least as high as the antenna, the level of the re-radiated signals decreases at a rate of about 3 dB for each doubling of the distance separating the masts. In Bands I and III, this variation can be appreciably modified by ground reflection, which can increase or reduce it by as much as 6 dB.

Table I gives the distances in kilometres at which the ratio between the direct and re-radiated signals is 32 dB neglecting the effect of ground reflection for different frequencies and different types of mast. It is assumed that the reflecting mast is at least 60 m higher than the transmitting antenna.

TABLE I

Frequency (MHz)	50		200		800	
Polarization	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
Cylindrical mast, 3 m diameter	1.4	1.4	1.2	1.2	1.2	1.2
Triangular lattice mast, 3 m side, least favourable orientation	1.5	2.4	1.5	0.9	2.4	2.4
Square lattice mast, 2.5 m side, least favourable orientation	2.4	2.4	2.9	1.2	1.7	1.7

The ratio of the direct and reflected signals is modified by the horizontal radiation pattern of the transmitting antenna.

2. Effects of multipath propagation

Experiments have been carried out in India [CCIR, 1982-86a] to determine the protection ratio requirements appropriate to television pictures with positive "ghost" images delayed by 0.4, 0.8 and 1.4 μs. The results in terms of mid-opinion assessments are summarized in Table II. In each case the 90% opinion values are about 4 dB higher.

TABLE II

Impairment grade (Rec. 500)	Protection ratio (dB) for delay:		
	0.4 μs	0.8 μs	1.4 μs
5	18	26	30
4	12	18	20

It was found that the results for colour and monochrome hardly differed. Likewise, use of moving or still pictures had little effect on the assessments.

3. Ghost prediction methods

A mathematical method for prediction of ghost delay and ghost amplitude has been developed in Canada [CCIR, 1982-86b]. This method relates primarily to the VHF bands. However, an appropriate correction is proposed for the UHF bands.

The method also includes a prediction of resulting picture quality according to the CCIR 5-grade scale used in Recommendation 500 based upon subjective measurements made in Canada of signals having varying amounts of ghost time delay and amplitude. However, some of these quality predictions do not correlate well with those given in Report 960 and further study is desirable. The conditions under which the Canadian subjective tests were made are not defined and care should be taken in interpreting the results of such test programmes.

4. Ghost cancelling

An enhanced quality television system introduced in Japan uses a ghost rejection technique based on the transmission of a reference signal inserted into a line in each field blanking interval [CCIR, 1986-90]. If television receivers are equipped with automatic waveform equalizers then, by utilizing the reference signal, it is possible to significantly reduce ghost impairments arising from advanced or delayed multiple echos within a time range of 45 μs.

REFERENCES

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HILL, P. J. [December, 1964] Measurements of re-radiation from lattice masts at VHF. *Proc. IEE*, Vol. 111, 12, 1957-1968.

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REPORT 1084

PROTECTION RATIOS FOR DIGITAL DATA SIGNALS MULTIPLEXED WITH TELEVISION SIGNALS

(1986)

1. Introduction

Recommendation 655 does not specify the protection ratios applicable when the wanted signal is a digital data signal multiplexed with the television signal.

This Report describes an interference criterion suitable for a signal of this type, and calculates protection ratios for an interfering emission in one of the channels adjacent to the wanted channel, in the image channel, or in an overlapping channel.

2. Interference criterion

For digital data reception, neither the 5-grade scale in Recommendation 500 nor the 4-grade teletext picture impairment criteria proposed in Part II of Report 956 can be used to assess the effect of interference, since a reduction of only a few decibels in the wanted-to-unwanted signal ratio will reduce quality from the maximum to the minimum grade. A given wanted-to-unwanted signal ratio in a geographical area characterizes the percentage of users in this area who lose reception. The interference criterion must thus be related to the bit error ratio (BER) and its geographical distribution.

It may be considered that a BER of less than 10^{-4} (1 error for about a page of teletext system A) permits satisfactory reception, and that impairment due to an interfering emission is equivalent to a given increase in the noise level at the RF input of the television receiver. The interference criterion is determined by the choice of the equivalent increase in noise level (or noise back-off).

As an illustration, the curves in Fig. 1 portray the results of previous statistical studies [Blineau *et al.*, 1980] and show the geographical distribution of BER for a teletext system A signal in the following two cases:

– A : mountainous region, TV receiver with envelope detection, good quality teletext receiver;

– B : urban region, TV receiver with quasi-synchronous detection, good quality teletext receiver.

The increase in BER equivalent to a noise back-off of 1 dB and 3 dB has been indicated on the curves for both measurement conditions.

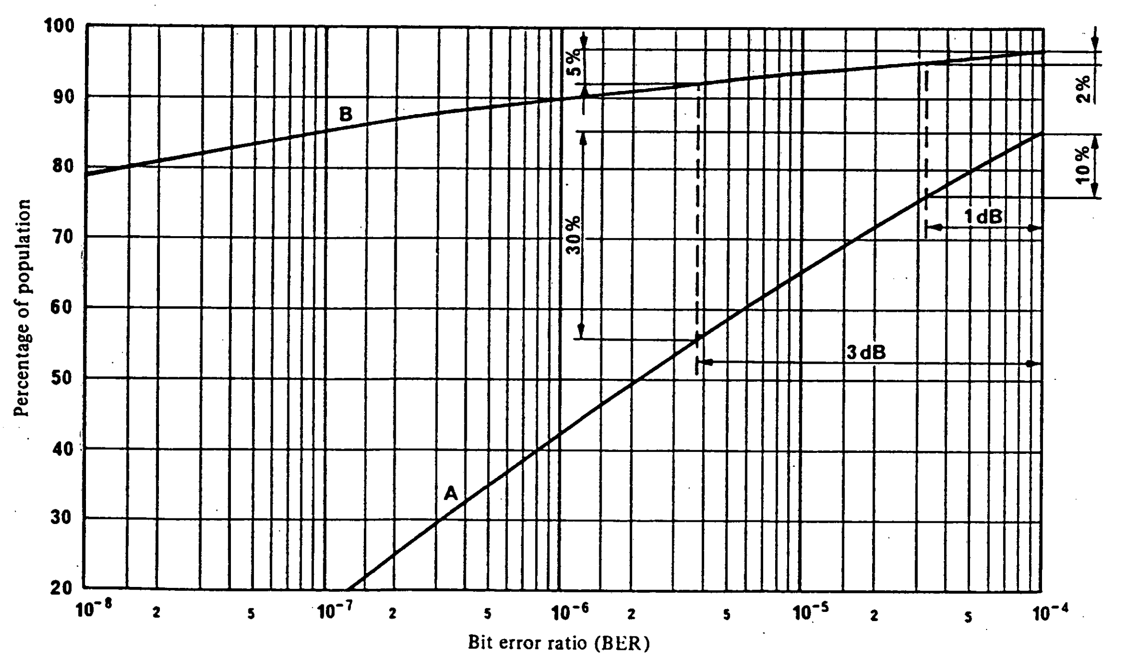

FIGURE 1 – *Bit error ratio distribution: percentage of the population enjoying BER below a specified value*

From a first approximation, it appears that a 1 dB noise back-off causes a loss of reception for 2% to 10% of users, whereas a 3 dB noise back-off causes a loss of reception for 5% to 30% of users, depending on the area and the television receiver performances.

Two interference criteria were thus considered: a stringent criterion (noise back-off = 1 dB) applicable particularly in areas where reception is difficult, and a less stringent criterion (noise back-off = 3 dB) applicable in areas with easy reception.

Note. – No distinction need be made between tropospheric and continuous interference. The ratio between the level of an interfering signal tolerable for 1% to 10% of the time (BER probably between 10^{-3} and 10^{-4}) and that of an interfering signal tolerable for 50% of the time (BER probably less than 10^{-5}) is only 2 to 3 dB.

3. Protection ratios for digital data signals

The protection ratio values which appear in this section are based on the method outlined in § 2 and relate to teletext system A signals multiplexed with an L/SECAM standard television signal. Further studies are necessary for other types of signal.

The values in question are given in Table I (where the interfering emission is an L standard emission and Fig. 2 (where the interfering emission is a continuous wave (Curve A′), an L standard TV emission (Curve B′) or a full frame teletext signal (Curve C′)). They relate to a stringent interference criterion (noise back-off = 1 dB). A less stringent interference criterion (noise back-off = 3 dB) produces values about 5 dB lower.

TABLE I

Position of the interfering emission	Image channel	Lower adjacent channel	Upper adjacent channel
Protection ratio for data signals (dB)	−22	−17	−16

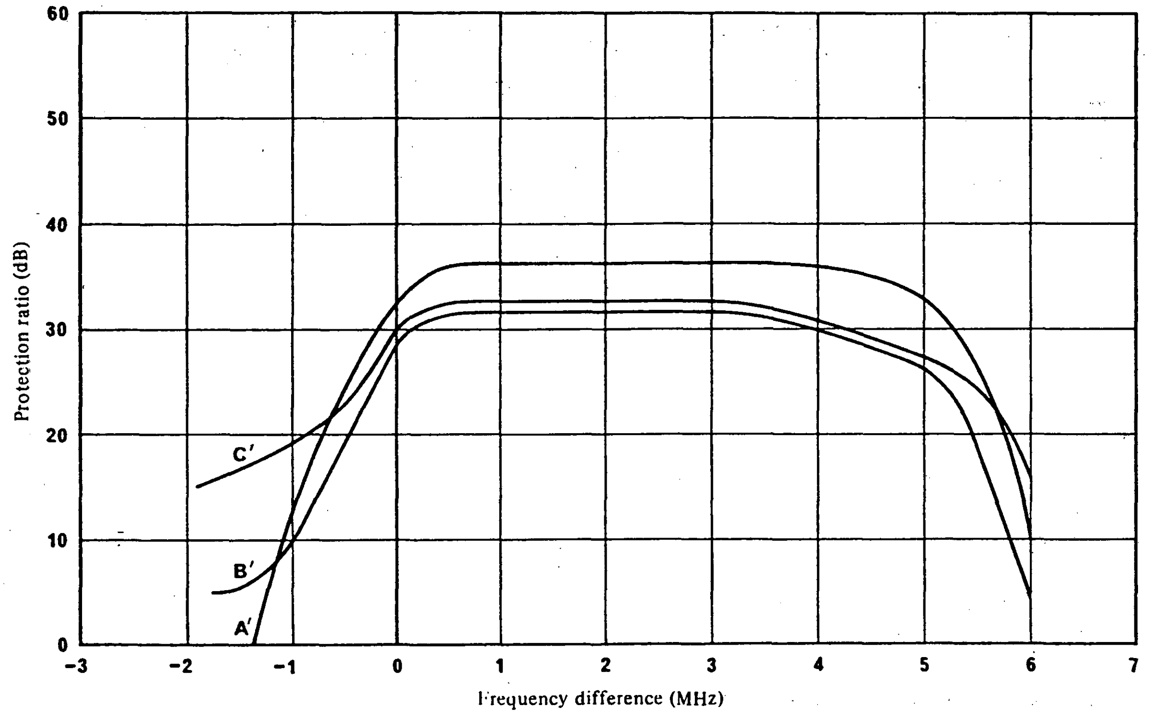

FIGURE 2 – *Protection ratios for teletext system A signals*

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REPORT 625-4

CHARACTERISTICS OF TELEVISION RECEIVERS AND RECEIVING ANTENNAS ESSENTIAL FOR FREQUENCY PLANNING

(Question 26/11, Study Programme 26A/11)

(1974-1978-1982-1986-1990)

1. Introduction

Many characteristics of television receivers may be defined, together with methods of measurement and practical values. Question 26/11 and Study Programme 26A/11 call for the study of the principal characteristics which may be required for frequency planning.

These characteristics are tabulated in § 4 of this Report in which it is suggested that the most recent mean numerical values should be collected.

The quality of the picture displayed and of the sound heard depends on characteristics of the complete television system from the studio to the receiver screen or loud-speaker, and in this context the main parameters of a television receiver, other than those primarily involved in frequency planning, may be of interest. The CCIR has collected a great deal of data which is embodied in various Recommendations and Reports, but much of this has been rendered obsolete by the development of receiver design techniques.

The definition of these characteristics, the measuring method applied and the presentation of the results in Tables I, V, VI and VII should be taken, where available, from IEC Publications 107-1, 107-2, 597-2 and 597-4.

It is important that CCIR definitions of receiver performance characteristics should not contradict those of the IEC. If this occurs, action should be taken by both organizations to resolve the difference.

Attention is drawn to the importance of effective participation by CCIR representatives in IEC work, especially in the field of definitions and methods of measurement of television receiver characteristics (Sub-Committee 12A). This information is important for planning and for achieving satisfactory quality targets in an overall television system, from picture source up to and including the receiver.

Apart from these characteristics, those relating to interference caused by television receivers should conform to the relevant CISPR recommendations.

2. Categories of receivers

2.1 An overall appraisal of picture quality should take into consideration the category of receivers which will be used in the broadcasting system envisaged.

It is proposed that data recorded in future for this Report should relate only to the mean values of characteristics for receivers that are typical of good, current engineering practice in the country in question. This is to avoid undue influence being exerted on future planning standards by receiver designs at the extreme upper and lower ends of the performance range.

Reference receivers can be defined taking into account the mean values and possible appropriate amendments to them (Report 805).

2.2 *Receivers for direct broadcasting from satellites*

The results of the many studies on characteristics of the receivers for broadcasting from satellites may be found in Report 473.

3. Receiving antennas

The numerical values of antennas characteristics contained in Recommendation 419 and Reports 122 and 482 relate to antennas *in situ*. Only data relating to the directivity, forward gain and cross-polarization protection of antennas tested under idealized conditions in a suitable site need be recorded.

The necessary definitions and measuring methods are contained in IEC Publications 597-1 and 597-2.

4. Principal characteristics required for planning

4.1 *List of characteristics*

TABLE I

Item	Characteristic	Publication IEC 107-1			Remarks
		Definition	Measuring Method	Presentation of results	
1	Noise-limited sensitivity	Clause 105 and Clause 109	Clause 110	For a peak-to-peak luminance signal-to-non-weighted noise ratio of 30 dB	The most unfavourable value for each of the broadcasting bands
2	Protection ratios	See § 4.3 of this Report			
3	Rejection of adjacent picture carrier	Clause 136	Clause 137	Clause 138	The most unfavourable value for each of the broadcasting bands
4	Rejection of adjacent sound carrier	Clause 136	Clause 137	Clause 138	
5	Image-frequency rejection	Clause 146	Clause 147	Clause 138	
6	Intermediate-frequency rejection	Clause 144	Clause 145	Clause 138	
7	Oscillator position	High or low			
8	Tuning tolerance	Clause 47	Clause 48	Clause 51	As a function of time
9	Receiver radiation	As specified in CISPR Recommendation No. 24/2			
10	Susceptibility of receiver to external interference	Under study			Interference not entering by the antenna
11	Intermediate-frequency values	See Table II			For the determination of the value of the intermediate frequency, see the example given in Doc. 44 of the African Broadcasting Conference, Geneva, 1963

4.2 *Examples of intermediate frequencies for television receivers*

TABLE II

No. of lines in system	Country	System (5)	Channel limits at intermediate frequency (MHz)	Intermediate frequency (MHz) (6)	
				Sound-channel	Video-channel
525	USA	M	41 to 47 (1)	41.25	45.75
525	Japan	M	54 to 60 (2) (4)	54.25	58.75
625	Spain, Norway, Netherlands, Federal Republic of Germany, Sweden, Switzerland, Italy, Yugoslavia	B, G	33.15 to 40.15	33.40	38.90
	USSR and some OIRT countries	D, K	31.25 to 39.25	31.50	38.00
	People's Republic of China	D			
	France	L	31.00 to 39.50	39.20 (3)	32.70 (3)
	UK	I	33.25 to 41.25	33.50	39.50
	African countries	K1	33.45 to 41.45 33.15 to 40.15 31.00 to 39.50	33.70 33.40 39.20	40.20 39.90 32.70

(1) According to Electronic Industries Association Standard Recommendation No. 109 C.

(2) Protected bands.

(3) According to Recommendation No. 103 of the Syndicat des Constructeurs d'appareils radiorécepteurs et téléviseurs (SCART). In Band I, a double transposition is used.

(4) Television receivers, all channels (VHF and UHF).

(5) See Annex I of Report 624.

(6) The usual position of the local oscillator is high. In those cases where it is low, the vision intermediate frequency is below the sound intermediate frequency.

The multiplicity of values of the intermediate frequency is a cause of increased cost of receivers, particularly those suitable for frontier regions where countries use standards with different radio frequencies.

Reception of television programmes with different standards may require as many as five pairs of values of the intermediate frequency involving the same number of multi-standard receiver types.

4.3 *Radio-frequency protection ratios* (see item 2, Table I)

Protection ratio as a parameter for frequency planning is defined as the ratio of wanted to unwanted signal levels at the receiver input, required to produce a specified grade of picture (or sound) impairment. Protection ratio cannot, in general, be obtained from objective measurements made of the parameters normally used to define receiver performance, for example, selectivity, overload, etc., but can be obtained by subjective tests made in accordance with Recommendation 500. The value will depend, among other things, on the nature of the wanted signal (monochrome, PAL, SECAM, etc.), on the type of unwanted signal (television, sound, pure CW, etc.) and on the frequency separation. The tests should be made on the types of interference described in Recommendation 655, except for co-channel interference.

The information should be presented in the form of graphs and/or numerical values showing the protection ratio observed for interference assessed as a Grade 4 impairment "Perceptible but not annoying" (Recommendation 500), as a function of frequency separation between the wanted and unwanted signals for each type of unwanted signal. Any dependence of the protection ratio on the wanted signal level should be indicated (owing to the non-linearity of the input stages). The graphs should cover frequency separation from zero to 1 or 2 channel widths above and below the wanted signal frequencies.

For frequency planning purposes the protection ratio figures so obtained are modified to take account of the grade of impairment that can be tolerated, bearing in mind the percentage of time the impairment will be suffered. For this purpose additional observations for more than one grade of impairment are valuable.

Protection ratios for image channel interference are also relevant to some aspects of international frequency planning and should be noted.

Protection ratios appropriate to the out-of-channel response of the receivers can be determined by direct subjective comparison with the in-channel response [Price, 1981].

4.4 Reference receiver characteristics

In order to obtain the protection ratios given in Recommendation 655, the minimum field strength values given in Recommendation 417, and meet the planning constraints given in Report 1086, the values given in Table III for reference receivers for different transmission systems should be met.

As receiver technology is improving rapidly, administrations are invited to study any improvement of the planning parameters which can result from improved receiver characteristics.

TABLE III

Reference receiver characteristics

Item	Characteristics	Related CCIR texts	Systems							
			B, G		L		D/PAL		I	
			VHF	UHF	VHF	UHF	VHF	UHF	VHF	UHF
1.	Noise-limited sensitivity (dBm)	Rec. 417	-61	-58	-61	-58	-61	-58	-61	-58
2.	Rejection of adjacent picture carrier (dB)(1)	Rec. 655	40	40	40	40	40	40	40	40
3.	Rejection of adjacent sound carrier (dB)(1)	Rec. 655	40	40	45	45	30	30	43	43
4.	Image frequency rejection (dB)	Rec. 655		40		40	45	40		50
5.	Intermediate frequency rejection (dB)	Rep. 1086	35	50	30	50	45	40	35	50
6.	Oscillator position	Rep. 1086	HIGH	HIGH	LOW(4)	LOW	HIGH	HIGH	HIGH	HIGH
7.	Receiver local oscillator level (dBm)(2) - Fundamental - Harmonics	Rep. 1086	-49(5) -57(5)	-43(5)	-63 -63	-55			-49(5) -57(5)	-43(5)
8.	Maximum input level (dBm) limited by transmodulation and intermodulation distortion(3)	Rec. 655 Rep. 805	-10	-10	-10	-10	-8.8	-8.8	-10	10

(1) An input level to the receiver of about 3 mV has been assumed.

(2) At antenna connector.

(3) Limiting values of: -30 dB, vision into sound, and
-40 dB, sound into vision

have been assumed (see IEC Publication 107-1).

(4) HIGH in Band I.

(5) These values are recommended by CISPR (Publication 13) and can be improved. For example, in relevant texts of CENELEC, -63 dBm is a common limit value for fundamental and harmonic levels in both the VHF and UHF bands; though a value of -55 dBm will apply to UHF fundamental levels until 1 January 1992. In Germany (Federal Republic of), the recommended value is -65 dBm in the VHF and UHF bands for both fundamental and harmonics.

The values given in Table III for noise-limited sensitivity are consistent with the minimum field-strength values given in Recommendation 417. Values for antenna gain and cable loss are given in Table IV.

TABLE IV

	Band I	Band III	Band IV	Band V
Minimum field-strength, dB (μV/m)	47	53	62(2)	67(2)
Antenna gain, dB	3.5	7.5	10	12
Cable loss, dB	1	1.5	3	4.5
Dipole conversion factor(1), dB	2	13	20.5	25

(1) 20 log $2\pi/\lambda$.

(2) The values shown should be increased by 2 dB for the 625-line (OIRT) system.

If receivers with a better noise performance, low noise pre-amplifiers or higher gain antennas are used, the minimum field-strength values could be considerably lower, as is indicated in Report 409.

5. Results

5.1 The numerical values listed in Tables V and VII are mean values taken from an extensive series of objective measurements, carried out in accordance with IEC Publications 107 and 138. Administrations are requested to review the numerical values listed in Tables V and VII to determine if those values are valid when performing measurements in accordance with the new versions, Publications 107-1 and 597-2. Administrations are encouraged to perform whatever measurements may be necessary to have those values up-dated accordingly.

The following tables are an example of how the numerical values of characteristics may be presented.

5.2 *Principal characteristics*

TABLE V

Item	Characteristic	Country					
		Italy	United Kingdom (1)				
1	Noise-limited sensitivity (dBm) Broadcasting band I III IV/V 12 GHz	(2) (3) −60 −60 −55	 −65				
2	Protection ratio (dB) Broadcasting band I III IV/V 12 GHz	See Rec. 655					
3	Rejection of adjacent picture carrier (dB) Broadcasting band I III IV/V 12 GHz	(4) −40 −40 −40	 −56				
4	Rejection of adjacent sound carrier (dB) Broadcasting band I III IV/V 12 GHz	(4) −40 −40 −40	 −43				
5	Image frequency rejection (dB) Broadcasting band I III IV/V 12 GHz	(5) −50 −50 −44	 −51				
6	Intermediate frequency rejection (dB) Broadcasting band I III IV/V 12 GHz	(6) −40 −50 −50	 −47				
7	Oscillator position Broadcasting band I III IV/V 12 GHz	High	High				

See notes at the end of Table V.

TABLE V *(continued)*

Item	Characteristic	Country					
		Italy	United Kingdom (1)				
8	Tuning tolerance (kHz) Broadcasting band I III IV/V 12 GHz	± 350 ± 350 (7) ± 350	± 50 (8)				
9	Receiver radiation Broadcasting band I III IV/V 12 GHz	(9)	(9)				
10	Susceptibility of receiver to external interference Broadcasting band I III IV/V 12 GHz						
11	Intermediate frequency values Broadcasting band I III IV/V 12 GHz	See Table I (Item 11)	(See Table I)				

(1) The following characteristics relate to System I colour television receivers [CCIR, 1974-78].

(2) For a luminance signal-to-unweighted noise ratio of 30 dB and a normalized output level.

(3) IEC Publication 107, Clause 3.3.2.

(4) IEC Publication 107, Clause 4.2.

(5) IEC Publication 107, Clause 4.5.2.

(6) IEC Publication 107, Clause 4.4.2.

(7) The tuning tolerance must be reduced to ± 50 kHz if the television set is provided with a teletext decoder. This tuning tolerance is achievable using an automatic frequency control or a frequency synthesizer.

(8) With automatic frequency control.

(9) See CISPR Recommendation No. 24/3 (1970).

Note. – In the future, measurements should be carried out in accordance with the revised version i.e. IEC Publication 107-1. The new references in the footnotes will be as follows:

(3) IEC Publication 107-1, Clause 110.

(4) IEC Publication 107-1, Clause 137.

(5) IEC Publication 107-1, Clause 147.

(6) IEC Publication 107-1, Clause 145.

6. Data relating to the receiving station

This section gives data on typical television antennas.

6.1 *Antenna characteristics*

For each of the channels to be received, the antenna characteristics to be considered are given in Table VI, which contains references to the relevant publications of the IEC.

TABLE VI

Characteristic	Definition	Measuring method (IEC Publication 597-2)	Remarks
Number of elements	See Note 1		
Impedance (ohms)	IEC Publication 597-1		– –
Gain in the nominal band (dB)	IEC Publication 597-1	Clauses 3.2 and 5.1	In relation to a half-wave dipole
Passband (MHz)	Derived from the above characteristic Tolerance on each usable channel ± 2 dB		
Directivity pattern	IEC Publication 597-1	Clause 3.3	
Angle of aperture (degrees)	Measured on the main lobe of the directivity pattern, with a 3 dB attenuation in relation to the maximum		
Attenuation of the back lobe in relation to the main lobe	Measured on the directivity pattern (dB)		
Cross polarization attenuation (dB)	Measured as in Note 2 with a linearly polarized emission		

Note 1. – For a Yagi-type antenna, the radiating elements are conductors designed to be excited by the wanted transmission.

The following may be distinguished:
- the driven element which supplies the wanted radio-frequency power through its two output terminals;
- the directors which are situated between the main radiator and the transmitter to be received;
- the reflectors which are situated behind the main radiator.

Other types of antenna may include plane or corner conductor systems. In that case, they will be described briefly.

Note 2. – The cross polarization attenuation is still under consideration by the IEC. Until the IEC fills this gap, the measuring arrangement for the directivity pattern or gain should be used, and the attenuation obtained should be measured by turning the relative polarization through 90°, between the emission and the antenna.

Note 3. – For each channel which can be received, the gain should be expressed in relation to a half-wave dipole.

6.2 *Results*

Typical values for the characteristics listed in Table VI are shown in Table VII.

TABLE VII

Characteristic		Country									
		France									
Number of elements											
Broadcasting band	I	2	4								
	III	3	10								
	IV/V	8	22								
Impedance [1] (Ω)											
Broadcasting band	I	75	300								
	III	75	300								
	IV/V	75	75								
Gain in the nominal band (dB)											
Broadcasting band	I	4 [3]	8 [3]								
	III	5	12								
	IV/V	10	16								
Passband (MHz)											
Broadcasting band	I	11	8								
	III	15	15								
	IV/V	80	80								
Angle of aperture											
Broadcasting band	I	59 [3]	52 [3]								
	III	58	36								
	IV/V	46	26								
Back lobe attenuation (dB)											
Broadcasting band	I	10	16								
	III	>20	32								
	IV/V	>20	>22								
Cross polarization attenuation (dB) [2]											
Broadcasting band	I	15	20								
	III	20	>20								
	IV/V	>20	>20								

(1) The 300 Ω nominal values are reduced to the nominal value of the antenna system used.

(2) As indicated Note (2) to Table VI, further studies are still required on this subject. However, protection against a linearly polarized wave, whose polarization plane is perpendicular to that of the antenna, should be greater than 20 dB. This limit only applies to reception in the main lobe of the antenna.

(3) In band I (lower part of band 8), the very high value of the ratio $\Delta f/f$ makes typical values measured at the picture-carrier frequencies more significant.

REFERENCES

PRICE, H. M. [1981] Measurements of the out-of-channel response of domestic television receivers. *EBU Rev. Tech.*, **188**, 176-180.

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[1970-74]: 11/260 (United Kingdom); 11/267 (United Kingdom); 11/346 (France); 11/328 (Italy).

[1982-86]: 11/409 (Italy).

REPORT 482-1

RECOMMENDED CHARACTERISTICS FOR COLLECTIVE AND INDIVIDUAL ANTENNA SYSTEMS FOR DOMESTIC RECEPTION OF SIGNALS FROM TERRESTRIAL TRANSMITTERS

(Question 7/11)

(1970–1986)

1. Scope

Installations may be classified according to the number of users served. An individual antenna serves one user, even though it may be associated with several receivers. A collective antenna serves all or part of a building and hence a larger number of users.

This Report applies to antenna systems for individual or collective use designed to receive television broadcasts in bands 8 (VHF) and 9 (UHF) and also to the associated equipment of such systems: the transmission line, amplifiers, couplers, etc., used to convey the signal to the television receivers, taking into account the transmission of data signals (e.g. teletext) in the structure of the television waveform.

– It does not apply to television antennas for cabled distribution systems.

– Reference is made to IEC Publication No. 728-1 (1986).

– The relevant figures identified by "*" are based on investigations carried out in Italy [CCIR, 1982-86a, b].

2. General input requirements

The received input signals lie in those parts of band 8 (VHF) and band 9 (UHF) allocated to terrestrial broadcasting and used for television.

The field strength of the wanted signal should be sufficient to be protected against interference.

3. Receiving system configuration

3.1 *Individual reception*

The receiving system consists of the antenna, the connecting cable and the television receiver.

3.2 *Collective reception*

The receiving system consists of the antenna (or a group of antennas), the head-end amplifiers, converters, filters, etc.), the distribution network and the television receivers.

4. Antenna characteristics

4.1	In unbalanced systems, the nominal impedance should be	75 Ω
	In balanced systems, the nominal impedance should be	300 Ω
4.2	Reflection coefficient:	
	television signals only:	< 0.33
	television and data signals:	< 0.2*

4.3 Gain: should be expressed relative to that of a half-wave dipole for each of the channels to be received.

4.4 Gain variation within a channel: ± 0.5 dB*

4.5 Front-to-back ratio: > 18 dB

4.6 Protection against a linearly polarized wave whose polarization plane is perpendicular to that of the antenna (reception in the main lobe): > 20 dB

4.7 Directivity characteristics: see Recommendation 419.

5. Coaxial cable characteristics

5.1 Nominal impedance: 75 Ω

6. Performance requirements of the receiving systems

6.1 Vision carrier levels

6.1.1 The vision carrier levels at system outlets (measured across a 75 Ω termination or referred to 75 Ω) for each channel should not exceed the following values:

	Minimum	*Maximum*
Band 8 (VHF) television	0.7 mV (−52 dBm)	14 mV (−26 dBm)
Band 9 (UHF) television	1.0 mV (−49 dBm)	14 mV (−26 dBm)

Where several adjacent channels are distributed, the maximum carrier levels at the RF input socket of the television receiver should be at a reduced level in order to avoid intermodulation in the television receiver itself [CCIR, 1982-86b].

6.1.2 The maximum carrier-level differences between distributed television channels at system outlets should not exceed 12 dB in band 8 (VHF) and not exceed 15 dB for a system covering both bands 8 (VHF) and 9 (UHF). The maximum level difference between adjacent channels should not exceed 3 dB.

6.2 *Mutual isolation between system outlets*

The isolation between two different outlets must be at least 22 dB for all the frequencies in the broadcasting bands. This value assumes that the frequency allocation and the intermediate frequency of the receivers have been planned to avoid interference.

Note 1. – This value is raised to 46 dB between an outlet for television signals in bands 8 and 9 and an outlet for frequency modulation sound broadcasting signals with two different users. The selection circuits required form an integral part of the installation.

Note 2. – The minimum isolation figure of 22 dB is under study; a higher value is a requirement in some countries.

6.3 *Response variations with frequency within a television channel at any system outlet*

6.3.1 *Amplitude response*

The variation of the amplitude response over any television channel should not be more than ± 2 dB relative to that at the vision carrier frequency, and the slope of the variation should not be more than 0.5 dB within any frequency range of 0.5 MHz.

6.3.2 *Group-delay response*

The group-delay variation within any television channel must not be more than 50 ns*.

This value is relaxed to 100 ns* if the television channels do not carry any data signal.

6.4 *Reflection coefficient*

In order to meet the above requirements for amplitude and delay response, the reflection coefficient of the passive and active equipment used in the receiving system should not exceed the following values:

	Television only	*Television and data* *
Passive equipment	≤ 0.33	≤ 0.2
Couplers and filters	≤ 0.33	≤ 0.2
Active equipment	≤ 0.33	≤ 0.2

6.5 *Oscillators and other equipment used in the system*

The levels of the energy radiated and the energy re-injected into the distribution system should be less than the values which may be specified by the CISPR.

The total frequency drift of the oscillators should not exceed the value of ± 50 kHz* (relaxed to ± 75 kHz if the television channels do not carry data signals) for variations in the supply voltage of ± 10% and a temperature range of −10 °C to +55 °C. This value applies to both band 8 (VHF) and band 9 (UHF).

6.6 *Carrier-to-noise ratio*

The carrier-to-noise ratio at any point from the head-end input to the system outlets shall not be less than the values given in Table I, where the noise bandwidth is also indicated.

TABLE I

System	Minimum carrier-to-noise ratio (dB)	Noise bandwidth (MHz)
625-line system I	43	5.08
B, C, G and H	43	4.75
L and K1	43	5.58
D and K	43	5.75
525-line system M	42	3.33

6.7 *Intermodulation*

6.7.1 *Channel amplifiers or converters*

When measured by the method described in IEC Publication No. 728-1, the ratio of the reference level relative to the interference signal shall not be less than 54 dB.

6.8 *Interference*

The installation should cause neither interference at fixed frequencies nor cross-modulation products (between signals from different transmitters) which, assuming they are referred to the receiver input, would interfere with reception from the wanted transmitters, in the service area as defined by the protected field.

6.9 *Reception of data signals in the collective antenna systems*

The introduction of teletext and other data services (see Report 802) requires that the technical characteristics of the receiving installations ensure satisfactory reception quality for both television and data services.

Theoretical and experimental investigations carried out in Italy [Cominetti and Stroppiana, 1984] have shown that, because of the different nature of the two signals (analogue and digital), the potential audience can be different for the two services particularly in the case of reception through collective antenna systems. Teletext reception in such installations poses special problems mainly caused by the many potential sources of impairments, such as channel converters, amplifiers, filters, coaxial cables and other passive components used to distribute the signals to the user's outlet.

Further investigations are necessary to ensure comparable performance regarding reception of television and data services.

REFERENCES

COMINETTI, M. and STROPPIANA, M. [1984] Ricezione Teletext negli impianti centralizzati d'antenna. *Elettronica e Telecomunicazioni*, 2.

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[1966-69]: XI/6 (United Kingdom); XI/25 (Canada); XI/165 (France); XI/169 (Spain); XI/184 (Italy).

REPORT 805-1

SUBJECTIVE QUALITY TARGETS OF OVERALL TELEVISION SYSTEMS *

Characteristics of reference receiving installations

(Question 14/11, Study Programme 14B/11)

(1978-1982)

1. Introduction

Many characteristics of television receivers may be defined together with methods of measurement and practical values. Question 14/11 and Study Programme 14B/11 call for the study of the principal characteristics of television receiving installations which may be required in meeting the necessary subjective quality targets for an overall television system.

The quality of the picture displayed and of the sound heard depends on characteristics of the complete television system from the studio to the receiver screen or loud-speaker, and in this context the main parameters of a television receiver, other than those primarily involved in frequency planning, may be of interest. The CCIR has collected a great deal of data which is embodied in various Recommendations and Reports, but much of this has been rendered obsolete by the development of receiver design techniques.

Table I of § 4 of this Report lists technical parameters which contribute to the determination of overall picture quality. Table II of § 5 gives typical measured values by way of example.

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* Information on specifications for low-cost monochrome television receivers is to be found in Report 483.
Information on the characteristics of television receivers and receiving antennas is to be found in Report 625.

The definition of these characteristics, the measuring method applied and the presentation of the results in Table I should be taken, where available, from IEC Publication 107-1 and 107-2 .

It is important that CCIR definitions of receiver performance characteristics should not contradict those of the IEC. Where this occurs, action should be taken by both organizations to resolve the difference.

Attention is drawn to the importance of effective participation by the CCIR representatives in IEC work, especially in the field of definitions and methods of measurement of television receiver characteristics (Sub-Committee 12A). This information is important for planning and for achieving satisfactory quality targets in an overall television system, from picture source to receiver.

Table I relates only to monochrome receivers. The characteristics of colour receivers will be added at a later stage.

2. Categories of receivers

2.1 Overall picture quality should take into consideration the category of receivers which will be used in the broadcasting system envisaged.

It is proposed that data recorded, in future, for this report should relate only to the mean values of characteristics for receivers that are typical of good, current engineering practice in the country in question. This is to avoid undue influence being exerted on future planning standards by receiver designs at the extreme upper and lower ends of the performance range.

A reference receiver could be defined taking into account the mean values and possible appropriate amendments to them.

2.2 *Receivers for direct satellite broadcasts*

No practical data are yet available. However, references are given below in which the results of the many studies on the subject may be found in Report 473 [CCIR, 1974-78a and b].

3. Receiving antennas

The numerical values of antennas characteristics contained in Recommendation 419 and Reports 122 and 482 relate to antennas *in situ*. Only data relating to the directivity, forward gain and cross-polarization protection of antennas tested under idealized conditions in a suitable site need be recorded.

The necessary definitions and measuring methods are contained in IEC Publications 597-1 and 597-2.

Additional information and data on antenna characteristics can be found in Report 625.

4. Characteristics contributing to overall reception quality

TABLE I

Item	Parameter	Reference IEC Publication 107-1			Remarks
		Definition	Measuring method	Presentation of result	
1	Passband (radio frequency and intermediate frequency): - video (MHz) - audio (kHz)	Clause 136	Clause 137 under consideration	Clause 138	For an attenuation of 0 dB rel. to vision carrier
2	Maximum luminance white (cd/m^2)	2.4.1 (1)	2.4.1.2 (1)	2.4.1.3 (1)	For a black-level of 2 cd/m^2. The point at which the bars corresponding to... MHz are no longer visible
3	Picture resolution (lines)	2.6.1 (1)	2.6.2 (1)		
4	Interlace ratio (%)		Clause 99		
5	Maximum distortion of the picture outline (%)	Clause 78	Clause 79	Clause 80	Total distortion
6	Scanning non-linearity (%)	Clause 73	Clause 74	Clause 75	
7	Audio frequency response characteristic (Hz)	Clause 27 (2)	Clause 28 (2)	Clause 29 (2)	Overall electrical characteristics
8	Maximum useful electric output power (W)	Clause 17 (2)	Clause 18 (2)	Clause 19 (2)	
9	Transmodulation: - vision into sound (dB) - sound into vision (dB)	Clause 45 or 51 (2) Clause 151	Clause 46 or 52 (2) Clause 152	Clause 47 or 53 (2)	
10	Maximum usable input signal (dBm)	Clause 132	Clause 133		The most unfavourable value for each broadcasting band

(1) These characteristics have not yet been taken into consideration by the IEC for inclusion in the new edition. It is proposed that the articles of IEC Publication 107 (1960) as indicated above, should be used as provisional references.

(2) Ref. IEC Publication 107-2.

5. Results

5.1 The numbered values listed in Table II are mean values taken from an extensive series of objective measurements. The results for Canada show the sample mean and include the sample standard deviation (σ).

TABLE II

		Country				
Item	Parameter	Italy	Canada(12)			
1	Selectivity (dB) Video Broadcasting band I III IV/V 12 GHz Sound Broadcasting band I III IV/V 12 GHz	(1) −6(2) −26	VHF band: - 6 dB points High gain = 3.7 MHz (σ = 0.3) Low gain = 3.6 MHz (σ = 0.4)			
2	Maximum luminance white (cd/m²)	(3) 100(4)	208 (σ = 48)			
3	Picture resolution (lines)	320(5)	241 (σ = 28.3)			
4	Interlace ratio (%)	40/60(6)				
5	Distorsion of the picture outline (%)	3(7)	H: 2.3 (σ = 1.1) V: 2.9 (σ = 1.1)			
6	Scanning non-linearity (%)	5 to 8(8)	H: 7.2 (σ = 4.4) V: 6.4 (σ = 2.7)			
7	Audio frequency response characteristic (Hz)	120 to 7000(9)	78 (σ = 67) to 5700 (σ = 1800)			
8	Maximum useful electric power (W)	1,2(10) 2	1.6 (σ = 0.5)			
9	Transmodulation: - vision into sound (dB) - sound into vision (dB)	(11) −30 −40	–			
10	Maximum usable input signal (dBm)	−30	–			

H: horizontal V: vertical

(1) Measurements carried out in accordance with IEC Publication 107, Clause 4.2.

(2) Rejection values for 4 MHz.

(3) Measurements carried out in accordance with IEC Publication 107, Clause 2.4.1.

(4) For a black level of 3 cd/m² (for a picture tube without a grey filter).

(5) Measurements carried out in accordance with IEC Publication 107, Clause 2.6.

(6) Measurements carried out in accordance with IEC Publication 107, Clause 2.9.

(7) Measurements carried out in accordance with IEC Publication 107, Clause 2.3.3

(8) Measurements carried out in accordance with IEC Publication 107, Clause 2.3.2 and for ± dB relative to 1000 Hz.

(9) Measurements carried out in accordance with IEC Publication 107, Clause 12.3.

(10) Measurements carried out in accordance with IEC Publication 107, Clause 13.2.5.

The power value of 1.2 W corresponds to a tube whose diagonal is < 51 cm (20 in.) and the power value of 2 W corresponds to a tube whose diagonal is ⩾ 51 cm (20 in.).

(11) Measurements carried out in accordance with IEC Publication 107, Clauses 4.8.2.3 and 4.8.2.5.

(12) [Munak and Gourgon, 1979].

Note. – In the future, measurements should be made in accordance with the revised version, i.e. IEC Publication 107-1. The new references in the footnotes will be as follows:

(1) IEC Publication 107-1, Clause 137.

(3) IEC Publication 107 (1960), Clause 2.4.1 (provisional reference).

(6) IEC Publication 107-1, Clause 99.

(7) IEC Publication 107-1, Clause 77.

(8) IEC Publication 107-1, Clause 74.

(9) IEC Publication 107-2, Clause 27.

(10) IEC Publication 107-2, Clause 18.

(11) IEC Publication 107-1, Clause 152.

Measurements on maximum usable input signal level shall be carried out in accordance with IEC Publication 107-1, Clauses 133 and 135.

REFERENCES

MUNAK I. and GOURGON M. [August, 1979] The technical performance of typical home colour-television receivers. *SMPTEJ*, Vol. 88, 8, 546-550.

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[1978-82]: 11/106 (Canada).

REPORT 122-4

ADVANTAGES TO BE GAINED BY USING ORTHOGONAL WAVE POLARIZATIONS IN THE PLANNING OF TELEVISION BROADCASTING SERVICES IN BANDS 8 (VHF) AND 9 (UHF)

(1956-1959-1970-1974-1982-1990)

Investigations have been conducted in several countries to ascertain the advantages which can be obtained in television broadcasting by using polarization discrimination in reception. The results of extensive studies made in Europe by the Federal Republic of Germany, France, Italy and the United Kingdom and also in the United States of America, have been made available in documents at Warsaw, 1956 and Geneva, 1958; and a reasonably definite answer may now be given to the question.

1. Band 8 (VHF)

In this band of frequencies, between 30 and 300 MHz, the median value of discrimination that can be achieved at domestic receiving sites by the use of orthogonal polarization may be as much as 18 dB, and under these conditions, the values exceeded at 90% and 10% of the receiving sites are about 10 dB and 25 dB respectively.

The values of discrimination are likely to be better in open country and worse in built-up areas or places where the receiving antenna is surrounded by obstacles. For domestic installations in densely populated districts, the median values of 18 dB will usually be realized only at roof level; and this value may be reduced to 13 dB or less at street level.

No significant changes in the polarization of waves in band 8 due to transmission through the troposphere have been observed over distances exceeding 200 km. Furthermore, there have been no reports of systematic changes in polarization effects with frequency in the metric band, neither with distance nor with type of terrain.

It must be emphasized, however, that to realize the discrimination ratios mentioned above, certain precautions are necessary at both the transmitting and receiving installations; cases have been reported in which, for a transmitter of horizontally polarized waves, some 7% of the radiated power was vertically polarized. It is clear that if the best discrimination is to be obtained for co-channel operation, the transmitters and antenna systems must be designed and installed so as to radiate as much as possible of the total power on the assigned polarization.

In the same way, to achieve the desired discrimination at the home receiving installation, the reception of the undesired orthogonally polarized waves on the antenna feeder and on the receiver itself must be reduced to the minimum practicable value.

It should, however, be noted that the above-mentioned advantage from the use of orthogonal polarizations can only be obtained when, in general, the polarization of the receiving antennas conforms to that of the wanted signal.

Due to problems with multipath reception in hilly and wooded terrain a comparison of vertical and horizontal polarization for VHF TV transmissions was made in Norway. The measurements show, in spite of higher field strengths for vertical polarization, that horizontal polarization in almost every measured site gave a better picture quality. After negotiations with neighbouring countries, Norway decided to use horizontal polarization for all their main stations [CCIR, 1986-90.a; Danielsen and Stokke, 1987].

2. Band 9 (UHF)

Investigations have been carried out in the United Kingdom to determine the polarization discrimination in band 9 (UHF) of antennas at typical urban and rural domestic receiving sites. The results showed that for orthogonally polarized signals the median value of discrimination was 18 dB, and under the same conditions, the values exceeded at 90% and 10% of the receiving sites were about 9 dB and 25 dB respectively. There is also some small variation of discrimination with angle relative to the direction of main response; however, for television planning purposes in the United Kingdom, a value of 15 dB is used for all relative bearings [CCIR, 1986-90b].

As in band 8, care is necessary to ensure that the transmitter and receiver respectively do not emit or receive radiation of the undesired polarization. Apart from this, however, experience indicates that in band 9 (UHF), the use of horizontal polarization offers advantages, because of the greater directivity obtainable at the receiving antennas; this reduces the effect of reflected waves, particularly in town areas. The European Broadcasting Union, therefore, considers that frequency assignments in these bands should be based on the general use of horizontal polarization, though exceptions may be made in cases where orthogonal polarization is necessary to achieve the desired protection.

3. Conclusion

From the studies described above, it is clear that the use of orthogonal polarization for broadcasting stations operating in the same frequency channel is of material assistance in discriminating against the reception of undesired signals. Worth-while advantages are obtainable over the whole band of frequencies from 40 to 500 MHz and within the normal broadcasting service ranges. From the uniformity of the discrimination obtained over these frequencies, it is considered to be almost certain that the advantages will extend to the top of the broadcasting band in band 9 at nearly 1000 MHz.

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DANIELSEN, A.B. and STOKKE, K.N. [1987] Comparative measurements of vertical and horizontal polarization for television transmission in the VHF bands. Telektronikk, 2.

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[1956]: Warsaw 267, 435 and 512.

[1958]: Geneva V/1, V/6, V/12, V/23 and V/27.

[1970-74]: United Kingdom, 11/267.

REPORT 1215

POLARIZATION OF EMISSION IN TELEVISION BROADCASTING

(1990)

1. Linear polarization

Linear polarization of emissions is in almost universal use in television broadcasting. The plane of polarization is usually horizontal but from the viewpoint of planning there is much to be gained from allowing the possibility of also using vertical polarization.

The available evidence suggests that the use of horizontal polarization provides improved picture quality in hilly and wooded terrain compared with vertical polarization, at least for the VHF bands (see Report 122).

The use of orthogonally polarized transmissions, together with appropriately polarized receiving antennas, offers significant advantages in terms of spectrum utilization. Planning based on the use of receiving antennas not offering polarization discrimination does not give this advantage [CCIR, 1986-90a].

2. Circular or elliptical polarization

There is a lack of information concerning the use of circular or elliptical polarization in planning the television broadcasting services. However, some administrations permit the use of circular or elliptical polarization as an alternative to the more usual horizontal or vertical. It is reported that the reception of circular polarized television emissions by simple portable or indoor antennas is improved because the orientation of these antennas by individual receivers is less critical than for the case of linear polarization [Trumbly, 1988].

However, it should be remembered that the use of simple portable or indoor antennas can lead to poor quality reception as a result of multipath propagation and low input signal levels.

Theoretically, the use of circularly polarized transmissions offers the possibility of filtering out most of the first order reflections [CCIR 1986-90b]. However, this advantage can only be achieved by the use of a circularly polarized receiving antenna and at this time such an antenna is not in practical use for television reception.

For a given transmitter power, a circularly polarized transmitting antenna will result in a field strength lower by 3 dB in the horizontal or in the vertical plane than that provided using a linearly polarized transmitting antenna, thus effectively giving a reduced coverage area.

3. Conclusion

From the foregoing it can be concluded that for optimum planning it is necessary to take full advantage of polarization discrimination, and that this can only be done economically and realistically by using horizontal and/or vertical polarizations.

REFERENCES

TRUMBLY, W.L. [1988] Developing antenna patterns to match desired UHF television coverage. 1988 NAB Engineering Conference Proceedings, 452-459

CCIR Documents:

[1986-90]: a. IWP 11/5-88/13 (EBU); b. 11/595 (IWP 11/5).

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DIENES, G. [1988] Circularly and elliptically polarized UHF television transmitting antenna design. 1988 NAB Engineering Conference Proceedings, 446-451

REPORT 483-4*

SPECIFICATIONS FOR LOW-COST MONOCHROME TELEVISION RECEIVERS

(Question 13/11)

(1970-1974-1978-1982-1986)

This Report is a reply to Question 13/11. It presents values for the characteristics of low-cost television receivers suitable for home and community use. Values are based on information in [CCIR, 1966-69a, b, c, d and e; 1970-74; 1974-78].

1. General

1.1 *Types of receiver*

These specifications apply to two types of low-cost monochrome television receiver giving a satisfactory performance:

Type A: Receivers intended to give acceptable performance at the lowest possible cost.

Type B: Receivers intended to give good performance at a reasonable cost.

Generally speaking *Type A* receivers would be home receivers whereas *Type B* receivers would often be community receivers.

It should be noted that in establishing the performance specifications listed below due consideration was given to the situation prevailing in many developing countries where the normal utilities have not reached the required level. As a result of this, the requirements of certain parameters of a television receiver are severe and this adds to the cost.

1.2 *Power supply*

Where feasible, the use of a.c. mains operated receivers is recommended. In some countries, battery-operated receivers are at present either of lower performance, or of higher cost.

The administrations concerned should specify the television standard to be employed and the mains voltage and frequency, if the receivers are to be mains-operated. Particular emphasis should be given to any difference that may exist between the mains frequency and the field frequency of the television system, whether due to intentional differences or to temporary disturbances.

For battery-operated receivers, satisfactory performance should be secured with the battery voltage 15% below the nominal value.

1.3 *Controls*

The following controls, at least, should be available to the user:

- power switch,
- channel selector and tuning,
- contrast,
- brightness,
- sound volume.

1.4 *Planning of uses*

In planning the uses of these receivers, administrations should take account of their differing characteristics, the range of signal intensity expected, and the possibilities for special antennas, pre-amplifiers and low-loss radio-frequency feeders.

Although it is desirable that receivers should be capable of operation on all channels, receivers equipped to receive only the channels of the transmitters serving the given area and conforming to the frequency plan may be acceptable.

* This Report is also of interest to Study Group 1.

Administrations should further take account of the effect of the size of the screen and the cabinet on cost. The recommended values given are considered appropriate for the expected use of the receivers.

The receivers should be simple, robust and well protected against the environment. Those intended for use in areas of high temperature, high humidity or dust, should be treated so that they can be used under the climatic conditions specified by the administration concerned. Appropriate tests, consistent with the relevant IEC Publications, should be prepared by the administrations concerned. The IEC Publications quoted in the text are the most up-to-date issues at the time of preparation of the Report. Administrations are requested to review the numerical values given in the Report to determine if those values are valid for measurements performed in accordance with the quoted IEC Publications.

1.5 *Safety*

The receiver should comply with the safety recommendations of IEC Publication 65.

1.6 *Methods of measurement*

The methods of measurement and the tests to be employed should be those recommended in relevant paragraphs of IEC Publications 106 (1974), 107-1 and 107-2. National regulations or tests differing from these standards should be quoted.

1.7 *Receiver tuning*

For all the measurements which follow, the receiver should be accurately tuned as described in IEC Publication 107-1, clause 37 or, if this is not appropriate, in some other specified manner.

2. General specifications

	Type A	*Type B*
2.1 *Recommended size (diagonal) for the screen*	28 cm (11 in.) or larger	48 cm (19 in.) or larger
2.2 *Frequency bands*	VHF or VHF and UHF	VHF or VHF and UHF
	(see § 1.4 above, second sub-paragraph)	

2.3 *Power supply for a.c. operation*

	Type A	*Type B*
Frequency:		
– nominal value (Hz)	To be specified by the administration concerned	
– maximum permissible variation (Hz)	± 2	± 2

Note. – If this variation is greater, the cost of the receiver will inevitably be higher.

	Type A	*Type B*
Voltage:		
– nominal value (V)	To be specified by the administration concerned	
– maximum permissible variation without extra equipment (%)	± 10	± 10
– surges of ...* ms duration and changes in amplitude of (%)	± 30	± 30

Note. – It will be up to the user to provide a means of voltage control for variations greater than ± 10%.

* The value is under study

3. Input characteristics

		Type A	Type B
3.1	*Input impedance at the antenna terminals* (Ω)	75 or 300	75 or 300
3.2	*Toleration of surge discharges at the input circuit (IEC Publication 315-1, clauses 25 and 26)*		
	Energy of each discharge (μJ)	...	...
3.3	*Maximum noise figure (dB) (least favourable channel)*		
	Band 8 – VHF	10	8
	Band 9 – UHF	16	12
3.4	*Noise-limited sensitivity at a signal-to-noise ratio of 30 dB and standard output (IEC Publication 107-1, clauses 109 and 110)* (dBm)		
	Band 8 – VHF	−50	−60
	Band 9 – UHF	−40	−55
3.5	*Characteristic of the automatic gain control (IEC Publication 107-1, clauses 117, 118 and 119)*		
	(−20 to −50 dBm) (dB)	8	6
3.6	*Maximum input level (IEC Publication 107-1, clauses 132 and 133)*		

4. Output characteristics

		Type A	Type B
4.1	*Minimum audio-frequency response characteristic within 6 dB (IEC Publication 107-2, clauses 26, 27 and 28)* (Hz)	150 to 5000	150 to 5000
4.2	*Maximum useful electric output power (IEC Publication 107-2, clauses 17, 18 and 19)* (W)	0.5	2
4.3	*Minimum picture resolution* (IEC Publication 107 (1960), sub-clause 2.6)** (lines per picture height)*		
–	6 MHz channel systems (4.5 MHz inter-carrier frequency)	225	280
–	7 or 8 MHz channel systems (5.5, 6 or 6.5 MHz inter-carrier frequency)	270	320
4.4	*Minimum brightness at white level for a black level of 3 cd/m² (IEC Publication 107,** 1960, sub-clause 2.4.1)*		
–	50 fields/s system (cd/m²)	70	120
–	60 fields/s system (cd/m²)	70	150
4.5	*Minimum interlace ratio (IEC Publication 107-1, clause 99)*	30/70	30/70
4.6	*Maximum picture motion expressed as a percentage of picture height for a difference of 1 Hz between the mains frequency and the field frequency (IEC Publication 107-1, clauses 70, 71 and 72)* (%)	0.8	0.4

* Alternatively, administrations may wish to specify their requirements on resolution in terms of an electrical bandwidth measurement (e.g. according to IEC Publication 107-1, clauses 163, 164 and 165) in which case the requirement must be negotiated with manufacturer.

** Since this point does not yet appear in the available parts of revised IEC Publication 107, reference to the 1960 edition must provisionally be retained.

		Type A	Type B
4.7	*Maximum relative non-linearity of scan over a complete field (IEC Publication 107-1, clauses 73, 74 and 75)* (%)	10	10
4.8	*Maximum distortion of the picture outline (IEC Publication 107-1, clauses 76 and 77)* (%)	10	6

5. Interference

5.1 *Intermediate frequency*

The picture and sound intermediate frequencies used in the receivers should be in accordance with those chosen for the establishment of the given frequency plan.* For standard K1, see, for instance, Doc. 44 of the African Broadcasting Conference, Geneva, 1963.

5.2	*Minimum rejection of the upper adjacent picture carrier (IEC Publication 107-1, clauses 136, 137 and 138)* (dB)	26	32
5.3	*Minimum rejection of the lower adjacent sound carrier (IEC Publication 107-1, clauses 136, 137 and 138)* (dB)	30	35
5.4	*Minimum image rejection (IEC Publication 107-1, clauses 146 and 147)* (dB)		
	Band 8 – VHF	40	40
	Band 9 – UHF	20	25
5.5	*Minimum intermediate-frequency rejection (IEC Publication 107-1 clauses 144 and 145)* (dB)		
	Band I – VHF	20	20
	Band III – VHF Bands IV, V – UHF	30	30
5.6	*Transmodulation and intermodulation (IEC Publication 107-1, clauses 153 to 158)* (dB)		
	Vision into sound	30	30
	Sound into vision	40	40
5.7	*Minimum attenuation of the sound carrier relative to the vision carrier at the video detector (IEC Publication 107-1, clauses 136 to 138)* (dB)	30	34

Note 1. – This requirement is to avoid beats in the receiver between the sound carrier and a subsequent colour sub-carrier.

Note 2. – An attenuation of 20 dB will be sufficient for both types of receivers in areas where transmissions are made only in black and white.

5.8	*Radiation (IEC Publication 106)*	In accordance with Recommendation No. 24/2 of the CISPR

Note. – Unless otherwise specified by the administration concerned, no measurements will be made below 0.5 MHz (LF Broadcasting).

* For economic reasons the number of different intermediate frequencies should be kept to a minimum (see Report 184).

6. Stability

		Type A	Type B
6.1	*Maximum drift of the local oscillator between 2 min and 60 min after the picture appears (IEC Publication 107-1, clauses 49, 50 and 51)* (kHz)		
	VHF	± 300	± 300
	UHF	± 500	± 500
6.2	*Drift of the local oscillator due to a change of + 5 to − 10% in the supply voltage (IEC Publication 107-1, clauses 52 and 53)* (kHz)		
	VHF	± 200	± 200
	UHF	± 300	± 300
6.3	*Minimum range of lock-in (IEC Publication 107-1 clause 93)* (%)		
	Vertical Horizontal	± 1	± 1
6.4	*Minimum range of hold (IEC Publication 107-1, clause 93)* (%)		
	Vertical Horizontal	± 2	± 2

7. Reliability

The precise specification of reliability for a complete equipment is a subject under general study at the present time but manufacturers of receivers of the type considered in this Report should utilize as far as it is possible components already reliability tested under appropriate conditions. Since it is expected that these receivers will be closely based on ones already in quantity production, data on the reliability performance of such receivers should be available under normal operating conditions.

The following figures are only provisional objectives suggested for receiver manufacturers and should on no account be considered as part of any contract.

	Type A	Type B
Desirable minimum mean operating time between failures requiring servicing, averaged over a production run (hours)	1000	1000

ANNEX I

SPECIFICATIONS FOR LOW-COST TELEVISION RECEIVERS

This Annex is attached for information.

1. Television receivers manufactured in the U.S.S.R. [CCIR, 1978-82, 1982-86] are classified into two categories: fixed and portable.

2. The classification is based on the differences in the basic technical characteristics which to a large extent determine picture and sound quality as well as the cost of the receivers.

3. Low-cost receivers in both categories may possess the following characteristics (standard D, K) as shown in Table I.

TABLE I

Characteristics	Typical values of characteristics (see Note 1)	
	Portable	Fixed
1	2	3
1. Size (diagonal) of screen (cm)	not more than 45	not less than 50
2. Frequency bands (see Note 2)	I, II, III, IV, V	I, II, III, IV, V
3. Noise-limited sensitivity of picture channel (dBm)	VHF −69 UHF −66	VHF −69 UHF −66
4. Synchronization-limited sensitivity (dBm)	VHF −74 UHF −70	VHF −74 UHF −70
5. Efficiency of the automatic gain control when the input signal is changed (from −15 to −62.5 dBm)		
− maximum change of the output luminance signal (dB)	3	2
6. Minimum picture resolution (lines):		
− horizontally	400 (see Note 3)	450
− vertically	400	500
7. Maximum non-linearity of picture over a complete field (%):		
− horizontally	± 10	± 8
− vertically	± 10 (see Note 3)	± 8
8. Maximum geometrical distortions (%)	3 (see Note 3)	2
9. Noise-limited sensitivity of the sound channel (dBm)	VHF −74 UHF −68	VHF −74 UHF −68
10. Maximum output power of a sound channel (W), not less than	(See Notes 2, 3)	4
For television sets with a 40 and 51 cm screen		2
11. Minimum reproducible frequency range relative to reference level (Hz)	100-10 000 (see Note 3)	80-12 000
12. Maximum residual heterodyne frequency drift in self-tuning (kHz)	± 100 (see Note 3)	± 100
13. Minimum selectivity (dB):		
− band −1.5 MHz and less	28	38
− point −1.5 MHz	30	40
− point +8 MHz	30	45
− band +8 MHz and above	reduced by 6 dB/MHz	reduced by 6 dB/MHz
14. Drift of local oscillator frequency due to changes of supply voltage of +5 to −10% (kHz) in bands I-III	± 300	± 200
15. Maximum admissible input signal, not less than (dBm)	−10	−10
16. Minimum value of maximum brightness (cd/m^2)	140 (see Note 3)	150
17. Intermediate frequency (MHz) of:		
− picture signals	38	38
− sound signals	31.5	31.5

TABLE I *(continued)*

Characteristics	Typical values of characteristics (see Note 1)	
	Portable	Fixed
1	2	3
18. Maximum permissible background distortion due to unsynchronized mains		
– geometrical (%)	0.7	0.5
– brightness (dB)	40 (see Note 3)	40
19. Maximum variation of raster size (%)		
– due to heating	5	5
– due to changes of supply voltage of +5% to −10%	6	6
20. Maximum relative unevenness of the flat part of the square pulses (%) (see Note 4)		
– line frequencies (2*T* pulse-bar)	7	7
– field frequencies	7	7
21. Maximum luminance-chrominance delay inequality (ns) (see Note 4)	± 150	± 150
22. Maximum non-linear distortion of the chrominance signal (%) (see Note 4)	10	10
23. Maximum permissible level of video/audio interference (dB)	−30	−36

Note 1. – The parameters were measured in accordance with IEC Publications 107-1 and 107-2.

Note 2. – To be determined by user requirements.

Note 3. – For television sets with screens of less than 40 cm, the values will be fixed for the specific model.

Note 4. – Standards established for colour television.

REFERENCES

CCIR Documents

[1966-69]: **a.** XI/53 (Italy); **b.** XI/132 (United Kingdom); **c.** XI/164 (France); **d.** XI/185 (Italy); **e.** XI/192 (India).

[1970-74]: 11/120 (Netherlands).

[1974-78]: 11/148 (USSR).

[1978-82]: 11/125 (USSR).

[1982-86]: 11/123 and 11/367 (USSR)

REPORT 1085-1

PLANNING METHODS FOR TERRESTRIAL TELEVISION IN VHF/UHF BANDS

(Question 43/11)

(1986-1990)

1. General

Broadcasting-transmitter networks should be planned in such a way that the required coverage of the area is provided using the minimum number of frequencies. The coverage area of each transmitter depends upon a number of technical factors, for example: transmitter power, minimum usable field-strength, radio-frequency protection ratio, the distance between transmitters sharing the same or adjacent channels, channel spacing, bandwidth of emission and factors influencing wave propagation. It may also depend on the channel distribution scheme.

When a large number of channels is to be planned or replanned for a particular AM or FM sound or television service, it has been found that utilizing the spectrum efficiently can prove difficult when only empirical methods are employed. For this reason, a theory of uniform transmitter networks was developed during the late 1950s and early 1960s [Eden and Kaltbeitzer, 1950; Eden *et al.*, 1960a, b; Fastert, 1960].

This method can be applied with success when some uniformity of standards exists for the services to be planned. Furthermore, the frequency band to be planned should be constrained as little as possible, i.e. there should ideally be complete freedom in assigning any frequency to any transmitter.

This theory is not only useful in designing new transmitter networks or remodelling existing ones, but also provides a powerful tool for determining optimal technical parameters such as channel spacing, transmitter characteristics, etc., and identifying the best attainable coverage.

Some countries may prefer to have a complete area coverage with a small number of programmes and others to sacrifice total area coverage in favour of providing more programmes in the more highly populated areas. In these cases, uniform network theory can be used to provide some reference values for attainable coverage. This can help when comparing the differing networks of individual countries which have chosen different methods for achieving their internal coverage. (For example, see [O'Leary, 1984] but care must be taken when using this method to include all relevant factors.)

The methods described below have already been used during the VHF/UHF European Broadcasting Conference (Stockholm, 1961), the African VHF/UHF Conference (Geneva, 1963) and the Regional Administrative Conference for FM Sound Broadcasting in the VHF band (CARR-1(2)), Geneva, 1984. They also helped in preliminary studies for the Geneva 1975 LF/MF Broadcasting Conference.

In this Report all data used as examples refer only to 625-line systems. The attention of administrations using other systems is drawn to this fact. Additional data concerning all systems are required.

2. Theoretical techniques for an international plan

2.1 *General*

Planning techniques resulting from the principle of uniform transmitter networks may be considered to comprise two basic elements:

- geometrically regular lattices,
- linear channel-distribution schemes.

Because of the many parameters and effects that may have an impact on frequency planning, e.g. varying propagation conditions, transmitter powers, transmitting-antenna heights and directivities, and terrain irregularities, the problem first requires simplification by assuming all transmitters to have equal powers, to have omnidirectional antennas all at the same height and with the same polarization, and to be situated on an infinitely extended area forming a geometrically regular lattice; also that propagation conditions do not exhibit variations throughout the area considered.

The development of such regular lattices is discussed in some detail in Annex I and leads to the following basic conclusions:

- full area coverage can most economically be provided by a lattice having equilateral elementary triangles i.e. having equally spaced geographically adjacent transmitters. Some overlap coverage is inevitable if complete area coverage is to be achieved. This can be expressed in terms of a "coverage factor". i.e. the sum of individual coverage/total area to be covered. The reciprocal of the coverage factor is often referred to as the coverage efficiency. This coverage factor has a minimum value of 1.21 for the optimum case of equilateral elementary triangles;

- because, for television broadcasting, the required co-channel protection ratio predominates over those for other frequency spacings by a large amount, optimum coverage is also likely to be achieved by maximizing the spacing of co-channel transmitters, i.e. by ensuring equilateral co-channel triangles;

- only particular numbers of channels allow both co-channel and elementary triangles to be equilateral. These are known as "rhombic numbers" and require that the number of channels, C, is such that:

$$C = a^2 + ab + b^2$$

where a and b are non-zero integers and without a common divisor.

For values of $C < 80$, these numbers are given by:

a	1	2	3	3	4	4	5	5	5	5	6	7	7	7	8
b	1	1	1	2	1	3	1	2	3	4	1	1	2	3	1
C	3	7	13	19	21	37	31	39	49	61	43	57	67	79	73

If, however, the total spectrum available for the network does not correspond to a number of channels coincident with a "rhombic number", a solution using the full available number of channels will still be possible but this will generally mean adopting a lattice formation in which either the co-channel or elementary triangles will not be equilateral. Such a solution may well permit substantially better coverage than that obtainable by restricting spectrum usage to that corresponding to the next lower rhombic number. Exceptionally, other channel numbers can also permit both equilateral elementary and co-channel triangles but in such cases linear channel distributions (see Annex I, § 3) cannot be used and hence interference levels are not necessarily uniform through the lattice. An example of such a network is given in Fig. 14.

If it is considered more important to have the elementary triangles equilateral, this may be achieved by a transformation (e.g. affine) which retains the longest side and rotates and extends the remaining sides to make them equal. An example of such a transformation for an 8-channel lattice is indicated in Fig. 3b.

Having once established lattices of the type described above, the problem is then to arrange the channels required in such a way as to minimize interference, remembering that every co-channel rhombus forms only part of a lattice extending over the whole planning area. The derivation of linear distribution schemes is discussed in some detail in Annex I.

Such a linear distribution has the property of having an identical interference situation on all channels, except for those on the highest and lowest frequencies (in cases where adjacent-channel interference is relevant).

The method can be extended to the case (an example of this is given in § 2.6) where it is desired to provide n programmes from each site using a total of nC channels in contiguous sub-bands each of C channels. In this case the channels assigned to each transmitter will be:

$$c,\ c + C,\ c + 2C, \text{ etc.,} \qquad \text{where } 0 \leqslant c \leqslant C - 1$$

2.2 *Implications of applying regular lattice planning principles in specific terrestrial television bands*

In the following sections, the application of these principles to the specific numbers of channels available in each band will be considered, and at the same time these examples will be used to develop further aspects of these planning principles.

However, before considering the implications in individual bands, it is appropriate to consider which frequency relationships, additional to co-channel, need to be taken into account in television network planning (see Report 1086).

These are:

Frequency relationship	Channel difference	Comments
Adjacent channel	1	See below
Radiation from local oscillator	4 or 5	For channel spacings and receiver intermediate frequencies in general use
Image channel	8, 9 or 10	

For any lattice based on approximately equilateral elementary triangles, it follows that any transmitter will be spaced almost equidistantly from six other transmitters which, except in the case of lattices with a very small number of channels, will all be on different channels. It follows therefore that unless very distorted elementary triangles are adopted, no lattice having less than eight channels can avoid having adjacent-channel overlaps. Figure 2b) shows an example of a 7-channel lattice which avoids adjacent-channel overlaps at the cost of distorting the elementary triangles hence requiring a substantial increase in the coverage radius required of individual transmitters.

2.3 *Band I*

The full extent of this band is 21 MHz. Hence, the maximum number of channels available is three for any transmission system currently in use having 7 MHz bandwidth. Only one form of lattice is possible with three channels, which has the following characteristics:

a) the three channels at the apexes of the elementary triangles;

b) equilateral elementary and co-channel triangles (three is a rhombic number);

c) co-channel spacing = $\sqrt{3}$ times the spacing between adjacent transmitters;

d) for complete coverage, the maximum distance between any transmitter and the nearest point on the coverage area of the next co-channel transmitter (at centroid of elementary triangle) is twice the coverage radius.

The implication of a) is that adjacent-channel overlaps are inevitable.

The implication of d) is that complete area coverage is only possible (even if any allowance for multiple interference or interference from other than co-channel transmitters is neglected), when the field strength at the extremity of the coverage radius exceeds that at twice the distance by at least the value of the required co-channel protection ratio.

Figure 1 shows, taking a three-channel lattice as an example, how a systematic use of frequency offsets and use of both horizontal and vertical polarization can reduce co-channel interference. In the general case, polarization discrimination can also be used to reduce adjacent-channel interference. However, in the particular case of three channels (as shown in Fig. 1), this is of limited advantage since the middle channel (B) is equidistant from two of each adjacent channels and polarization discrimination could only be obtained against one of each pair. The same principles, can of course, be applied to any lattice. It may be seen that:

- the separation distance between co-channel transmitters without either polarization or offset protection is now three times that between adjacent channel transmitters;
- all of the nearest ring of six co-channel transmitters have offsets but only three also have the opposite polarization (this is because while three offset options are possible, there are only two polarizations).

In view of the high values of co-channel protection required for a television service, even taking account of the reduction in interference possible by frequency offset and polarization discrimination, full area coverage cannot be provided by a three-channel lattice, i.e. it is not possible to provide complete coverage over an extended area using Band I alone.

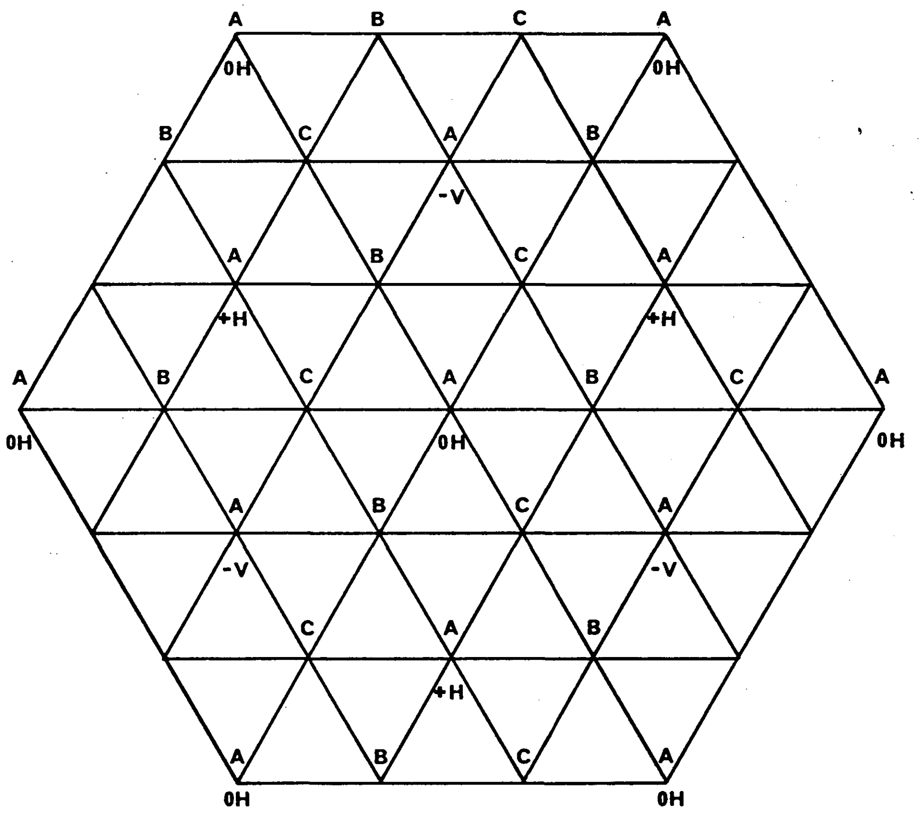


FIGURE 1 – *3-channel lattice demonstrating use of frequency offsets and polarization to reduce interference*

A, B, C: channels
H, V: polarizations
0, +, –: offsets (1/3 line time-base)

Offsets and polarizations shown for channel A only

2.4 *Band III*

The total available spectrum is 56 MHz, permitting either 7 channels of 8 MHz channel width or *vice versa*. Whereas television systems using both 7 and 8 MHz nominal bandwidth are in use in ITU Region 1, it should be noted that in the UHF television bands a channelling of 8 MHz has been adopted throughout the Region. It would seem therefore that in any future planning this standard should also be adopted uniformly. Moreover, adoption of 8 MHz channelling would not preclude retention of television systems requiring 7 MHz nominal bandwidth if desired. However, for completeness, the following discussion examines both 7- and 8-channel lattices.

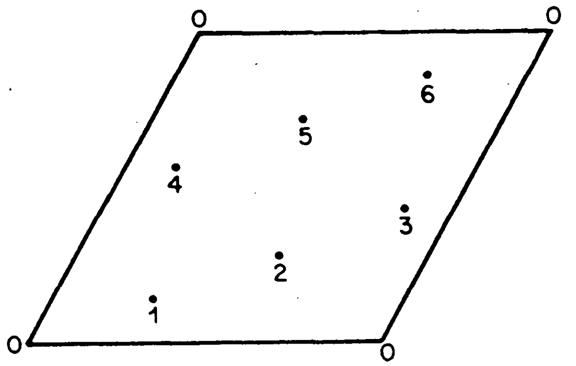
2.4.1 *Seven-channel lattice*

Superficially, the most appropriate lattice is that indicated in Fig. 2a) which has equilateral elementary and co-channel triangles (possible because 7 is a "rhombic number").

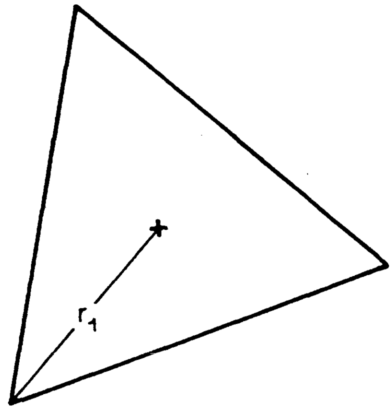
The lattice has the following characteristics:

- overlaps between adjacent channels;
- a co-channel distance of $\sqrt{7}$ times the distance between geographically adjacent transmitters. (The ratio of co-channel distance to the distance between transmitters is $\sqrt{\text{No. of channels}}$. This is an intrinsic characteristic of such a lattice.)

An alternative form of 7-channel lattice is that shown in Fig. 2b). This was the lattice adopted for Band III by the African VHF/UHF Broadcasting Conference (Geneva, 1963). The preference for this lattice was presumably based on the greater adjacent-channel distances, but, as indicated by Figs. 2c) and 2d), this was obtained at the cost of a considerable distortion to the elementary triangles and consequently a need for a 22% greater coverage radius by individual transmitters to achieve complete area coverage.

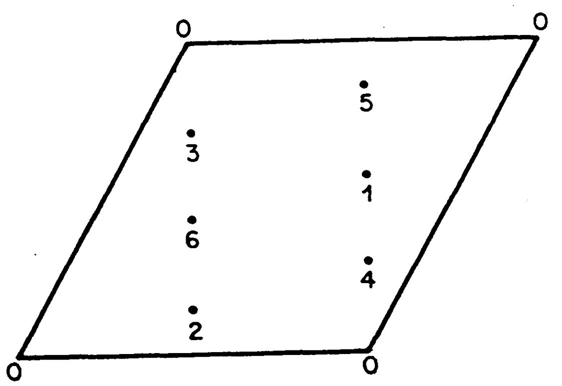


a) Equilateral elementary triangles

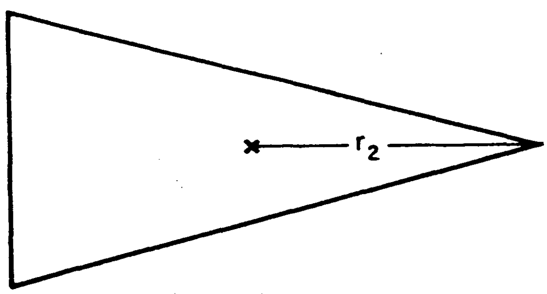


c) Elementary triangle from *a)*

r_1 : minimum radius for complete coverage



c) Avoiding adjacent channel overlaps



d) Elementary triangle from *b)*

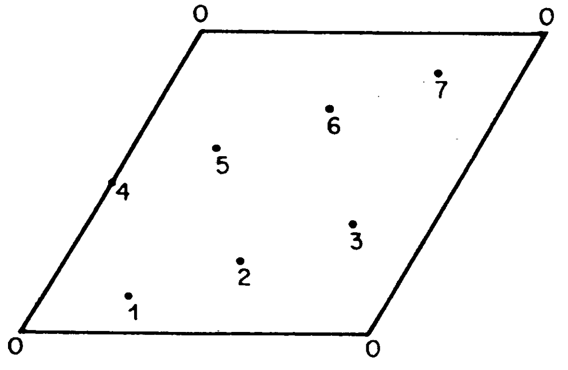
r_2 : minimum radius for complete coverage
Ratio r_2/r_1 = 1.22

Note. – Figs. *c)* and *d)* are scaled to same co-channel distance.

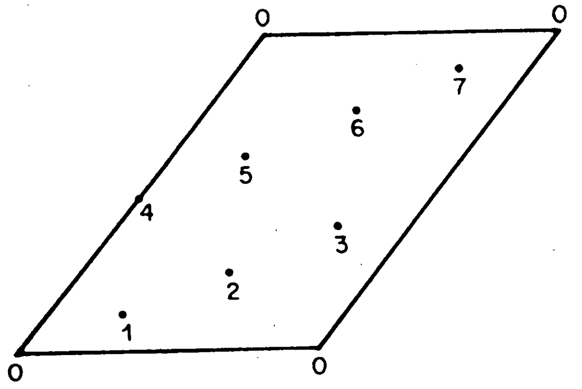
FIGURE 2 – *Examples of 7-channel lattices*

2.4.2 *Eight-channel lattice*

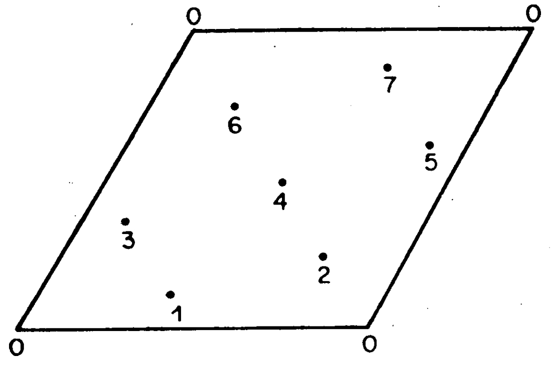
Not being a rhombic number, it is not possible to construct a linear channel distribution with both equilateral elementary and co-channel triangles. The lattice most closely approximating to this is that shown in Fig. 3a) (equilateral co-channel) and Fig. 3b) (normalized to give equilateral elementary triangles). Figure 3c) indicates an alternative lattice having more distorted elementary triangles for which the smallest distance between transmitters is not equal to that between adjacent channels. This does not, however, preclude some adjacent-channel overlap if full area coverage is to be achieved.



a) Nearest approximation to equilateral elementary triangles



b) Lattice *a)* transformation to give equilateral elementary triangles



c) Alternative to reduce importance of adjacent-channel interference

FIGURE 3 – *Examples of 8-channel lattices*

2.5 *General comments on planning in VHF television bands*

As previously mentioned, it is not possible to produce full coverage over an extended area with the three channels available in Band I. Such a single coverage can, however, be expected with the seven or eight channels available in Band III, but this band cannot generally provide two coverages. In any case, the extent of sporadic-E propagation in the lower Band I channels causes severe restrictions on the percentage of time for which a service may be achieved.

In principle, it would be possible to use both Bands I and III together in a coordinated manner to provide a high degree of area coverage with two programmes, i.e. using five channels for each programme. However, this implies adoption of a 7-MHz channelling system in at least one of the bands.

This also presents the following problems:

- while it is logical to use two of the three Band I channels together to ensure equal coverages, this may present engineering problems at the transmitter site;
- the third (presumably middle) Band I channel would in any event have to be used in conjunction with a Band III channel, thereby increasing antenna costs at both transmitting and receiving terminals and presenting problems in achieving equal coverages;
- the principles of linear lattice planning, as previously described, cannot be applied to such a composite network in view of the different propagation characteristics and non-continuous channelling.

Nevertheless, it is possible to envisage the use of a combined Band I and III two-programme network based on a 10-channel lattice such as indicated in Fig. 4 with the channels paired as shown. It will be appreciated that for such a pairing then, if channels 0-2 are in Band I, each Band I channel is paired with one in Band III. To keep two Band I channels together, the positions of channels 2 and 7 and of channels 3 and 9 could be transposed. As this particular lattice has 2-channel spacings on one side of each elementary triangle, it might be thought that pairings could be made along this axis. However, it is not possible to produce complete pairings of alternative numbers in a consecutive sequence unless the total is divisible by four.

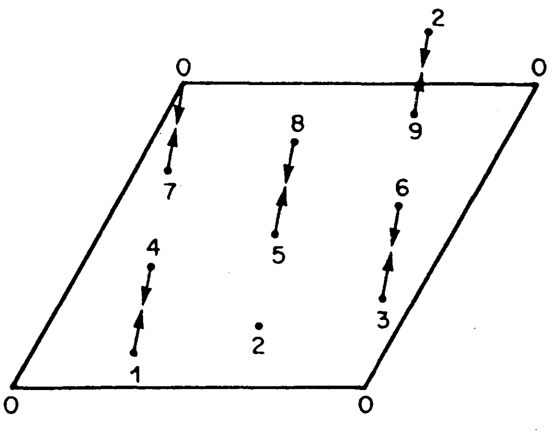


FIGURE 4 – *10-channel lattice indicating "pairings" to provide two programmes*

2.6 *The UHF band*

Although the UHF band consists of Bands IV and V, it is convenient for planning purposes to consider these as a single entity. An 8 MHz channelling scheme was adopted in these bands by both the European and African Broadcasting Conferences (Stockholm, 1961 and Geneva, 1963, respectively). Channels were numbered consecutively from 21 (470-478 MHz) to 81 (950-958 MHz) the upper limit of Band IV being channel 34 and the lower limit of Band V being channel 35. With a total of 61 channels in the two bands (even though all may not be fully available for broadcasting) it is clear that multiple coverages can be provided.

The concept of subdividing the total band into sub-bands allocated to individual coverages/programmes, as was done in the African area of the Regional Administrative Conference for FM Sound Broadcasting in the VHF band (CARR-1(2)), Geneva, 1984, presents problems in the UHF television band because it would imply a wide range of spectrum usage in each coverage area. This in turn produces engineering difficulties due to the large bandwidth required of both transmitting and receiving antennas.

Because different countries in the overall planning area may have differing requirements, it may be more convenient to base planning on the use of a single 61-channel lattice designed so as to enable frequencies to be "grouped" together in different ways. This method was adopted by both the European (1961) and African (1963) Broadcasting Conferences.

The lattice used at the European Broadcasting Conference is represented in Fig. 5 and that for the African Broadcasting Conference in Fig. 6. Both have as a common feature, frequency separations of three channels between adjacent transmitters in one direction through the lattice. This permits easy "grouping" for three programmes using channels n, $n + 3$, $n + 6$.

Extension to four programmes by adding ($n + 9$) would not be appropriate, firstly because this represents a large spread in one dimension of the lattice, and secondly because of the risk of image channel interference between channels n and $n + 9$. However, the lattice adopted at the 1961 Stockholm Conference also has 10 channel spacings between adjacent transmitters in another direction through the lattice, enabling groupings to be made either of n, $n + 3$, $n + 6$, $n + 10$ (see Note) or n, $n + 3$, $n + 6$, $n + 13$. Of these, the former is preferable in respect of total spread of spectrum, the latter preferable in respect of the location spread within the lattice configuration. Without further extension of the location spread within the lattice, it is possible to envisage further extensions of this "grouping" principle within the "European" lattice to provide:

- five programmes using: n, $n + 3$, $n + 7$, $n + 10$, $n + 13$;
- six programmes using: n, $n + 3$, $n + 6$, $n + 10$, $n + 13$, $n + 16$.

Note .— Or, as a symmetrical alternative, n, $n + 4$, $n + 7$, $n + 10$.

The lattice adopted at the 1963 African Conference appears less amenable to extension of "groupings" above three programmes without unduly large spectrum spread or the introduction of an image channel relationship, n and $n + 9$, at the same transmitter site.

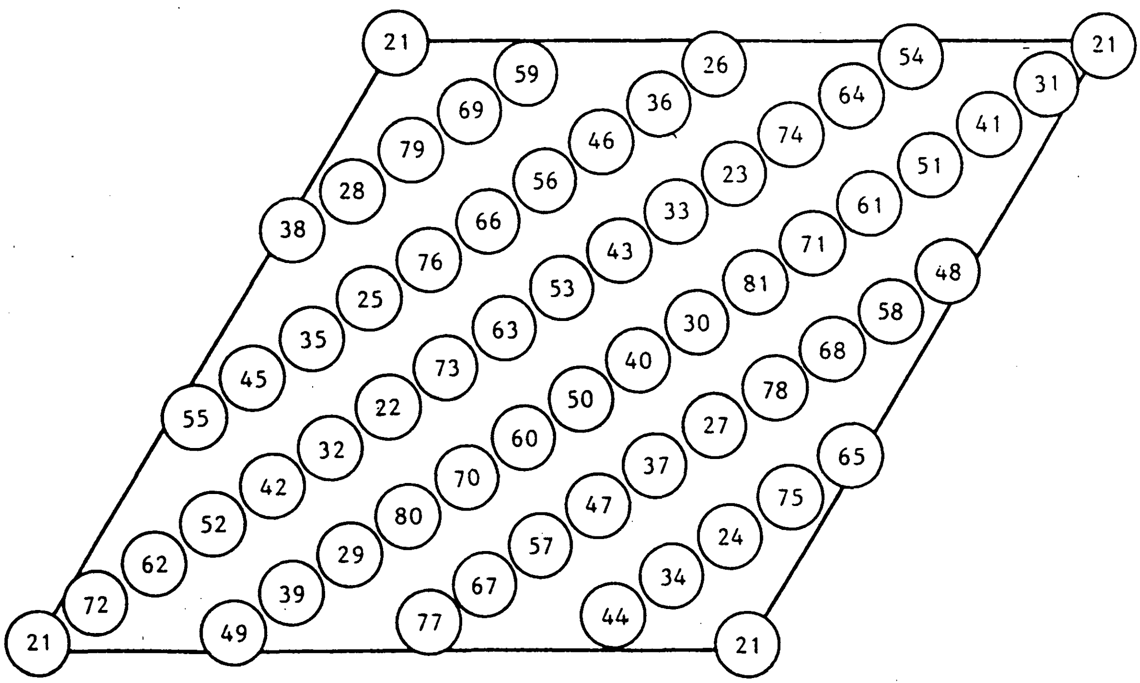


FIGURE 5 – *Theoretical apportionment of channels in Bands IV and V, adopted by the European Broadcasting Conference (Stockholm, 1961)*

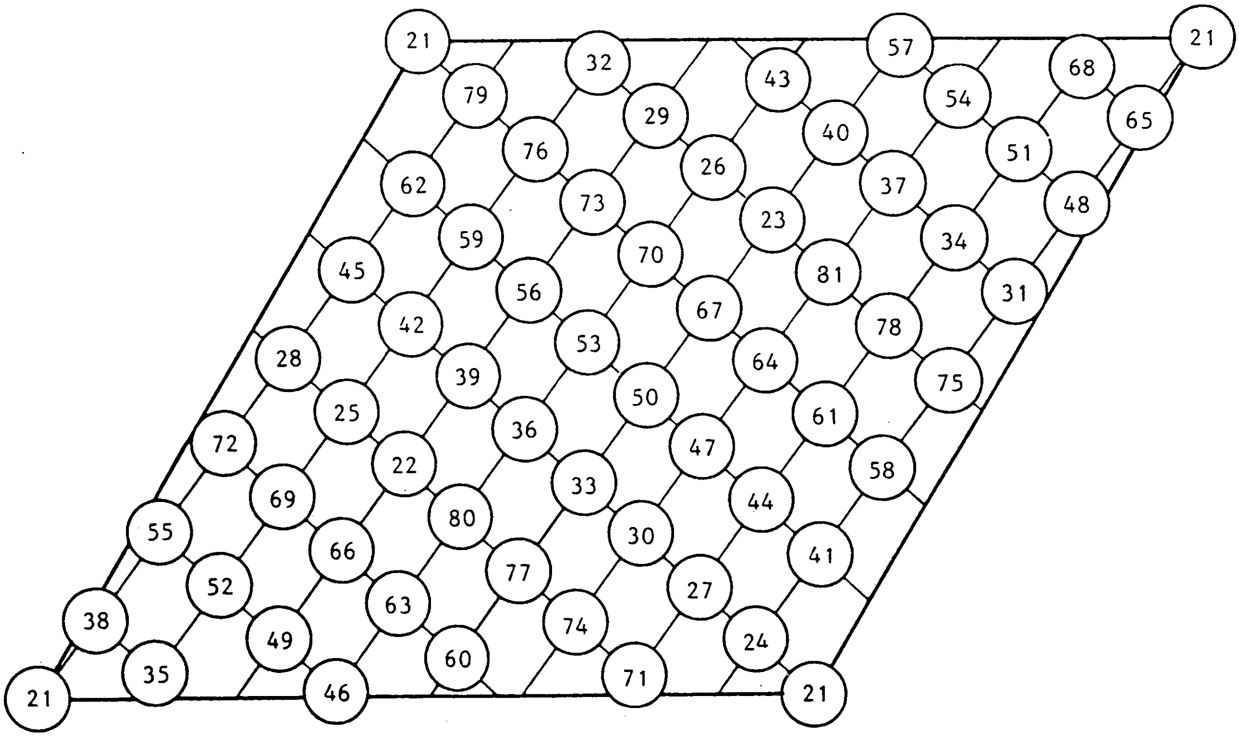


FIGURE 6 – *Bands IV and V – Theoretical lattice adopted by the African Broadcasting Conference (Geneva, 1963)*

3. Frequency offset plan

3.1 General

Optimum application of a lattice, as illustrated in Figures 5 and 6, and described in Annex I with respect to linear channel distribution, does not depend solely on the nominal frequency of an assigned channel. An excellent tool for ensuring better use of television broadcasting frequency bands is the possibility of assigning a suitable offset to the channels, thereby optimizing the protection between transmitters using the same channel (see Recommendation 655, Tables II, VII and VIII). The optimum co-channel spacing can then be calculated by means of these offsets and used as the basis for the co-channel lattice.

3.2 Non-precision offset

Optimum spacing between co-channel transmitters is obtained by specifying offsets providing the same protection between all transmitters in a co-channel lattice, namely 8M, 0 and 8P (offset by multiples of a third of the line frequency; protection ratio of 30 dB throughout, tropospheric interference), alternately allocated to the transmitter triplets of the half-lattices (see Figure 7). The transmitters along the long diagonal are the only ones to have a relative offset of 0 and are therefore less well protected (protection ratio of 45 dB). However, this is compensated by the fact that the co-channel spacing between the transmitter pair is 1.73 times that of the transmitter triplets with an effective 1/3-line offset.

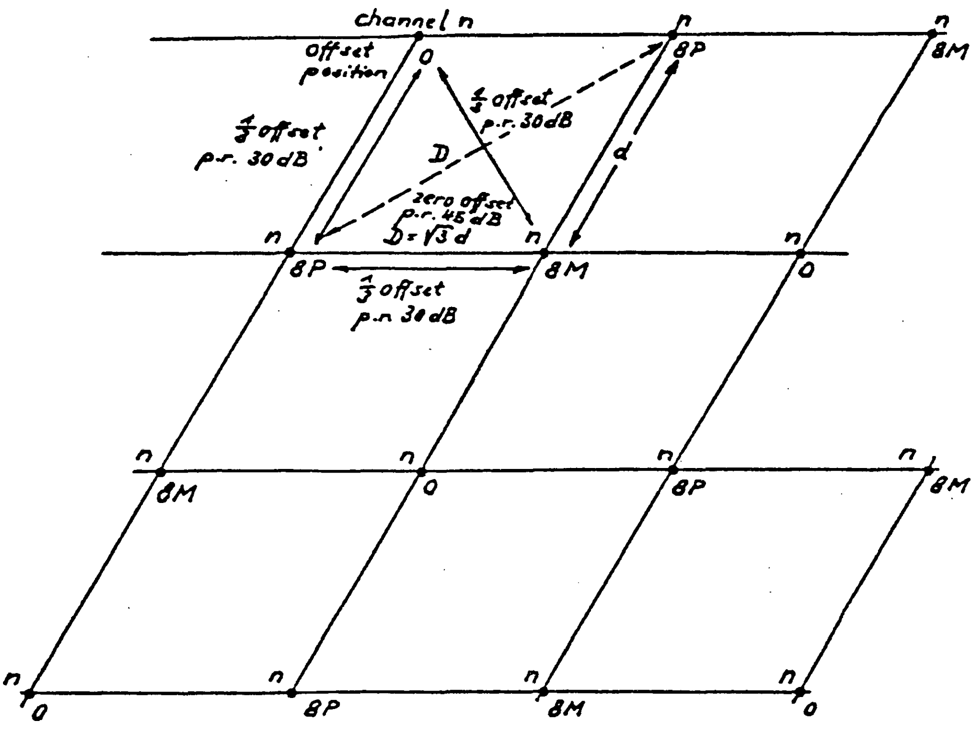


FIGURE 7

Frequency offset distribution in a co-channel lattice
(frequency offset plan)

3.3 Precision offset

A further improvement in the efficiency of spectrum utilization can be achieved by using precision offset. However, the possibilities are limited if the network planning is based on a co-channel lattice as the transmitters along the long diagonal, which have a relative offset of 0, can only be operated with a non-precision offset and the co-channel spacing in the lattice is determined by this required minimum spacing.

3.4 Offset distribution in precision offset operation

Apart from the protection ratios for vision signals, Recommendation 655 also specifies the protection ratios for the accompanying analogue sound. In the common offset distributions (8M, 0, 8P) of television channels there is a difference of approximately 10 kHz between the sound carriers of adjacent co-channel transmitters, resulting in a required protection ratio of 31 dB (Recommendation 655, Table XI).

In the case of precision offset, a protection ratio of only 22 dB is required for the vision signals. To obtain the same protection ratio for the sound signals, it is necessary to adjust the offset by several multiples of the line frequency. The difference in the frequency of the sound signals has to be approximately 50 kHz to obtain a protection ratio of 22 dB (equal to that of the vision signals). The protection ratios of the vision signals are not changed provided that these signals are not offset relative to each other by more than three times the line frequency.

4. Capacity of the TV bands

4.1 *Capacity of the VHF bands*

As previously discussed, Band I can, at most, provide three channels and this only if a 7 MHz channelling system is adopted. Unless used for purposes not requiring complete area coverage, this band can therefore only be considered as a supplement to Band III.

The combined VHF band can provide 9 channels, if a transmission system requiring 8 MHz channelling is used and either 10 or 11 channels for a system requiring only 7 MHz channelling. In the former case, it would be unrealistic to consider providing coverage of more than a single programme using VHF only, but with 10 channels there is an option of providing two programmes with fairly high, although probably not total, area coverage. In such a case, it would seem desirable to attempt to minimize interference as much as possible by systematic use of both horizontal and vertical polarization.

It must also be remembered that in a practical situation the simplifications introduced into the theory (see § 2.1) will not generally apply. One result is that more channels will be needed for a given degree of coverage than the theory suggests. Other problems are mentioned in § 2.5.

Any form of composite Band I/Band III coverage will entail additional costs for the broadcasting authority because of the need for separate transmitting antennas. The use of log-periodic receiving antennas may avoid this requirement for the viewer, provided that both services use the same polarization in individual areas, although such an antenna would be physically rather large.

A further option to be considered if two programmes are to be provided at VHF is to complete coverage by means of UHF relays. This may well be practicable in countries where it is not intended to provide more than three programmes within the UHF band.

4.2 *Capacity of the UHF bands*

Experience gained in Europe may be used to estimate the capacity of the UHF bands in a practical case. It has to be noted that a maximum of only 48 channels (21 to 68) is available and that there is a gap of up to 5 channels between Bands IV and V which is unavailable for broadcasting in parts of Europe. However, it has generally been found possible to achieve three programme coverage with protection against interference for 99% of the time. In some cases, for example in the United Kingdom, the time for which protection is achieved has been reduced to 95% and it has then been found possible to achieve four programme coverage.

In any case, it is necessary to consider whether area coverage or population coverage is being sought. If the population distribution is fairly uniform, there may be little difference between the two concepts. However, if much of the population is concentrated into urban areas, there can be a large difference. In this case, it may be possible to achieve coverage of the urban areas with larger number of programmes than would be the case if a more uniform coverage had been the aim.

5. Assessment of planned coverage

In either the VHF or UHF bands, it is desirable to relate predicted or measured field-strength values to the satisfaction of television viewers with the quality of their received vision and sound signals. If this is to be done, it is important that the distribution of measurement locations should be heavily influenced by the population density. The method described in Report 228 is not appropriate if the population density is not uniform. It is also necessary to consider the extent to which non-standard receiving installations may be used by viewers. The use of high-gain antennas or low-noise pre-amplifiers in areas of low population density permits an extension of the coverage achieved by a transmitter without requiring an increase in the field-strength values provided.

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ANNEX I

LATTICE PLANNING: BASIC PRINCIPLES FOR THE DEVELOPMENT OF GEOMETRICALLY REGULAR LATTICES HAVING LINEAR CHANNEL DISTRIBUTIONS

1. Basic assumptions

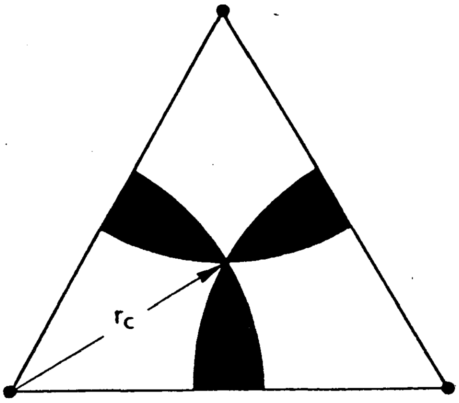
It is assumed that all transmitters:

– have the same powers, effective antenna heights and polarization and are all non-directional; and
– are situated on an infinitely extended area having uniform propagation characteristics.

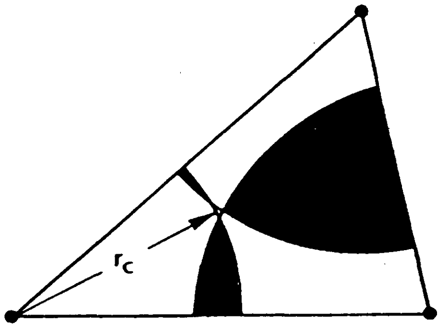
2. Geometrically regular lattices

Transmitters are considered to be situated at the points of intersection of two sets of parallels, each equidistant and covering the whole area. These two sets of parallels subdivide the area into parallelograms each corresponding to one intersection point, i.e. to one transmitter site. Hence complete coverage would be obtained if each transmitter uniquely provided coverage of an area equal in size (although almost certainly not in shape) to the parallelogram.

For convenience, a third set of parallels may be considered to be drawn through the intersection points, thereby dividing each parallelogram into two equal triangles. Assuming non-directional transmitting antennas and hence circular coverage areas (in the absence of interference or with uniform interference) complete area coverage requires the coverage range r_c of each transmitter to be equal to the largest of the distances from corners to centroid of the elementary triangle (see Fig. 8). Some coverage overlap is inevitable but for efficient coverage this should be minimized.



a) Equilateral triangle



b) Non-equilateral triangle

FIGURE 8 – *Examples of elementary lattice triangles showing necessary overlaps to achieve complete coverage*

Such minimum overlap results if the triangles are equilateral although the increase in overlap will be slight for small deviations from the equilateral condition. In this optimal condition, the parallelograms become rhombi, and the distance from each corner to the centroid of the triangle $= r/\sqrt{3}$. For this condition, the coverage area of each transmitter (Sc) is given by:

$$Sc = \pi \left(\frac{r}{\sqrt{3}}\right)^2 = \frac{\pi\, r^2}{3}$$

and the area of each parallelogram $S = \dfrac{\sqrt{3}\, r^2}{2}$

The quotient Sc/S is known as the coverage factor (or alternatively S/Sc as the coverage efficiency). The highest value of Sc/S is that obtained with equilateral triangles and is equal to $2\pi/3\sqrt{3} = 1.21$. Despite giving a lower coverage efficiency, the use of a lattice with non-equilateral triangles may have advantages in some circumstances. This will be discussed when channel distribution is considered.

High co-channel protection ratios, of the order of 30-45 dB even for non-continuous interference, are required in television broadcasting. Consequently, co-channel coverage areas must not overlap but also be well separated. From the above explanations, it is clear that if the co-channel transmitters form an equilateral triangular lattice with distances, D, between neighbouring co-channel transmitters, the maximum coverage factor, c, will result:

$$c = 2\pi r_c^2/\sqrt{3}\,D^2$$

Full area coverage will require the use of a sufficiently large number of channels, C. Identical co-channel triangular lattices for these C channels should then be superimposed in such a way that the resulting lattice is entirely geometrically regular again. The number of possible solutions to this problem is rather restricted.

All possible solutions can be found if the co-channel parallelogram (or rhombus) is subdivided by two sets of $C - 1$ equidistant lines, parallel to either pair of sides of the parallelogram. In Figs. 9a), and 10a), this is shown for an equilateral co-channel lattice and $C = 7$, or $C = 12$, respectively. Geometrical regularity of the resulting lattice of elementary triangles is obtained when each of the $C - 1$ parallels of one set contains just one transmitter. The $C - 1$ parallels of the other set contain also just one transmitter, if C is a prime number (e.g. 7). If C is the product of two or more primes, p_i, (e.g. $12 = 2 \times 2 \times 3$) there are also solutions whereas in the other set only parallels which are multiples of p_i (or of their products $\prod_{i=1}^{i<n} p_i$) carry p_i (or $\prod_{i=1}^{i<n} p_i$) transmitters (Figs. 10c) to 10e)). For C = 7, all possible solutions (except one which need not be considered as all transmitters would lie at one of the sides of the triangle) are shown in Figs. 9b) to 9f).

It is advantageous at this stage to introduce a system of non-rectangular coordinates (x, y) having its origin (0, 0) in the lower left-hand corner and the coordinates being directed towards the lower right-hand corner (x) or the upper left-hand corner (y), respectively. The subdividing parallels are at unity distance from one another.

In this system of coordinates, all the solutions of Figs. 9b) to 9f) have one transmitter at y = 1 but its position with respect to x varies between x = 1 and x = 5. The coordinates of all the other transmitters in each of the solutions are multiples of the respective first one, e.g. in Fig. 9b, the coordinates are (1, 1), (2, 2), (3, 3), (4, 4), (5, 5) and (6, 6). Coordinates exceeding C can be normalized by reducing the real multiple by C or by a multiple of C, as the original and the resulting values of the coordinate are congruent to each other modulo C.

It can be seen from Figs. 9b) to 9f) that some of the solutions are "symmetrical" ones (triangular symmetry) e.g. those of Figs. 9c) and 9e), or those of Figs. 9b), 9d) and 9f). This reduces the number of "genuine" solutions to two. Hence, it follows that, except for $C = 3$ with one genuine solution, all of them can be found if the coordinates of one of the transmitters are assumed to be $x \leqslant C/2$, and y = 1 (or *vice versa*), i.e., to the left of the dashed vertical lines in Figs. 9a) and 10a) and, more precisely, inside the parallelogram formed by dashed lines. Thus, in the example of Fig. 9 ($C = 7$) only the coordinates (1, 1) and (2, 1) need to be considered, whereas in the example of Fig. 10 (C = 12) only "genuine" solutions are presented.

The solutions of Figs. 9 and 10 are derived from an equilateral co-channel triangular lattice. In such a lattice the square of the distance, d, between coordinates (x1, y1) and (x2, y2) with (x2 − x1) = a and (y2 − y1) = b is $d^2 = a^2 + ab + b^2$. In Figs. 9 and 10 the co-channel rhombus has a sidelength, D, which corresponds, in either case, to C units, and an area $S = \sqrt{3}\,D^2/2 = \sqrt{3}\,C^2/2$. If this area is subdivided into C congruent elementary parallelograms, each area will be $Sc = \sqrt{3}\,C/2$ and, in the case where the elementary area is a rhombus, $Sc = \sqrt{3}\,d^2/2$, i.e. $d^2 = C$. Figures 9 and 10 show that the elementary triangles are, in general, not equilateral and have sidelengths d_1, d_2 and d_3. Only in exceptional cases (Figs. 9c) and 9e) is the elementary triangle equilateral. Solutions where both the co-channel and the elementary triangles are equilateral exist only when C is a rhombic number, i.e. when there are two integers, a and b, which fulfil the equation $C = a^2 + ab + b^2$. This is a consequence of the fact that the coordinates of all transmitters can only be integers. Equality of the areas of equilateral and non-equilateral triangles exists if:

$$3d^4 = 4d_1^2 d_2^2 - (d_1^2 + d_2^2 - d_3^2)^2$$

Example: in Fig. 10d) the sidelengths are:

$$d_1 = \sqrt{13},\ d_2 = 3,\ d_3 = 4$$

hence:

$$3d^4 = 4 \times 13 \times 9 - (13 + 9 - 16)^2$$

or

$$d^2 = \sqrt{13 \times 12 - 12} = 12 = C$$

Values of rhombic numbers for $C < 80$, together with originating integers a and b are given in § 2.1 of the main text. This also lists some of the basic conclusions derivable from the above considerations of the present Annex.

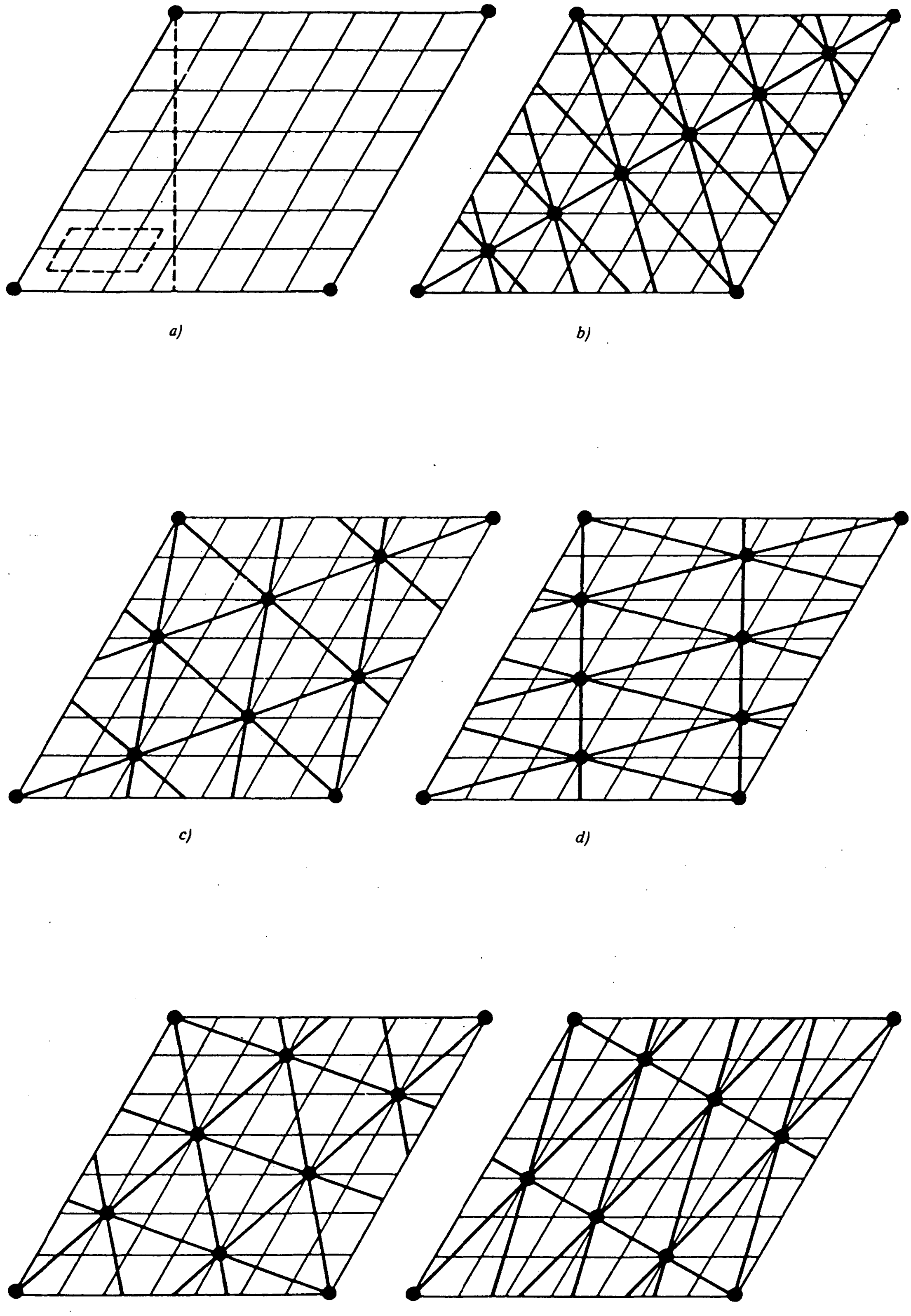
Some further conclusions are also possible:

– if transmitters situated at the corners of the co-channel rhombus suffer interference from other transmitters situated elsewhere on the area of that rhombus and using different channels, e.g. adjacent or image channels, then the distance of such transmitters from the corners should be maximized, i.e. they should be situated as closely as possible to the triangles centroid. Such interference will, nevertheless, lead to a reduction in coverage and, to compensate for this loss, an increase in the required number of channels will be necessary;

– the effect of interference depends mainly on the distance between the transmitters involved and the protection ratio required. Because of the smaller distance between the centroid and the corners of the co-channel triangles, it may happen that co-channel interference is no longer predominant. This does not apply to most television systems. For information, it may noted that it applies particularly in the case of adjacent-channel interference at 100 kHz spacing in FM sound broadcasting. In such circumstances, equilateral elementary triangles may be preferable to equilateral co-channel triangles. However, regardless of what solution is chosen, the number of channels required for full area coverage will increase.

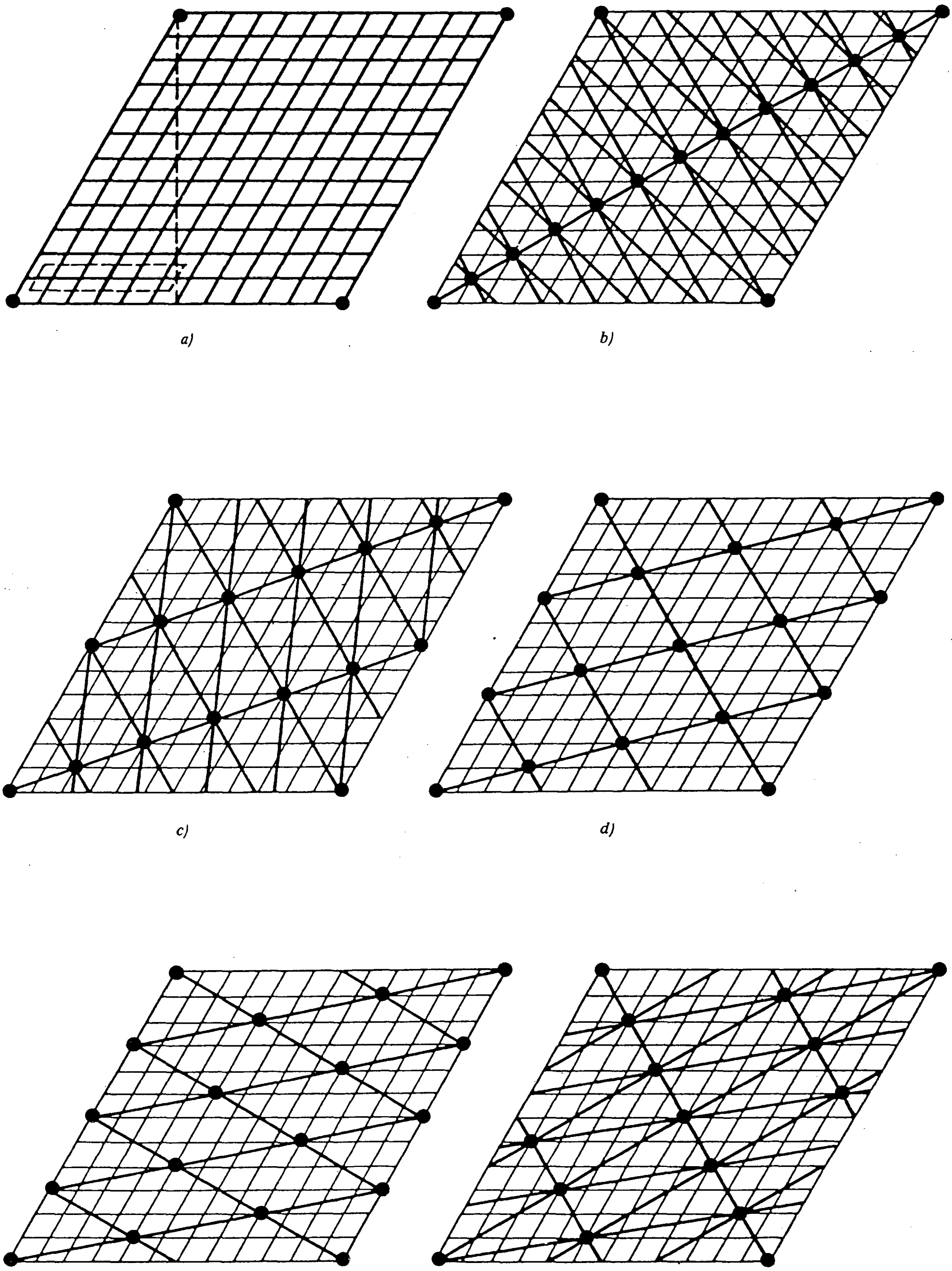
3. Linear channel distribution schemes

Having established the geometric nature of the lattice, it remains to find an arrangement for the C channels necessary for full coverage in such a way that interference is minimized. At this stage it seems appropriate to recall that every co-channel rhombus is part of an infinitely extended lattice consisting of C regularly superimposed co-channel lattices. Each result obtained by the lattice-planning method will therefore be characterized by a periodical repetition in all directions of the geometry and channel arrangement shown, by way of examples, on the area of a co-channel rhombus.



a) b) c) d) e) f)

FIGURE 9 – *Derivation of possible channel distribution for an equilateral co-channel lattice with C = 7*



a) b)

c) d)

e) f)

FIGURE 10 – *Derivation of possible channel distribution for an equilateral co-channel lattice with C = 12*

For the purpose of channel-arrangement considerations, it seems appropriate to use channel number 0 as a reference and to assign it in any one example to the corners of the co-channel rhombus. As a consequence, the numbers of the channels (1, 2, ... $C - 1$) in the arrangement will automatically be characteristic of the difference in channel numbers between the transmitter under study and those at the corners of the co-channel rhombus. However, when considering, as an example, adjacent-channel interference, it must be borne in mind that this type of interference does not only exist between channels 0 and 1, but also between channels 1 and 2, 2 and 3, etc. For reasons of simplicity and for reasons of the regularity of the resulting channel-distribution scheme, it seems appropriate to assign channel 1 to a transmitter at coordinate (x1, y1) which, according to earlier explanations, should be fairly close to the centroid, and channel 2 to the transmitter at coordinates (2x1, 2y1), etc. This implies that channel numbers assigned to equidistant transmitters situated along a straight line will have the same difference. If this difference is greater than 1 channel, numbers greater than C may result which should be normalized by subtraction of C, or a multiple of C. The original and normalized channel numbers are, thus, congruent to each other modulo C. The resulting channel-distribution schemes are called linear distributions. Of course, other solutions exist, but non-linear distributions, although not necessarily useless, are less manageable, these are discussed briefly in § 5.

For the study of coverage efficiency, the consideration of linear channel-distribution schemes is advantageous since the interference situation in each of the C superimposed co-channel lattices is identical, except for some irregularities linked to the lower and upper of the C channels. This exception can, however, be disregarded if the C channels are assumed to form a cyclical system of channels where channels 0 and $C - 1$ are adjacent to each other. Such adjacency would, by the way, result if it were attempted to obtain coverage with n programmes by using a sequence of subsequent channels subdivided into n groups of C channels each. A cyclical system of channels is shown in Fig. 11.

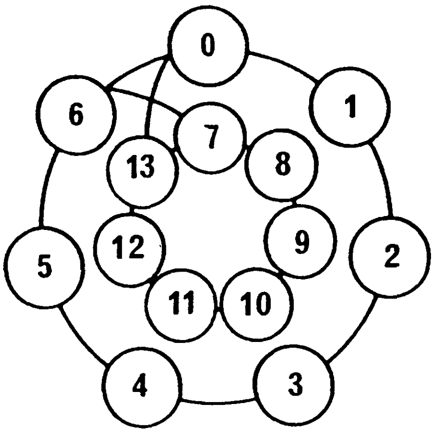


FIGURE 11 – *Cyclical system of channel grouping (n = 2)*

As the interference situation in all C channels as well as for each transmitter in any one of the co-channel lattices is identical, the coverage areas of all transmitters are also identical, both in size and shape. Verification of the coverage obtained by all transmitters in the C channels does, therefore, not require more than the determination of the coverage area of one single transmitter.

Linear channel distribution schemes also allow interference other than co-channel to be taken into account. For the television service, these include interference from the adjacent channels (± 1), from the image channel (+8 or ± 9 or +10) and from the local oscillator of a receiver tuned to channel ± 4 or – 5. These channels should ideally be located in the vicinity of the centroid of one of the two triangles forming a co-channel rhombus. Their distance from the corners should, in principle, be larger if the protection ratio is greater. In linear-channel distribution schemes, for reasons of symmetry, channels with equal difference from that of the reference transmitter but of opposite sign are at symmetrical positions relative to these two centroids.

Remembering that channels z and $C - z$ are symmetrical to each other, there can obviously exist no more than $C/2$ different channel distributions, i.e., taking the example of Fig. 9b), only three; these are shown in Fig. 12 and indicated in the three columns. The two centroids are marked by the symbol G. The third solution would provide the largest distance from the corners to the adjacent channels. In the example of Fig. 9c), the distance of each transmitter from the nearest corner is identical; hence, the possible three solutions are, in this case, equivalent, so that in reality there exists only one single "genuine" solution because of additional symmetry. This special condition occurs where C is a rhombic number and the lattice comprised of equilateral triangles.

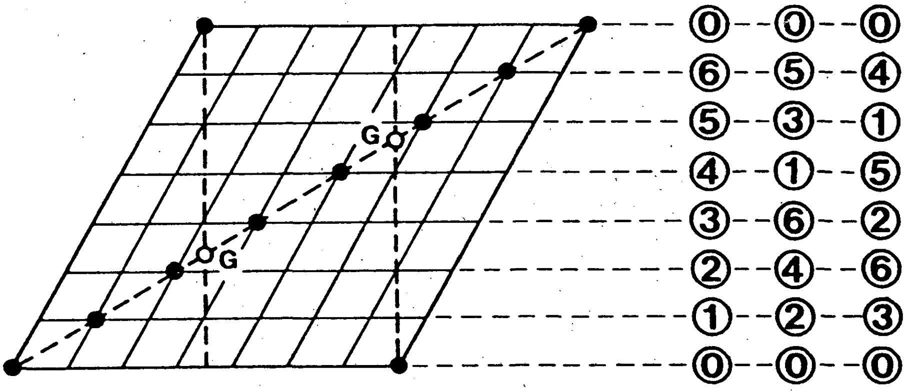


FIGURE 12 – *Examples for channel allocation in a regular equilateral lattice (C = 7)*

The number of possible solutions increases, in principle, with the number of channels necessary for full coverage. However, the difference in channel numbers, Δ, between neighbouring transmitters and the numbers of channels available, *C*, should have no factor (other than 1) in common, since in such a case only channel numbers that are multiples of this common factor would be used, whereas the remaining channel numbers would be unused. It is obvious that in such circumstances no linear channel-distribution scheme could ever be obtained. Hence, the full number of *C*/2 solutions (the integral part of this fraction) will only exist if *C* is a prime number. If *C* is the product of two or more primes, the number of solutions is considerably lower. For $C = 12$, for example, only two solutions exist; they are shown in Fig. 13 for the geometry example of Fig.10f). Once again the two centroids are marked by the letter G. Neither solution is entirely satisfactory when used with this geometry.

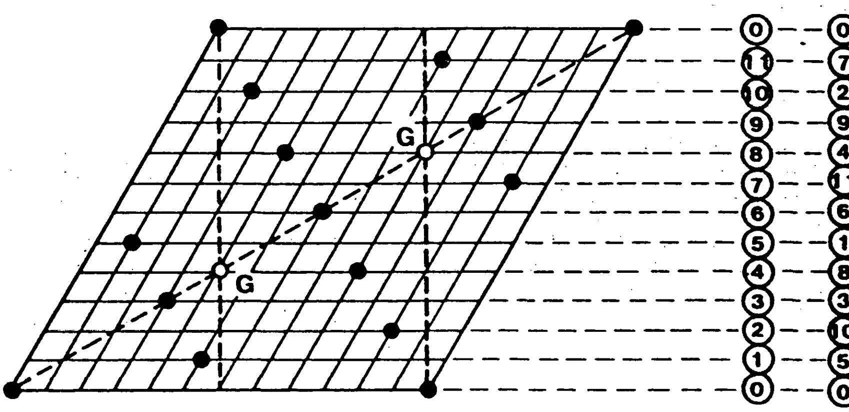


FIGURE 13 – *Examples for channel allocation in a regular equilateral lattice (C = 12)*

Figure 14 shows an example for $C = 19$, the elementary triangles of this solution are equilateral. The channel-distribution scheme selected is fairly appropriate for UHF television broadcasting systems G, I or L, as it takes the best possible account of interference with channel differences of 1, 9 and 18, assuming that the 61 channels comprising the full UHF band are subdivided to provide three programmes each with 19 frequencies. The distance of these channels from the corners are $\sqrt{3}$ times, 2 times and $\sqrt{3}$ times the sidelength of the elementary triangle, respectively. The position with a channel difference of 5 is fairly unsatisfactory, as it is immediately adjacent to that of the reference channel. It can easily be verified that, with this geometry, no solution can be found for which the channel differences of 1, 5, 9 and 18 are all equally good and satisfactory.

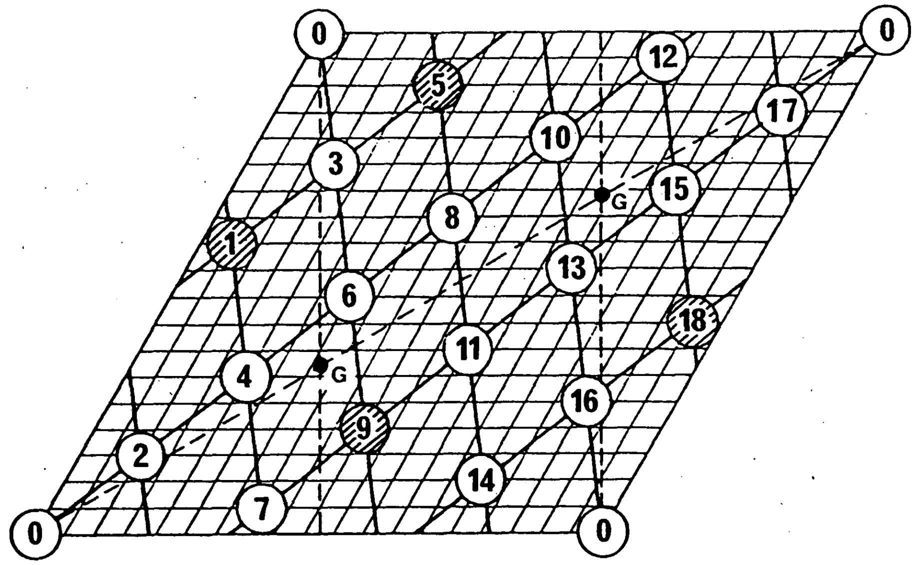


FIGURE 14 – *Example of 19-channel lattice – Appropriate for UHF television in the case of three programmes to the provided in separate sub-bands*

It can be concluded at this stage that the problem of achieving full area coverage can be solved, using the flow-chart of Fig. 15 by determining:

Step 1: The coverage factor, $c_{(1)}$, when only one channel is used and when, in the absence of noise, account is only taken of co-channel interference:

$$c_{(1)} = 2\pi r_{(1)}^2 / \sqrt{3}\, D^2$$

Step 2: The minimum number of channels, C_{min}, necessary to provide full coverage: $C_{min} \cong 1.2/c_{(1)}$.

Step 3: The most favourable geometry (equilateral or near-equilateral elementary triangles) for C_{min} or slightly larger values, if necessary or appropriate.

Step 4: The most appropriate channel-distribution scheme for the geometrical solution of step 3.

Step 5: The coverage factor, c_1, obtainable with any of the C channels taking account of all types of interference:

$$c_1 = 2\pi r_1^2 / \sqrt{3}\, D^2$$

Step 6: The coverage factor, c, obtainable with all channels: $c = c_1 C$.

Step 7: The power level necessary to permit noise-free reception at a distance r_1 from the transmitter for about 90% of the locations.

– To obtain the optimum result, Steps 3 and 4 may require repetition in an iterative procedure;

– if the power level determined in Step 7 exceeds a reasonable or a predetermined value, either the co-channel distance, D, has to be reduced and the whole procedure to be repeated, or the number of channels, C, has to be increased;

– if in Step 6 the resulting coverage factor, c, is not equal to (for equilateral elementary triangles), or sufficiently greater than (for non-equilateral elementary triangles), 1.2, the whole procedure has to be repeated starting either with Step 3 or, if necessary, from the beginning, however with an increased value of C. An affine transformation may be of help, if interference from other channels exceeds, or is comparable to, co-channel interference.

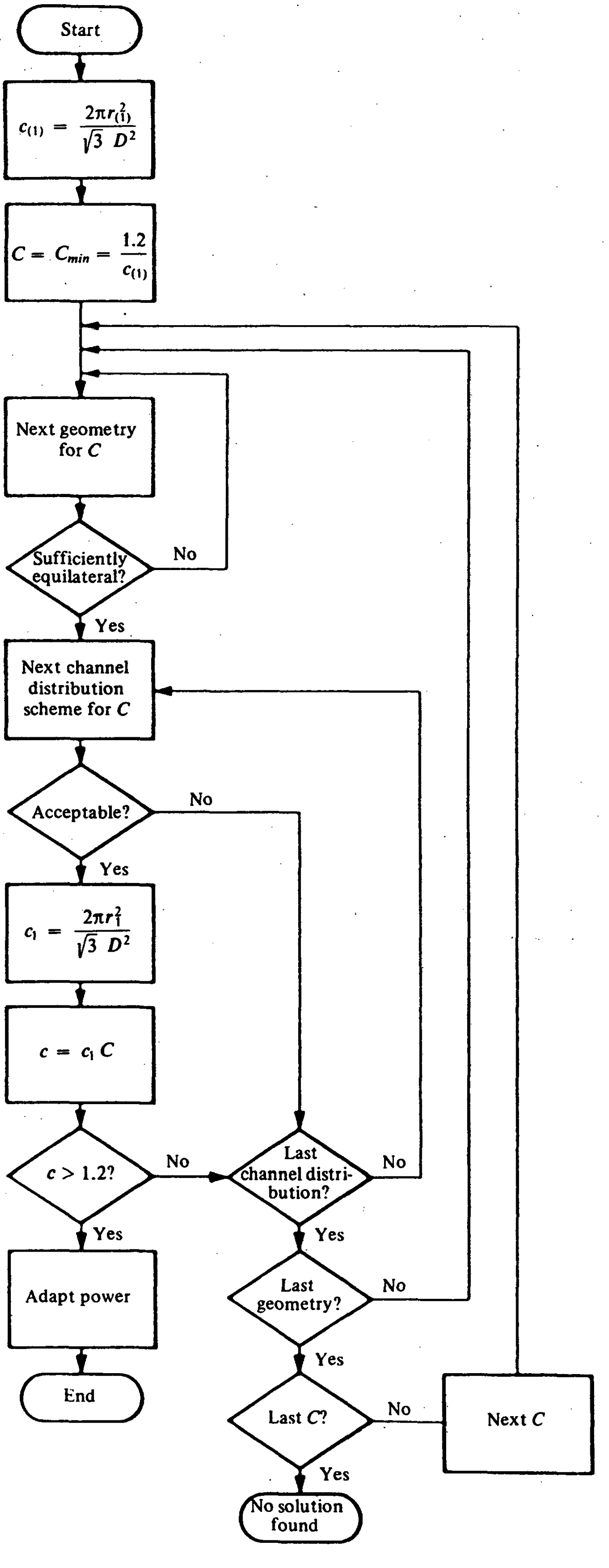


FIGURE 15 – *Flow-chart for determining regular lattices*

4. Multiple coverage and channel grouping

Having solved the optimization problem of obtaining full area coverage with a minimum number of channels, it is fairly easy to solve the problem of providing full area coverage with more than one programme. It is obvious that the number of channels, C, necessary for coverage with P programmes is $C_P = CP$. This may be achieved either:

- by extending the cyclical system of C channels to comprise P cycles of C channels each; in Fig. 11 this solution is shown for $C = 7$ and $P = 2$. This solution takes advantage of the fact that in a cyclical system channels $C - 1$ and C are already adjacent to each other. Hence, in principle, no further interference will need to be considered with the only exception of those types of interference which were not previously involved because of the small number of channels used. For example, in Fig. 12, as only 7 channels are used, no image-channel interference can arise from channel +9. This will change when multiple coverage with 7 channels per programme is envisaged since channel 2 in the second network is 9 channels above channel 0 in the first network, etc.;
- by treating the entirety of C_P channels as a whole, i.e., a single lattice of C_P channels.

The first method ensures identical coverages with P programmes, apart from specific exceptions such as smaller adjacent-channel interference levels on the highest and lowest channels. It provides equal channel spacings of transmissions at each site, which can be considered to have both advantages and disadvantages. The second method is more flexible since the number of lattice solutions increases with the total number of channels. It involves grouping together P lattice assignments at each single site. These should be selected from points in close proximity to each other. If more than two channels are grouped at a single site and the channels are obtained from a straight line through the lattice, they will, as with the first method, have equal spacings.

The grouping implied in the second method involves a certain amount of distortion of the basic lattice. This need not be detrimental but it is obvious that it is the elementary triangles resulting from the grouping rather than those of the original basic lattice which should be near-equilateral. For this reason basic solutions with elementary triangles which are far from equilateral may be of interest.

5. Non-linear distributions

It was stated earlier that non-linear channel distributions may also provide valid solutions, but are generally less manageable. Figure 16 shows such a non-linear distribution based on a 9-channel lattice by way of example. This has the feature of providing a lattice with co-channel and elementary triangles that are both equilateral even though 9 is not a rhombic number. It may be seen that this distribution does not have the property of equal steps in channel numbers in any one direction through the lattice. Because of this, interference levels will not necessarily be the same at all transmitter locations.

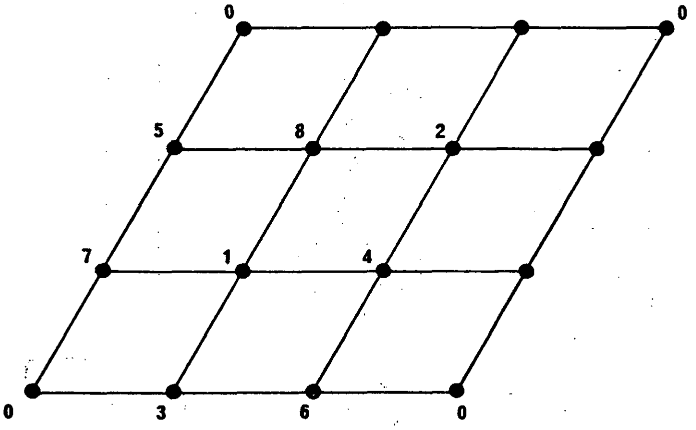


FIGURE 16 – *Example of non-linear network for 9 channels*

REPORT 485-1

CONTRIBUTION TO THE PLANNING OF BROADCASTING SERVICES

(Question 4/11, Study Programme 4B/11)

(1970–1982)

PART I

STATISTICS OF SERVICE

1. The protection ratio is frequently used in the planning and assignment of broadcast stations and service, both visual and aural. It is usually defined as the minimum permissible power ratio of the wanted-to-interfering signals available at the receiver input, to provide the desired quality grade of service. Because the field strengths which induce the receiver input signals vary with time and from location to location it is necessary to include some of the statistics of this variability in the description of service and for the protection of this service.

The television or frequency-modulation broadcasting service to a relatively small area in the presence of a single source of interference may be described by an algebraic-statistical equation (1). A small area is one for which changes in the type of terrain and in the distance from the pertinent transmitting antennas are negligible in terms of determining the median values of field strength.

$$R(Q) = E_d(50,50) - E_u(50,50) + G_d - G_u - H(T) - H(L) \tag{1}$$

where

$$H(T) = k(T) \sqrt{\sigma_{td}^2 + \sigma_{tu}^2}$$

$$H(L) = k(L) \sqrt{\sigma_{ld}^2 + \sigma_{lu}^2}$$

$R(Q)$: protection ratio (dB) of the wanted to the interfering signal at the receiver input required to provide a service quality Q under non-varying conditions. Subscripts d and u refer to the wanted and unwanted signals, respectively;

$E(L', T')$: the level of field strength exceeded for T'% of the time in at least L'% of the locations (dB rel. 1 µV/m);

$E(50,50)$: median field strength in time and location (dB rel. 1 µV/m);

G : effective receiving antenna gain in the pertinent direction (dB);

$k(X)$: standard normal variate, tabulated in many statistical textbooks:

$k(50) = 0$; $k(70) = -0.525$; $k(90) = -1.282$; $k(99) = -2.326$;

σ_t : standard deviation for variation in field strength with time (dB);

σ_l : standard deviation for variation in field strength from location to location (dB).

For the purpose of describing service, equation (1) may be interpreted as follows. If service of quality grade Q is defined to be available at a given location only when the protection ratio at the receiver input exceeds the required value $R(Q)$, i.e. the non-varying protection ratio is exceeded for T% of the time, then in the area for which equation (1) holds, at least L% of the locations will have this quality of service, $Q \cdot H(T)$ and $H(L)$ are the factors which represent the effects upon the service to the area of the signal variability in time and with location, respectively.

In equation (1) the following assumptions have been made:

– the various fields have approximately Gaussian distributions both in time and with location. Experience [USA] indicates that this is a fair approximation between the 5% and 95% levels;

- both the time correlation and location correlation between the desired and interfering signals are negligible. Terms including these correlation terms may be added to the radicals of $H(T)$ and $H(L)$, if desired;
- the variability in antenna gain throughout the small area is assumed to be negligible. Terms for the variability in antenna gain may be added to the radical of $H(L)$ but such terms should be minor for outdoor installations compared with the location variability of the field strength.

It is noted from equation (1) that there are three interdependent parameters needed to describe the service to the area – i.e. Q, L, T. For convenience, Q and T are usually standardized and with these standard values of T and Q a value of L may be computed from (1). For example, Q may be chosen as "satisfactory" service and T as 90% or 99%. When several sources, i, of interference, including noise, are present at the area, the L_i for each source of interference acting independently and alone may be computed from equation (1), and the resultant L may be computed as the product of the values of L_i so long as the values of Q and T are the same for the individual computations of L_i [USA].

$$L = \prod_{i=1}^{i=n} L_i = L_1 L_2 \ldots . L_n \tag{2}$$

The above resultant value of L is a reasonably good approximation for values of L equal to 50% or greater.

Equation (1) may be rearranged to give:

$$R(Q) + H(T) + H(L) = Ed(50,50) - E_u(50,50) + G_d - G_u \tag{3}$$

The right-hand side of equation (3) is recognized as being equal to the ratio of the median value of the wanted-to-interfering signal powers at the receiver input. When the signals are of the non-varying type, $H(T)$ and $H(L)$ are zero and the ratio of the median values of the receiver input powers is equal to the ratio $R(Q)$. But, when there is time and location variability (and T or L exceeds 50%) a greater ratio of median receiver input powers is required for the same quality of service Q, the increase being represented by $H(T)$ and $H(L)$ for time and location variability in signal strength, respectively. In effect, a statistical, multi-dimensional protection ratio may be created to represent the left-hand side of equation (3).

For allocation and assignment computations $R(Q)$ may be combined with $H(L)$ and sometimes $H(T)$ to create a new multi-dimensional power input statistical ratio which is more easily used with available propagation data. These ratios have often been confused with the non-varying protection ratios. When possible $H(T)$ should be combined with the median values of field strength to avoid the creation of a statistical protection ratio which varies with distance.

For protection of service areas iso-service contours of equal location probability L(Q and T being preset) are drawn to depict the coverage of the broadcasting station and these iso-service contours are protected. Standard values for L need to be adopted by the CCIR in addition to presently recognized standards for T and Q, to set protection standards for iso-service contours under conditions of signals variable in time and with location.

2. Co-channel television interference

For this type of protection, $H(L)$ is combined with $R(Q)$, and $H(T)$ is merged with $E_u(50,50)$. Thus, under the assumption that the time fading ranges of the interfering fields are at least twice as great as those for the wanted fields:

$$R(L, Q) = R(Q) + H(L) \approx E_d(50,50) - E_u(50,100 - T) + G_d - G_u \tag{4}$$

$$E_u(50,50) + H(T) \approx E_u(50,100 - T)$$

$R(L, Q)$ is convenient for use in computations to protect the service of the wanted station, especially since it is not dependent upon distance. However, $R(L, Q)$ may be frequency dependent, since $H(L)$ is frequency dependent, as shown in Table I. This Table is given as an example only and for various types of terrain, the values of σ may be higher or lower than those given.

3. Adjacent-channel interference

When the fading of the interfering signal is much smaller than that for the wanted signal, $H(T)$ may be combined with $E_d(50,50)$. Such would be the case for adjacent-channel interference in System M, if the value of $R(Q) = -20$ dB, as proposed in [CCIR, 1966-69] is adopted. For such conditions:

$$R(L, Q) = R(Q) + H(L) \approx E_d(50,T) - E_u(50,50) + G_d - G_u \quad (5)$$

$$E_d(50,50) - H(T) \approx E_d(50,T)$$

When the time fading of the wanted and interfering signals are approximately the same, $H(T)$ cannot be conveniently combined with one of the median field strength signals. $H(T)$ is then assumed to have a typical value which is independent of distance, and is combined with $R(Q)$ and $H(L)$.

$$R(L, T, Q) = R(Q + H(L) + H(T) \approx E_d(50,50) - E_u(50,50) + G_d - G_u \quad (6)$$

4. Conclusion

It is concluded that defining only the non-varying protection ratio for the broadcast services is not sufficient to define the quality of a service nor to define protection requirements for such service. It is also necessary to define the percentage of time T for which this ratio is to be exceeded as well as the percentage of locations L for which the desired quality of service Q is desired. Given this more completely specified statistical quality of service, available propagation and antenna pattern data may be employed to determine the ratio of wanted to interfering field strengths which may be needed to provide the required protection. From these field strengths the required service contours and station separation may be compiled.

TABLE I - *Examples of values for H(L)*

Frequency (MHz)		70	100	200	700
$\sigma_{ld} = \sigma_{lu} = \sigma_l$	(dB)	7	7	8	12
$H(50)$	(dB)	0	0	0	0
$H(70)$	(dB)	− 5	− 5	− 6	− 9
$H(90)$	(dB)	−12	−12	−15	−22
$H(99)$	(dB)	−23	−23	−26	−39

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PART II

DEFINING QUALITY OF SERVICE FOR TELEVISION BROADCASTING

1. Introduction

Part I indicates that three inter-dependent parameters, i.e. quality grade, location and time, are required to describe service to an area. Standardization on these parameters is essential in planning for the protection of a television service and an approach towards this objective is outlined in the following sections.

2. Grading system

Before agreement can be reached on which grade of service should become standard, it is essential to agree on the classification system to be used. The 5-point scale system used in Recommendation 500 appears satisfactory for this purpose. It would, however, be useful to have the grade identified in terms of the median as required in the calculation methods suggested in Part I, § 1. While Annex II to Report 405 indicates methods for assessing the impact of additional interfering signals on quality grade, these approaches do not take the location parameters into account.

3. Percentage of time

Recommendations 417 and 418 indicate that the broadcasting service should be protected for a period of time between 90% and 99%. If the period of time selected is 90% it means that the desired quality of service will not be met 10% of the time. Moreover, since the minimum quality of service during that 10% of the time is not specified it could be of unusable quality and still meet the indicated objective for broadcasting. The quality of service during the worst 1% to 10% of the time is a factor which, under certain conditions, must be taken into account.

In the case of interference from other television broadcasting stations it is not really essential to specify the quality of service during the worst 1% to 10% of the time because of the nature of propagation variation, i.e. if good quality is available 90% of the time, the quality would not be unusable in the remaining 10% of the time but rather it would deteriorate gradually for smaller time intervals. If, however, the interference source is intermittent (e.g. from a land mobile system) and the percentage of "on" time is factored into the protection criteria for broadcasting, it is evident that the normal 90% to 99% protection times may have to be increased in order to avoid the possibility of unusable signals 10% to 1% of the time. Moreover, in some cases the "on" time interval is difficult to establish or control especially if multiple interference sources are permitted. It is therefore suggested that such interference sources may have to be considered as transmitting continuously when assessing their impact on television.

4. Standardization of Q and T

Equation (3) in Part I describes the relationship between the "service quality" grade Q, percentage of locations L, and percentage of time T. In terms of Recommendation 500, Q must be interpreted as the *impairment* grade due to interference and/or noise.

It is evident that it is possible to describe the same service in terms of all three parameters Q, T, L in an infinite number of ways. If, however, two of the parameters are fixed, the third variable may be used to complete the description of service. Thus if appropriate values for Q and T are fixed, the service can be described in terms of the corresponding L.

Since Q and T may take on a range of values it is suggested that boundaries on these values be determined. Recommendation 417 implies that at least a satisfactory grade of service is required in the absence of interference before protection may be sought. It is recommended therefore that Grade 3.5 be used as the lower boundary. Within the prime coverage area of a television transmitter however, a performance somewhat better than Grade 3.5 is generally expected at most locations. Since Grade 5, for various reasons, is often unachievable in practice, it seems inappropriate to standardize on it. On the other hand, Grade 4.5 with its minor imperfections, is usually achievable with adequate signal strengths and it is therefore recommended that Grade 4.5 be used as the upper boundary in terms of picture impairment for standardization purposes.

Recommendation 417 indicates that the percentage of time for which protection may be sought should lie between 90% and 99%. It is therefore recommended that 90% and 99% of the time be used as the lower and upper boundaries of time for standardizing on quality of service in the absence of interfering signals.

It is suggested that if the two lower boundaries (i.e. Grade 3.5, 90% of the time) are applied to the extremity of the coverage area and the two upper boundaries (i.e. Grade 4.5, 99% of the time) are applied to the prime coverage area, it will agree with the general expectations of planners for television service.

5. Percentage of locations

While this parameter is an essential factor in describing the quality of broadcast service no attempt has been made at standardization. Several approaches to standardization are possible and a relative rather than an absolute standard is proposed herein. The reference impairment proposed in this case is that ensuing from thermal noise as the only source of impairment. The objective of this approach is to ensure that a significant percentage of viewers are unaffected by the introduction of interfering sources.

With respect to standardizing on the percentage of locations which should receive the standardized values of Q and T, two options exist. It is possible to specify the percentage of locations directly and, by making estimates regarding typical receiving installations, determine the corresponding median field strength. Alternatively, it is possible to specify a median field strength and, by making estimates regarding typical receiving installations, determine the corresponding percentage of locations. Of these two, the second option is preferred, firstly because a field strength level is more readily confirmed than a percentage of locations, secondly because the percentage of locations does not have to be determined with accuracy for the purpose of calculating protection from interfering sources, and thirdly because a definite field strength for the desired signal is the most useful parameter for the purpose of calculating protection ratios. The relationship between field strength, quality of service and assumptions is described elsewhere [O'Connor, 1968]. In the absence of interference the field strengths close to those given in Recommendation 417 can provide Grade 3.5 service 90% of the time at approximately 60% of the locations (5-point scale). Field strengths some 17 dB greater can provide Grade 4.5 service 99% of the time at approximately 75% of the locations [CCIR 1978-82].

6. Suggested standard

It is therefore suggested that agreement be reached to adopt impairment Grade 3.5 for 90% of the time at the extremity of the protected area and Grade 4.5 for 99% of the time at locations where median field strengths are at least 17 dB greater than at the extremity. If agreement can be reached on these or similar criteria, a simple method of assessing the impact of interfering sources on reception quality becomes available.

7. Interfering sources

Part I shows that, where an interfering source is present and is expressed in terms of the same Q and T of the desired signal, the resulting L (provided L is greater than 50%) may be estimated as the product of L_d and L_i, where L_d is the percentage of locations receiving the desired quality in the absence of interfering signals, and L_i is the percentage of locations which would receive the desired quality if the interfering signal were the only additional source of degradation. L_i is therefore proportional to the number of locations which would continue to receive the stated Q and T after the introduction of the interfering signal. Thus once agreement has been reached on standardized values of Q and T, the impact of an interfering source can be estimated simply by requiring the interfering source to be expressed in terms of the same Q and T and then specifiying the value of L_i. For example, L_i would have to have a value of 90% if it is desired to ensure that service in a coverage area is not degraded at more than 10% of the locations receiving the desired quality in the absence of interference.

The value of L_i which is acceptable may vary depending on the nature of the interference, the location within the coverage area for which protection is sought, and the protective measures which might be taken.

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REPORT 1086-1

FREQUENCY PLANNING CONSTRAINTS

(625-line systems)

(Question 43/11)

(1986-1990)

1. Introduction

In order to ensure effective planning of terrestrial television broadcasting services in the frequency ranges 47-68 MHz (Band I), 174-230 MHz (Band III) and 470-960 MHz (Bands IV and V), it may be necessary to take into account certain constraints on the use of frequencies in order to avoid interference to other TV broadcast transmissions and to ensure compatibility with other broadcasting services, e.g. with the sound broadcasting service in the frequency range 87.5-108 MHz.

This Report identifies the constraints that may result from the technical limitations of receiver design and also from the transmission of several TV and VHF/FM sound broadcast programmes from the same site or from non co-sited transmissions with overlapping service areas. Co-channel, adjacent-channel and image-channel transmissions are dealt with in Recommendation 655.

Interfering signals can be maintained at acceptable levels by ensuring sufficient geographical separation between the transmitting stations involved, but the limited part of the spectrum allocated to television broadcasting services requires economy in frequency usage and demands the re-use of channels at distances as short as possible.

No account is taken of interference resulting from radiation of harmonics and intermodulation products at transmitter sites, on the assumption that the broadcasting authority can take the necessary precautions to reduce such spurious radiation to acceptable levels.

2. Constraints introduced by television broadcast receivers

2.1 *Television receiver local-oscillator radiation*

Because of the possibility of interference being caused by the use of superheterodyne receivers, the use of certain channels is precluded.

Except for system L and some system K1 receivers, local oscillators operate at frequencies between 38.0 and 40.2 MHz above the vision carrier of the wanted signal. Hence, if the channel separation is 7 or 8 MHz and channel *n* is used by one service, the choice of channel *n* + 4 or *n* + 5 for a neighbouring service depending on the system used (see table in § 4) would result in interference being caused from local oscillators in receivers which are tuned to channel *n*.

For system L and some system K1 receivers, the local oscillator operates at a frequency 32.7 MHz below the vision carrier of the wanted signal and the affected channel in this case is n-4.

The above information is derived from Report 625.

Additionally, with such a difference in channel numbers, interference caused by an intermediate frequency beat may occur. In practice, these problems are gradually decreasing with improved receiver technology.

Radiation from television receivers in the range 47-68 MHz may affect VHF/FM reception. This may occur when the television local-oscillator frequency lies near the carrier frequency of a VHF/FM transmission (see Report 946).

2.2 *Image channel*

Image-channel interference occurs when transmissions are separated by about twice the intermediate frequency. The image channel affecting receivers tuned to channel *n* would be *n* + 9, except for systems B (*n* + 10), for systems D and K (*n* + 8 and *n* + 9), system K1 (*n* + 9 and *n* + 10) and system L (*n* − 9).

Although the improved image-channel rejection characteristics of modern receivers minimize the problem, rejection is not complete and the situation should be avoided in preparing a frequency plan. Image-channel interference is not a problem within Bands I and III.

2.3 *Harmonics from VHF/FM receiver local-oscillators*

Second or third harmonics of VHF/FM receiver local-oscillators, depending on whether the local-oscillator frequency is high or low respectively, may fall within Band III. It would therefore be preferable to choose the VHF/FM transmission frequencies and the television channels in such a way that this condition does not occur; however, this can not be generally taken into account when preparing frequency plans.

2.4 *Harmonics and intermodulation products generated under overload conditions in receivers*

High input levels of VHF/FM and/or television signals can lead to non-linearities in the input stage of receivers, giving rise to the generation of harmonics and intermodulation products. A general consideration of such interference mechanisms when elaborating a frequency plan is not possible. Problems should be solved on an individual basis, e.g. notch filters and attenuators might be used in the receiving installation.

3. Transmitting antenna system limitations

In many instances, co-sited television transmissions may utilize a common antenna system. The minimum possible frequency separation is determined by the practical design limitations of combining units.

For planning purposes, the minimum frequency spacing should in general be not less than 2 channels in Bands I and III and 3 in Bands IV and V. Although it is also technically feasible to design combining units to operate at spacings down to 2 channels in Bands IV and V, these may become more expensive, particularly for high power transmitters.

It is theoretically possible to assign adjacent channels to co-sited transmitters provided that two emissions are orthogonally polarized and with similar e.r.p. However, there are likely to be significant engineering problems at the transmitter site. In addition, severe problems are to be expected at receiving installations which will have to use separate antenna systems to receive the two signals.

4. Conclusions for television planning procedures

Table I indicates, for the various television systems, the differences in channel numbers which should be avoided for co-sited transmitters, because of radiation from local oscillators or image-channel interference. For non co-sited transmitters with overlapping coverage areas, the problems are considered to be less severe. It would be prudent, however, to avoid those channel relationships in initial planning.

TABLE I

System	Difference in channel numbers	
	Local-oscillator radiation	Image-channel interference
Bands I and III		
B, I, K1	5	–
D, L, K1*	4	–
Bands IV and V		
B	5	10
D, K	4	8, 9
G, H, I	5	9
K1	5	9, 10
L, K1*	4	9

* if the same local oscillator frequency as system L.

It should be noted that these constraints refer to uniform channel spacing for the whole planning area. In the case of transmitters using different systems and/or different channel spacings, with overlapping coverage areas, a detailed case-by-case investigation is necessary.

REPORT 1087-1*

FREQUENCY SHARING BETWEEN THE BROADCASTING SERVICE (TELEVISION) AND THE FIXED AND MOBILE SERVICES BELOW 1 GHz

(Question 39/11)

(1986-1990)

1. Introduction

The WARC-79 increased the number of frequency bands that might be shared between the broadcasting service and the fixed and mobile services below 1 GHz.

This Report examines possible criteria for sharing the spectrum between these services.

2. Possible ways of sharing

If the same portion of the frequency spectrum is allocated to two or more services, sharing may be effected in one of the following ways:

- use of the same frequency band by different services at different times;
- simultaneous use of different parts of the shared bands by different services;
- simultaneous use of the same parts of the shared bands by different services, but in separate geographical areas;

2.1 *Sharing by using separate hours of operation*

As channel assignments to broadcasting stations are usually made on an unlimited time basis, time sharing appears impossible. In practice, broadcast schedules often indicate that the stations are out of operation for several hours each day, and sharing might then seem feasible. However, apart from the fact that the timing of schedules will vary from country to country, broadcast transmissions for maintenance purposes outside programme hours are essential. In addition, important events may require substantial extension of the normal programme schedules from time to time. Furthermore, considerable expansion of the hours of television broadcasting can be foreseen. Under these circumstances it may be difficult, if not impossible, to reach a time-sharing agreement on even a national basis without limiting the present broadcasting services and prohibiting further expansion.

2.2 *Sharing by using separate frequencies of operation*

This type of band sharing requires, in its simplest form, a subdivision of the allocated bands into different parts. However, this is not really a case of frequency sharing, because each individual part of the spectrum could be expected to be allotted to only one service on a national basis.

In more complex cases, sharing of this type could mean the use of frequencies, or frequency ranges, by one service interleaved with the frequencies used by the other service. This situation can be found, for example, in band 9 in those parts of the European Broadcasting Area where system G is used. Sharing under these conditions may be considered to be a possibility. It should not, however, be overlooked that the number of countries in which this type of sharing might be implemented is fairly limited and that the planning of the television services in this band has been made on the basis of protection ratios which apply for 8 MHz channel separation.

* This Report constitutes a partial answer to Question 39/11. It should be brought to the attention of Study Groups 8 and 9.

2.3 *Sharing by geographical separation*

This simultaneous use of shared bands by different services in separate geographical areas should be such that each service is not essentially affected by interference from the other service. Whether or not two different services can share the same part of the spectrum under these conditions, depends on several factors including propagation, the minimum field strength to be protected, and the required protection ratio.

Service areas of television transmitters can be presented in the form of maps, where the limit is determined by a field-strength contour derived from statistical propagation curves. The actual service area will normally differ due to terrain irregularities. For the broadcasting service, it is essential that the actual service area be protected against interference from other services. Consideration should also be given to the need to afford protection for rebroadcast purposes. The greatest care must therefore be taken to identify the area in which protection of the broadcasting service is required.

When the present bands 8 and 9 were planned for television, careful consideration was given to protection from stations in the television service. Individual stations, rebroadcast stations and networks were established without regard to the possibility of frequency sharing with other services in the future. These television systems may therefore be very sensitive to interference from a completely different service. Where sharing is contemplated, great care must be exercised if established viewing patterns are not to be adversely affected.

Another possibility is to interleave within a television channel at frequencies or frequency ranges between the vision carrier, the colour sub-carrier and the sound carrier, where the protection required is relatively low. However, existing CCIR texts contain limited information about the interference potential of the television signal to other services. This problem needs further study. It should be noted that, particularly in Bands I and III, the feasibility of sharing of this type may be complicated by the use of overlapping television channels.

Nevertheless, careful planning of frequency assignments to stations of the fixed and/or land mobile services might lead to further improvements in spectrum utilization without resulting in additional interference to broadcasting stations operating in the same frequency range. However, it seems to be inevitable that sharing with other services would lead to a reduction in flexibility for the further development of the broadcasting service. The addition of new broadcasting stations, and the re-assignment of channels to existing stations, will become more difficult, the more extensively the band is shared. This holds true when the other service is operated on a secondary or permitted basis, whereas any further development of the broadcasting service could be rendered impossible when the other service is operated on a primary basis.

3. Out-of-channel interference

It is known that the broadcasting service is susceptible to interference by stations of another service at frequencies outside the wanted channel. Overloading effects, neighbouring channel interference, image-channel interference or oscillator radiation can lead to a deterioration of the service provided by a broadcasting station if care is not exercised. A study carried out in Ireland on interference effects from mobile stations to broadcasting reception when the bands allocated are adjacent to one another indicates that care has to be taken when different services make use of adjacent bands in the same area. Further study is needed to assess the problem more fully.

4. Basic considerations for the establishment of sharing criteria

In considering the case of interference from stations of other services to the broadcasting service, it is necessary to recognize that the public is very sensitive to interference to broadcasting reception. It is therefore desirable to protect not only the service areas but also to take into account areas of poor reception. This is perhaps more important in cases where the broadcasting service has been well established for a long period of time.

Criteria for the protection of the broadcasting service (television) are given in the Annex. In the application of these criteria, the following points should be taken into account:

4.1 *Minimum field strengths to be protected*

According to Recommendation 417 the minimum (median) field strengths for which protection may be sought in planning are 48, 55, 65 or 70 dB(μV/m) for Bands I, III, IV and V, respectively. It is noted that some countries may use different values.

Improvements have been made in television receivers, antennas and preamplifiers, and many viewers enjoy adequate reception with field strengths lower than those shown above. Present coverages sometimes take this into account by allowing for secondary service zones.

In such instances it would be desirable, or even essential, to seek protection to lower values, the level being determined by the available field strength of the wanted signal and the degree of protection against interference already afforded. With respect to these requirements for protection, values as low as 46, 49, 52 and 58 dB (μV/m) for Bands I, III, IV and V are given in Report 409; corresponding values adopted by the RARC, Nairobi, 1986 were 46, 49, 53 and 58 dB (μV/m).

4.2 *Interference assessments*

Interference assessments should be made for several reception points within the service area of the television transmitter. These points should be those which would seem to be most likely to suffer from interference.

4.3 *Rebroadcast stations*

For rebroadcast stations, it is necessary to ensure that both the received and transmitted television channels are protected against interference.

4.4 *Mobile stations*

The area in which mobile stations operate must be well defined. Two general categories can be identified:

a) The mobile station can operate in areas close to the service area of the television station;

b) The mobile station can only operate in areas which are well separated from the service area of the television station.

In category a), calculations need to be made for locations of the mobile station nearest to the service area of the broadcasting transmitter and for more elevated locations within the mobile operation area using appropriately increased effective antenna heights. It is also necessary to consider the problem of overloading in cases where the mobile station operates close to a television receiving site.

In category b), a reasonable simplification of the problem is to assume that interference from a mobile station, operating anywhere within the service area of its base station, may be regarded as originating from an antenna of appropriate height situated at the base station site. This approximation is likely to be valid only in the case where there is a separation distance of at least 150 km between the nearest points of the land mobile service area and the television service area. Under these circumstances, the propagation curves of Recommendation 370 indicate only a small variation of field-strength with distance or with change of effective transmitting antenna height. Thus, the precise location of an individual mobile station makes little difference. It can be considered appropriate to use an effective antenna height of 75 m for the pseudo transmitter (with the same erp as the mobile station) as this corresponds to a common height for land mobile service base stations.

However, the field-strength value derived in the above process will be higher than that given by real mobile transmitters because the actual antenna height of the latter will be only about 3 m. Radiation from the mobile antenna will be subject to losses from the local environment, principally clutter loss at higher frequencies (UHF) and ground reflection effects at lower frequencies (VHF). While no precise value can be given for the field-strength adjustment factor needed to account for these losses and the change in effective height from 3 m to 75 m, reasonable estimates of the adjustment factor fall in the range -9 to -20 dB (for a separation distance of at least 150 km), independent of frequency. The range of adjustment values is intended to deal with the range of practical cases from that of a base station with a similar height to the service area of the mobile stations to that where the base station site is relatively elevated. Further investigations of this adjustment factor are needed. The CCIR report to the RARC AFBC(2) proposes, for planning purposes, a value of -15 dB should be used.

5. Conclusion

The possibilities of sharing between the television broadcasting service and the fixed and mobile services have been studied generally with the aim of forming a basic framework for the establishment of sharing criteria. Only the effects of sharing on the broadcasting service have been taken into account.

Extensive studies are necessary to assess the effects of sharing quantitatively before being in a position to firmly establish sharing criteria.

EBU studies [CCIR, 1982-86] covering part of Europe have shown that from consideration of existing average co-channel distances in the television networks, and of minimum separation distances for base stations of the land mobile service in Bands I and III, the following could be tentatively concluded:

- in Band I, base stations of the land mobile service may normally be inserted in the existing, not completely exploited TV spectrum. The interfering effect on the receiving end of transposers has not been taken into account and may be the more critical factor in some instances;
- in Band III, base stations of the land mobile service could normally be inserted only in TV networks which are built up of high-power transmitters only. In fact, the base stations would in this case replace the low-power transmitters of the TV service in a country and make further development of the TV networks in that country impossible;
- the interfering effects of mobile stations need further study;
- the specific possibilities of sharing may differ widely, both from country to country and within a single country.

REFERENCES

CCIR Documents

1982-86]: 11/249 (EBU).

ANNEX

Criteria for the protection of the broadcasting service (television) from the fixed and mobile services in the shared bands below 1 GHz

1. Minimum field-strength values to be protected

The minimum values of field-strength for the broadcast service (television) which require protection from the fixed and mobile services are:

46 dB (μV/m) in Band I at 10 m above ground level
49 dB (μV/m) in Band III at 10 m above ground level
53 dB (μV/m) in Band IV at 10 m above ground level
58 dB (μV/m) in Band V at 10 m above ground level

The values have been adopted by the RARC, Nairobi, 1986.

It is noted that some countries may use other values.

2. Protection ratios

Ratios for the protection of AM vestigial sideband television systems against overlapping channel interference are given in CCIR Recommendation 655, Sections 5 and 6. The values for a non-controlled condition should be used.

3. Protection margin

The protection margin (PM) is given, in dB, by:

PM = FS - combined value of (NF + AF) for all interfering sources

where: FS is the minimum field-strength value in dB (μV/m) given in Section 1,
NF is the nuisance field in dB (μV/m) discussed in Section 3.1,
AF is the adjustment factor (in dB), intended to deal with antenna discrimination and clutter loss, discussed in Section 3.2.

The combination of multiple interference from co-sited and non co-sited sources is discussed in Sections 3.3 and 3.4, respectively.

The calculated protection margin should be positive at all locations where the television service is required.

3.1 Nuisance field (NF)

The calculation of nuisance field is given in Annex 1 to Recommendation 655. The field-strength, for t%* and 50% time, from the interfering source should be calculated using Recommendation 370 and Report 239. Information regarding fixed stations or base stations of the mobile service with effective antenna heights of less than 37.5 m is given in Section 4 below.

3.2 Adjustment factor (AF)

Four distinct cases of interference to a station of the television service from stations of the fixed or mobile services can be identified, these are dealt with separately below.

3.2.1 Interference from stations of the fixed service or base stations of the mobile service which are orthogonally polarized with respect to a station of the television service.

In this case the adjustment factor is equal to the antenna discrimination of -16 dB, as given in Recommendation 419.

3.2.2 Interference from stations of the fixed service or base stations of the mobile service which have the same polarization as a station of the television service.

In this case the adjustment factor is equal to the relevant receiving antenna directivity discrimination value given in Recommendation 419.

3.2.3 Interference from a mobile station operating at more than 150 km from a station of the television service.

No polarization discrimination can be taken into account because:

- the mobile transmitting system, consisting of an antenna and the body of a vehicle, cannot be assumed to radiate with only horizontal or vertical polarization;

- the effect of environmental clutter near the mobile transmitting can be expected to introduce a degree of depolarization.

It would be impracticable to carry out calculations for all possible mobile station locations, taking account of propagation losses and receiving antenna directivity discrimination. A reasonable simplification of the problem is to carry out interference calculations for the erp of the mobile station assuming this to be situated at the base station site with an effective antenna height of 75 m. It is then appropriate to use an

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* Between 1 and 10%. The precise value of t within this range should be specified.

adjustment factor of between -9 and -20 dB* to allow for the effect of clutter loss and ground reflection effects near the mobile station.

In some cases it may be possible to include an additional adjustment to allow for the directivity of the television receiving antenna, as given in Recommendation 419.

3.2.4 Interference from a mobile station operating relatively close to a receiving site from a station of the television service.

In this case, it is necessary to carry out detailed calculations for individual, worst-case paths. No polarization discrimination can be taken into account, for the same reasons as are explained in item 3.2.3.

3.3 Multiple interference from co-sited sources

The interference arising from multiple co-sited sources should be combined by means of the power-sum method

$$Ec = \sqrt{\sum_{i=1}^{n} Ei^2}$$

Where Ei = The value, in μV/m, of (NF + AF) for each individual co-sited source. As indicated in Section 3, NF is expressed in dB (μV/m) and AF in dB. The sum of these two is converted to μV/m to express Ei.
n = Number of co-sited sources,
Ec = Effective interference in μV/m.

Note: The value of Ec represents one of the terms to be included in the procedure given in Section 3.4, after conversion to dB (μV/m).

3.4 Multiple interference from non co-sited sources

The interference arising from multiple non co-sited sources should be combined by using the simplified multiplication method given in Report 945.

4. Effective transmitting antenna heights

The case of low values of effective transmitting antenna height (<10 m for VHF and <37.5 m for UHF), and especially that of negative heights, is not dealt with adequately within present CCIR texts in Volume V. A method for dealing with this problem has been proposed by the JIWP-AFBC(2) which involves extrapolation from the existing propagation curves and in particular by replacing an effective transmitting antenna height of less than 0 m by 0 m.

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* Further investigations of this adjustment factor are needed.
The CCIR report to the RARC AFBC (2) proposes for planning purposes, a value c -15 dB should be used.

REPORT 626-1

SIMPLIFICATION OF SYNCHRONIZING SIGNALS IN TELEVISION

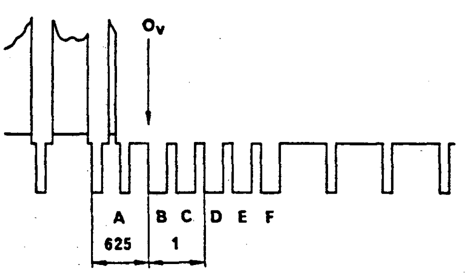
(Question 1/11, Study Programme 1E/11)

(1974-1978)

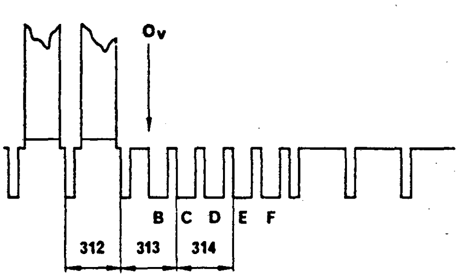
Proposals have been made that the television synchronizing signal should be simplified firstly by reducing the number of equalizing pulses [CCIR, 1963-66; 1966-69; 1970-74a, b and c; Recommendation 472, note (5)] and secondly reducing the number of broad pulses [CCIR, 1970-74a and b]. Study Programme 1E/11 requests investigation into the effect of reducing the number of equalizing pulses.

The simplification of the synchronizing signal leads to a simplification of synchronizing generators and also makes available more line-periods of the field-blanking interval for injecting test or measuring signals, standard reference frequencies [CCIR, 1970-74d], commercial information (e.g. facsimile transmissions), auxiliary audio signals for bilingual programmes, sub-titles for the deaf, remote control and supervision of unattended centres [CCIR, 1970-74b] or for the transmission of any other information.

Studies [CCIR, 1970-74d] have been made which indicate that, in the member countries of OIRT, the characteristics of the receivers are such that the "second" sequence of equalizing pulses may be completely eliminated without deterioration of the quality of line interlace and, furthermore, the number of equalizing pulses in the "first" sequence may be reduced to one of standard duration, according to Fig. 1. These results are confirmed by experiments [CCIR, 1970-74c] carried out in the USSR, not only upon receivers, but also upon monitors, radio-relay equipment, transmitters, video tape recorders and industrial television equipment. These experiments have also shown an improved performance with video tape recorders, receivers and other equipment containing flywheel circuits [CCIR, 1970-74c]. In the USSR, the use of a single pre-equalizing pulse and no post-equalizing pulses (Fig. 1) is permitted. However, the reduction in the number of broad pulses leads to impairment of interlace and other disadvantages, and thus has been proved unacceptable [CCIR, 1970-74c and d]. Following laboratory studies and experiments carried out in operational conditions by the OIRT [CCIR, 1974-78a], it was decided to continue to investigate the possibility of simplifying synchronizing signals.



First field



Second field

FIGURE 1

A : Single equalising pulse at the end of each second field

B, C, D, E, F : broad pulses

Note. – Experiments mentioned in [CCIR, 1970-74a and b] examined effect of deleting broad pulses F and E and replacing them by line sync. pulses where appropriate.

Laboratory experiments [CCIR, 1970-74b] and field trials conducted in Italy [CCIR, 1974-78b] seem to indicate that one pre-equalizing pulse and no post-equalizing pulses are satisfactory for domestic receivers, provided that the single pre-equalizing pulse, situated in the middle of line number 625 (Fig. 1) has a duration of about 2.8 μs. The same set of experiments included tests in which not only was the number of pre-equalizing pulses reduced to one and the post-equalizing pulses absent, but also the number of broad pulses was progressively reduced from five to two (see Note to Fig. 1). It was found that with this form of field-synchronizing waveform, the number of broad pulses could, in the foreseeable future, be reduced to three without appreciable increase in receiver instability.

Experiments carried out in the United Kingdom [CCIR, 1970-74a] on monochrome and colour receivers with a pre-equalizing pulse in the middle of line number 625, no post-equalizing pulses and only three broad pulses (Fig. 1 and Note), revealed that a small but significant number of receivers suffered impairment of interlace, probably due to the 2.5 μs duration of the single pre-equalizing pulse operating upon receivers having integrators with a time-constant less than 100 μs. The reduced number of broad pulses (three) also produced a tendency for the "vertical hold" controls of some receivers to require more critical adjustment.

REFERENCES

CCIR Documents

[1963-66]: XI/115 (United Kingdom).

[1966-69]: XI/55 (USSR).

[1970-74]: **a.** 11/266 (United Kingdom); **b.** 11/309 (Italy); **c.** 11/340 (USSR); **d.** 11/34 (OIRT).

[1974-78]: **a.** 11/53 (OIRT); **b.** 11/423 (Italy).

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[1970-74]: 11/84 and Corr.1 (OIRT).

REPORT 409-4

BOUNDARIES OF THE TELEVISION SERVICE AREA IN RURAL DISTRICTS HAVING A LOW POPULATION DENSITY

(1966-1970-1978-1982-1986)

Where television services are to be provided for a sparsely populated region, in which better receivers and antenna installations are likely to be employed than those considered in Recommendation 417, administrations may find it desirable to establish the appropriate median field strength for which protection against interference is planned as low as shown in Table I.

TABLE I

Band	I	III	IV	V
dB(μV/m)	+46	+49	+58	+64

These values refer to the field strength at a height of 10 m above ground level.

In the absence of interference other than noise, field strengths of the order of 40 dB(μV/m) in Band I, 43 dB(μV/m) in Band III, 52 dB(μV/m) in Band IV and 58 dB(μV/m) in Band V can give satisfactory pictures; however, it is generally observed that the public begin to lose interest in installing television reception equipment when the field strength falls much below these levels.

The values given in this Report have been obtained from field-strength investigations at the edge of the coverage area and picture quality assessments for Bands I and III in rural districts of Australia [CCIR, 1963-66], India [CCIR, 1974-78] and Italy, and for Bands IV and V at both rural. and urban locations in Italy and the United Kingdom [CCIR, 1982-86]. It may be noted that in Bands IV and V where man-made noise is not generally a problem, the field-strength values quoted for rural areas may also be applied in urban areas.

Note. – See Recommendation 417.

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CCIR Documents

[1963-66]: XI/168 (Australia).

[1974-78]: 11/439 (India).

[1982-86]: 11/247 (EBU).

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[1978-82]: 11/333 (Italy).

REPORT 484-2

RATIO OF PICTURE-SIGNAL TO SYNCHRONIZING-SIGNAL

(Question 1/11, Study Programme 1D/11)

(1970-1974-1986)

Study Programme 1D/11 considers the possibility of adopting one single figure for expressing the ratio of picture-signal to synchronizing-signal, for both the video and the radiated signals, independently of the systems employed.

It is considered desirable that such a ratio should reach as high a value as possible, compatible with receiver requirements.

It is felt that, to reduce the relative amplitude of the synchronizing signal below the values normally used, might give rise to difficulties in receivers and some types of studio equipment.

At the present time, the possible values of picture-signal to synchronizing-signal ratios that can be considered for a single standard are as follows: 7/3 and 10/4.

Since the ratio 10/4 is the higher of the two and is more generally used for radiated signals (some countries using it also for the video signal), administrations should consider the possibility of adopting this value in the future.

Recent investigations in the Federal Republic of Germany have shown that it is possible with modern receivers to reduce the relative amplitude of the synchronizing signal significantly, below a value corresponding to a ratio of 10/4. A ratio of, for example, 8/2 can easily be afforded without affecting the synchronization reliability of the receivers [CCIR, 1970-1974]. Further studies should therefore be carried out to investigate the effect of a reduction to such a ratio on all parts of a television system. The cost of the necessary modification of the transmission facilities to a ratio of 8/2 must also be taken into account before administrations can be asked to consider the adoption of such a value in the future.

Recent studies on receivers in India confirm stability with a ratio of picture signal to synchronizing signal of 8/2 [CCIR, 1982-86].

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CCIR Documents

[1970-74]: 11/72 (Germany (Federal Republic of)).

[1982-86]: 11/397 (India).

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REPORT 961-1

TERRESTRIAL TELEVISION BROADCASTING IN THE 12 GHz BAND (BAND VI)

(Question 1/11, Study Programme 1G/11)

(1982-1986)

1. Introduction

Experimental amplitude-modulation terrestrial television broadcasting systems in the 12 GHz band have been set up in the Federal Republic of Germany [CCIR, 1974-78a], in the Netherlands [CCIR, 1974-78b], and in Switzerland [CCIR, 1974-78c] for system G, and in Japan for system M [CCIR, 1974-78d and e]. Further, an operational station for the same broadcasting system has been working in Japan since 1979 [CCIR, 1978-82a].

The WARC-BS-77 has established for Regions 1 and 3 a frequency and orbital position Assignment Plan for the broadcasting-satellite service in the 12 GHz band shared with the terrestrial broadcasting service. The Regional Administrative Radio Conference, Geneva, 1983 has established an analogous Plan for the broadcasting-satellite service in Region 2.

2. Technical characteristics

2.1 *Systems using amplitude modulation*

2.1.1 *Characteristics of the radiated signal*

Both amplitude modulation and frequency modulation are applicable to terrestrial television broadcasting in the 12 GHz band. A system of amplitude modulation requires higher transmitting powers but will allow more television channels.

Amplitude modulated television signals in the 12 GHz band should conform to the standards given in Report 624 so that they can be received by a conventional television receiver equipped with a frequency converter.

2.1.2 *Protection ratio*

The ratio of wanted-to-unwanted signal power at the receiver input is an important factor in planning terrestrial television systems. The protection ratio required when considering interference between two amplitude-modulation vestigial-sideband (AM-VSB) television signals is given in Recommendation 655. The protection ratio between two frequency modulation television signals can be found in Report 634.

The required ratios are essentially independent of frequency band. However, in applying them to the planning of a terrestrial system in the 12 GHz band, it is necessary to take into account both signal fading and the frequency stability of transmitters. With regard to the latter, an experiment in Japan has shown that it is not practicable to use precision offset techniques for AM-VSB systems in the 12 GHz band [CCIR, 1978-82b].

2.1.3 *Equipment characteristics*

2.1.3.1 *Transmitter*

Specifications of AM-VSB transmitters for a terrestrial television service in the 12 GHz band can be virtually the same as those in Bands III, IV and V.

In order to simplify the transmitters, the vision carrier could be amplified together with its accompanying sound carrier, but this may cause intermodulation. In Japan, the ratio of sound to vision power has been altered from 1/4 in Bands III, IV and V, to 1/10 in the 12 GHz band in order to reduce the 920 kHz beat between the sound carrier and the colour sub-carrier.

2.1.3.2 *Receiving equipment*

In experiments so far reported, the frequency converters used at the receiving points have only to change the frequency from the 12 GHz band to a frequency within Bands IV and V. The converter has been mounted directly behind the parabolic reflector, giving rise to negligible feeder loss. Experience gained has led to the conclusion that a converter noise figure of 7 to 10 dB can be realized without excessive cost, and that considering transmitting power, converter noise figure, mounting facilities, beamwidth and influence of wind, an antenna diameter of 40 cm is reasonable.

For establishing the standards for terrestrial television broadcasting in the 12 GHz band in Japan, a converter with a noise figure of 10 dB, equipped with an antenna of 40 cm diameter, was assumed. In practice, converters with noise figures of 6 to 8 dB have been used in Japan.

2.2 *Television using frequency modulation*

For FM television systems, only limited information is available and further studies are required. However, some tests [CCIR, 1982-86] to determine basic propagation conditions have been carried out in the United States of America.

3. The minimum power flux-density

At frequencies above 1 GHz it is common practice to use the power flux-density, expressed in W/m^2, as a measure for the signal strength.

The signal strength in this band has been calculated taking account of the above considerations and of the necessity of having a figure for the planning of a terrestrial amplitude-modulation broadcasting network in the 12 GHz band.

Table I gives the characteristic parameters for the calculation of the minimum power flux-densities, derived from the experimental and operational systems mentioned above.

The power flux-density Φ (dB(W/m^2)) at the receiving point is given by:

$$\Phi = F + 10 \log k\,T\,B + (S/N)_{RF} - 10 \log a \qquad \text{dB(W/m}^2\text{)} \qquad (1)$$

The proposed minimum power flux-densities for a satisfactory grade picture at the receiving antenna range from -85.5 dB(W/m^2) to -70.2 dB(W/m^2) for amplitude-modulation systems. The differences in the values are due to different assumptions for the picture quality, the receiver noise performance and the receiving antenna gain, as shown in Table I.

A minimum power flux-density of -70 dB(W/m^2) has been adopted for the operational AM system in Japan.

4. Polarization of transmission

Measurements of scattered waves from objects local to the receiving antenna have been carried out in the 12 GHz band in urban Tokyo. From the results, it has been found that the use of horizontally- or vertically-polarized transmission is advantageous over circularly-polarized transmission to reduce interference to other service areas where orthogonal polarization is used. Although it has been found that there is an advantage in using circularly-polarized transmissions to reduce multipath interference (see Report 562), in practice multipath interference need not be taken into account. Measurements in urban areas of Tokyo have shown that picture impairment, due to multipath interference alone is no lower than grade 4 on the 5-grade scale (Recommendation 500), provided that the impairment due to noise is no lower than grade 3 or the field strength is not more than 20 dB below the free space value. This performance can be achieved by using a parabolic reflector receiving antenna of at least 40 cm diameter and a frequency converter having a noise figure of 6 dB [Saito *et al.*, 1977].

In Japan, the transmissions are normally horizontally polarized, but where necessary, vertical polarization is used.

TABLE 1

Television system		G (Germany, Federal Republic of)	G (Switzerland)	M ([1]) (Japan)	G/FM (Switzerland)
Noise figure of converter (dB)	F	10	9	10	9
Radio-frequency signal-to-noise ratio at input to television receiver (dB)	$(S/N)_{RF}$	43 ([2])	40 ([3])	42	19 ([4])
Diameter of parabolic reflector (m)	D	0.6	0.6	0.4	0.6
Efficiency of antenna (%)	η	50	–	50	–
Miscellaneous losses in reception (misalignment etc.) (dB)	L	–	–	2	–
Antenna gain (dB rel. isotropic radiator)	G	34.5	34	31	34
Effective antenna area 10 log a (a in m^2)	A	– 8.5	–	– 14	–
10 log kTB (dBW)	–	– 137 ([5])	–	– 136.2 ([6])	–
Minimum power flux-density (dB(W/m^2))	P	– 75.5	– 80	– 70.2	– 101

([1]) Operational system.

([2]) $(S/N)_{RF}$ at the edge of the service area when using an antenna with a cosecant vertical pattern producing the same fieldstrength in the entire service area.

([3]) Corresponds to grade 4.5 of Recommendation 500.

([4]) $(S/N)_{RF}$ at receiver input; modulation index $m = 1$.

([5]) Noise bandwidth $B = 7$ MHz.

([6]) Noise bandwidth $B = 6$ MHz.

5. Effect of interference

In planning a terrestrial network, interference can be a factor which determines the required flux density of the wanted signal. Methods of calculating field strength or transmission loss which are of interest for assessing interference probabilities are indicated in Reports 562 and 569.

6. Effects of propagation

For the planning of a terrestrial broadcasting system in the 12 GHz band, losses due to diffraction by buildings are of particular importance; consideration may also have to be given to attenuation due to precipitation. Relevant information is given in Report 562.

During investigations in San Francisco using a 20 MHz bandwidth FM system [Bentz, 1982] very little diffraction around obstacles or penetration through obstacles – including foliage – was noted. However, in many cases of obstructed transmission paths, it was possible to use a reflection as a better source of the signal. Because of the highly directional beam of the receiving antenna, whether a horn or parabolic dish, it was possible to select a *single* reflection. For this reason multipath interference was rarely encountered. Rain attenuation was considerable, as indicated by long-term measurements at fixed locations, and would have to be taken into account in the system design in the form of adequate transmitter power. Based on the parameters of this specific test, satisfactory reception was reported at approximately 70% of the desired target area.

7. Frequency-sharing with the broadcasting-satellite service

Frequency-sharing between the broadcasting-satellite service (BSS) and terrestrial services is discussed in Report 631. Frequency-sharing between the BSS and the terrestrial television service in the 12 GHz band can be accomplished by operating terrestrial transmitters in those parts of the band not used by the BSS in the area where the transmitters are situated.

It is important from the viewpoint of spectrum utilization to know the factors affecting the required separation between the operating frequencies of both services. In Japan, field and laboratory tests were conducted using Japan's medium-scale broadcasting satellite for experimental purposes (BSE) and terrestrial broadcasting transmitters in the 12 GHz band. The tests have shown that even in the worst case there is a high probability that interference to reception of a broadcasting-satellite service from unwanted signals is not determined by intermodulation in the receiver but by its selectivity. The receivers used for the tests were of a type using a diode-mixer converter (see Report 473). Interference from the BSE to the terrestrial broadcasting service in a channel overlapping the BSE signal was not observed during the tests [CCIR, 1978-82b].

8. Operational system

In 1977, eighteen television channels in the frequency range 12.092 GHz to 12.2 GHz were assigned for terrestrial television services in Japan to improve reception in areas where signals in Bands III, IV and V are severely degraded by multi-path interference. The first operational translator station started service in an area of Tokyo in 1979. The station provides seven AM-VSB channels at a maximum e.i.r.p. of 6.7 W/channel. The maximum coverage distance from the transmitter is about 1 km, defined by a required power flux-density of -70 dB(W/m^2) [Momoura and Kikuchi, 1979].

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[1974-78]: **a.** 11/156 (Germany, (Federal Republic of)); **b.** 11/172 (The Netherlands); **c.** 11/22 (Switzerland); **d.** 11/34 (Japan); **e.** 11/308 (Japan).

[1978-82]: **a.** 11/79 (Japan); **b.** 11/247 (Japan).

[1982-86]: 11/320 (USA).

SECTION 11F: DIGITAL METHODS OF TRANSMITTING TELEVISION INFORMATION

REPORT 629-4

DIGITAL CODING OF COLOUR TELEVISION SIGNALS

(Question 25/11, Study Programmes 18L/11, 25G/11, 25L/11 and 25M/11)
(1974-1978-1982-1986-1990)

1. Introduction

Study Group 11 has brought together, during the study period 1982-1986 and previously, a large amount of information concerning the coding, processing, transmission and recording of picture signals in digital component form in the studio. This work has resulted in Recommendation 601 concerning the encoding of the digital video signal for studio production, and Recommendation 656 concerning studio interfaces for the digital video signal.

Additionally, this work has been taken into account in the Recommendation for the digital recording format (Recommendation 657) and the studies by Study Group 11 on bit-rate reduction (Report 1089) and the CMTT studies concerning the transmission of picture signals.

This Report summarizes the work on coding methods for signals within the studio complex, derived from both analogue and digital sources, and provides the basis for Recommendation 601 concerning the encoding parameters of the digital television signal in the studio. This is complimented by Report 962 which concerns the filtering, sampling, and multiplexing of digital signals.

2. Basic principles

2.1 Studio digital encoding parameters for conventional television

Two different approaches to the coding problem have been proposed:

- *component coding:* in this approach the luminance and colour difference signal components are digitally coded separately and transmitted as separate bit streams, time-multiplexed together. When the colour television signal exists in the composite NTSC, PAL or SECAM form, it will be necessary first to separate the signal into its luminance and colour difference components;
- *composite coding:* in this method the composite colour signal is coded in its composite form as a single bit stream.

The first method has advantages over the second because, in the future, it will be possible for the signal to be transmitted in digital form, from the source to the broadcasting transmitter. Only at the broadcasting transmitter will it be necessary to generate the composite signal. Thus, at least for transmission purposes, the differences between NTSC, PAL and SECAM would disappear with a consequent simplification of the problems of the international exchange of programmes [CCIR, 1974-78a], except when different scanning standards are involved. (International programme exchange refers to the provision of the interface required for video tape recording equipment and of the interface with transmission equipment.) The second method is claimed to have advantages when, as is likely to happen during the period in which digital techniques are being introduced into broadcasting, the complete chain contains several digital and analogue sections in cascade.

Most administrations now agree that there would be considerable advantages in using component coding for studio standards. The reasons for this are as follows:

- recent technological developments, particularly in the fields of semiconductor storage and magnetic recording have opened up new and attractive possibilities in electronic picture processing and special effects. Such facilities have only been available in the past using expensive film techniques [CCIR, 1978-82a];

- component coding offers a uniform world standard, with the exception of field rate. Such a standard has the greatest number of significant parameter values common to 525-line and 625-line systems. It allows equipment and operation to have the maximum number of common features, a situation which is not achievable with analogue or composite digital standards. Except for field rate (which could be switchable), studios throughout the world would use many items of common equipment and programme production and exchange would be much simplified.

In determining the bit rate reduction method that might be used at the studio, prior to interconnection to any long-distance transmission facilities, it is important to take account of the digital hierarchies being standardized by the CCITT [CCIR, 1974-78b].

In [CCIR, 1978-82b], the EBU has proposed that, to facilitate international exchange of programmes, a signal based upon the separate coding of luminance and colour-difference signals should be used. Studies conducted by the EBU have clearly demonstrated the value of digital coding in avoiding some of the limitations associated with PAL and SECAM systems and indicate the feasibility of a universally compatible digital standard [CCIR, 1978-82c]. Considerations such as this, combined with similar proposals from other administrations, resulted in Recommendation 601 which suggests that the use of component coding is to be preferred for all studio and international exchange purposes.

2.2 Studio digital encoding parameters for HDTV

This subject has been dealt with by IWP 11/7 as required by Decision 60, and results as of May 1989 were contributed to the Extraordinary Meeting of Study Group 11 for HDTV [CCIR, 1986-90a].

The contributions discuss several approaches to a digital HDTV studio standard based on the concepts of a common image format or a common data rate.

The subject is still under consideration by IWP 11/7 and particular areas of study for which IWP 11/7 is seeking contributions are:

- digital signal characteristics
  - (a) digital signal levels
  - (b) form of coding
  - (c) dynamic range
- digital interface requirements
  - (a) parallel and serial interfaces
  - (b) synchronising words, number of bits, etc.
- digital synchronizing signals
- digital test signals
- requirements for digital image processing
  - (a) requirements for horizontal and vertical blanking
  - (b) image size change allowable through editing processes etc.

3. Coding methods

The initial processes in all digital coding methods which are under study are sampling and quantizing.

3.1 *Bandwidths and sampling*

The sampling process is determined by three basic factors:

- the sampling structure, i.e. the relative position of the samples in space and time;
- the number of samples per line;
- the filtering process, which may be one-, two-, or three-dimensional.

The sampling structure mentioned above may, or may not, be repetitive with respect to the picture. Likewise, the number of samples per line may, or may not, be constant from line to line.

The classical theory requires the sampling frequency to be equal to or greater than, twice the highest signal frequency, i.e. Nyquist sampling. However, studies have shown that lower sampling frequencies (i.e. sub-Nyquist sampling) can be used in practice [Messerschmid, 1969].

3.1.1 *For component signals*

The EBU [CCIR, 1974-78c] has suggested that those countries digitally coding the separate components should use a sampling structure repetitive from picture to picture. This approach is supported by [CCIR, 1974-78d]. Repetitive sampling structures may be either orthogonal [CCIR, 1974-78e] or interleaved.

Report 962 describes in some detail the work leading to the choice of sampling parameters listed in Recommendation 601 as the basis for a studio code and so only a brief summary is required here.

A number of sampling frequencies for the luminance signal of the 4 : 2 : 2 level were studied by administrations, in particular 12 MHz, 12.5 MHz, 13 MHz. 13.5 MHz and 14.3 MHz. The factors studied, which would have a potential bearing on the choice of sampling frequency, included basic picture quality, picture quality after processing, cost-performance relations, potential capacity of digital VTRs, bit-rate reduction to transmission hierarchy levels and compatibility with composite signals and composite coding.

During the course of their studies, some administrations saw advantages in choosing a sampling frequency related to their composite signal colour sub-carrier frequency, because this could be advantageous in a mixed use of component and composite coding nationally. However, they considered that the benefits of a world-wide unification of sampling-frequency might alter the balance of advantages in favour of the agreed value.

A luminance sampling frequency of 13.5 MHz was adopted for a world-wide standard. It is a compromise between, on the one hand, the need to choose values which allow practically realizable and economic equipment and, on the other, the need to allow a sufficient degree of picture processing. Also, this frequency is the only one in the range of 12 to 14.3 MHz that permits an integer number of samples per lines for both the 525 and the 625 line systems [CCIR, 1978-82d, e, f, g, h, i and j]. The sampling frequency applied to the colour-difference signals was set at half that applied to the luminance signal after checking that this would allow adequate quality in chroma-key (colour matte) processing. The digital interface for studio equipment is discussed in Report 1088 entitled "Interfaces for digital video signals in 525-line and 625-line television systems".

It was anticipated that present and envisaged applications of television are unlikely to be covered by a single set of digital parameters. *An extensible family of compatible digital coding standards* corresponding to different applications was therefore proposed [CCIR, 1978-82k, l and m].

The members of the family are denoted by a sequence of integer numbers such as 4 : 2 : 2 or 4 : 4 : 4. These numbers represent the relation of the sampling frequency for the luminance signal (first number) to the sampling frequencies for the colour difference signals (subsequent numbers). The convention adopted is that the number 4 represents the main sampling rate of 13.5 MHz (nominal). Thus, for example, the 4 : 2 : 2 member of the family is characterized by 13.5 and 6.75 MHz sampling frequencies for the luminance and the colour difference signals respectively as defined in Recommendation 601.

One possible set of such standards is considered in [CCIR, 1978-82m] as corresponding to the following levels:

- a studio standard;
- a lower standard using the same scanning parameters but resulting in lower bit rates and costs, suitable for lower quality applications;
- a higher quality standard having a capability beyond that provided by present scanning standards.

In [CCIR, 1978-82n] it is suggested that an internationally compatible digital code would be a component code incorporating line-locked (orthogonal) sampling, an identical number of samples per line for both the 525- and 625-line systems and membership in an extensible family of compatible digital codes having simply related sampling frequencies. The definition of preferred sampling frequencies should be the subject of further studies.

Subjective assessments of an extensible family of component coded digital television systems were performed during 1980 and 1981 by the EBU [CCIR, 1978-82d and f], the SMPTE [CCIR, 1978-82g], and by NHK in Japan [CCIR, 1978-82o; Nishizawa *et al.*, 1981]. The tests included the binary derived family members 4 : 4 : 4, 4 : 2 : 2 and 4 : 1 : 1 with luminance sampling frequencies ranging from 12 MHz to 14.3 MHz. The results of all these tests were consistent and tended to verify the 4 : 2 : 2 member as the preferred selection for the standard studio interface and verified the choice of a sampling frequency of 13.5 MHz as an appropriate compromise between acceptable picture quality after processing and bit-rate requirements. This is also supported by [CCIR, 1978-82e].

The possibility of using the 4:2:2 level of Recommendation 601 with pictures having a wider aspect ratio (16:9 instead of 4:3) is presented in [CCIR, 1986-90b], which points out that most studio equipment requires only minor modifications and the same interface as in Recommendation 656 can be used. However, in such applications it should be noted that wider aspect ratio signals should not be intermixed with conventional (4:3) aspect ratio signals.

[CCIR, 1978-82k] presents a description of an extensible family of compatible digital codes which is based upon a component code bearing the ratios of sampling rates of 4 : 1 : 1 (luminance to colour-difference). Such codes would be easily transcodable to an NTSC composite digital interface code and the family could be readily extensible upward to be suitable for higher definition television when advances in technology warrant it. Also, the family of codes is extensible downward to lower definition interface codes for special applications, e.g. electronic news gathering.

The 4:4:4 level described in the Annex to Recommendation 601 is under study by both the EBU and the SMPTE. The intended purpose of a 4:4:4 interface is for complex graphics and post-production. It is not the intent to replace the 4:2:2 interfaces already specified in Recommendation 656, as they are deemed more than adequate for normal studio operations. The 4:4:4 interface is expected to stipulate PCM coding with more than eight bits per sample. Agreement has been reached within the EBU and SMPTE to include consideration of the keying signal as part of the basic signal set. This level of Recommendation 601 is now referred to as 4:4:4:4 or 4x4. Work is concentrated on fitting the information within the current interface described in Recommendation 656. Amongst the issues still under investigation are the effects of various algorithms for dynamic rounding, to minimize the number of bits per sample, also the filtering characteristics and the requirements for keying signals. Dynamic rounding is a process which conceals the errors which arise when a sample is reduced in word-length, as from 10 bits to 8 bits.

[CCIR, 1978-82p] suggests design criteria and a possible application for a lower level within an extensible family of compatible digital codes. System parameters and test results are given for an experimental codec operating at half of the bit rate of the main studio standard. This system features non-binary relationship between luminance sampling frequencies of related levels and a 3:1 relationship between sampling frequencies of luminance and line sequentially encoded colour difference signals. [CCIR, 1982-86a] describes a subjective evaluation, using static text pictures of a number of possible lower level standards, including the effects of line- and field-offset sub-sampling and of line sequential processing of the colour-difference signals. [CCIR, 1982-86b] contains a theoretical study of the picture distortion encountered when using line sequential transmission of colour-difference signals with a cycle of two fields.

[CCIR, 1986-90c] suggests parameter values for a cost effective lower level of signal coding using 2 2/3: 1 1/3: 1 1/3 sampling rates. Use of these parameters, rather than 2:1:1, allows a slow roll-off response to be used, thus simplifying the filters.

There appears to be little further interest in lower members of the Recommendation 601 digital encoding standards. The current effort appears to be directed towards achieving the goals originally identified for the lower members of the family, such as ENG and field operations, with the 4:2:2 member, by use of bit rate reduction techniques.

Rossi [1981] describes a set of digital filters adapted for a binary family, that accomplishes a two-to-one sampling rate down conversion, a one-to-two sampling rate up conversion, by comb filter interpolation.

There are equipment advantages for members of a family to have compatible numbers of samples per line. The members of the digital family should be chosen having regard to other possible television signal representations, in order to limit the number and complexity of transcoding operations in the signal chain. [CCIR, 1982-86c] lists some of the representations that have been proposed.

The nominal durations of the active-lines for 525/60 and 625/50 systems are slightly different. To bring the two systems together in the digital component domain, a "digital active line" (DAL) is defined. This has sufficient digital samples to cover either the 525/60 or 625/50 active lines. There are obvious advantages in that both systems now need precisely the same amount of digital line storage, and the DAL can be processed in exactly the same way for either the 525 or 625 line systems. The number of samples associated with analogue blanking is different, but this need not be carried through into the digital component domain. Blanking appropriate to the national broadcasting standard should be applied at the point where the signal is converted to analogue.

The 525 active line is the longer of the two, and with the tolerances currently in practical use, more than 710 samples are needed to cover a line. The 720 samples per digital active line given in Recommendation 601 was chosen because it conveniently meets this requirement.

Definition of luminance (E'_Y) and colour-difference ($E'_R - E'_Y$) and ($E'_B - E'_Y$) signals

A proposal for the construction of luminance and colour difference signals forms part of Recommendation 601 as follows:

$$E'_Y = 0.299\ E'_R + 0.587\ E'_G + 0.114\ E'_B \qquad \text{(See Note)}$$

whence

$$(E'_R - E'_Y) = E'_R - 0.299\ E'_R - 0.587\ E'_G - 0.114\ E'_B$$
$$= 0.701\ E'_R - 0.587\ E'_G - 0.114\ E'_B$$

and

$$(E'_B - E'_Y) = E'_B - 0.299\ E'_R - 0.587\ E'_G - 0.114\ E'_B$$
$$= -\ 0.299\ E'_R - 0.587\ E'_G + 0.886\ E'_B$$

Note. – Report 624 Table II refers.

Taking the signal values as normalized to unity (e.g., 1.0 V maximum levels), the values obtained for white, black and the saturated primary and complementary colours are as follows:

TABLE I

Condition	E'_R	E'_G	E'_B	E'_Y	$E'_R - E'_Y$	$E'_B - E'_Y$
White	1.0	1.0	1.0	1.0	0	0
Black	0	0	0	0	0	0
Red	1.0	0	0	0.299	0.701	−0.299
Green	0	1.0	0	0.587	−0.587	−0.587
Blue	0	0	1.0	0.114	−0.114	0.886
Yellow	1.0	1.0	0	0.886	0.114	−0.886
Cyan	0	1.0	1.0	0.701	−0.701	0.299
Magenta	1.0	0	1.0	0.413	0.587	0.587

While the values for E'_Y have a range of 1.0 to 0, those for ($E'_R - E'_Y$) have a range of +0.701 to −0.701 and for ($E'_B - E'_Y$) a range of +0.886 to −0.886. To restore the signal excursion of the colour-difference signals to unity (i.e. +0.5 to −0.5), coefficients can be calculated as follows:

$$K_R = \frac{0.5}{0.701} = 0.713;\ K_B = \frac{0.5}{0.886} = 0.564;$$

Then

$$E'_{C_R} = 0.713\ (E'_R - E'_Y) = 0.500\ E'_R - 0.419\ E'_G - 0.081\ E'_B$$

and

$$E'_{C_B} = 0.564\ (E'_B - E'_Y) = -\ 0.169\ E'_R - 0.331\ E'_G + 0.500\ E'_B$$

where E'_{C_R} and E'_{C_B} are the re-normalized red and blue colour-difference signals respectively.

In the case of a uniformly-quantized 8-bit binary encoding, 2^8, i.e. 256, equally spaced quantization levels are specified, so that the range of the binary numbers available is from 0000 0000 to 1111 1111 (00 to FF in hexadecimal notation), the equivalent decimal numbers being 0 to 255, inclusive.

In the case of the 4 : 2 : 2 system described in Recommendation 601, levels 0 and 255 are reserved for synchronizing data, while levels 1 to 254 are available for video.

Given that the luminance signal is to occupy only 220 levels, to provide working margins, and that black is to be at level 16, the decimal value of the luminance signal, $\overline{Y}$, prior to quantization, is:

$$\overline{Y} = 219\,(E'_Y) + 16,$$

and the corresponding level number after quantization is the nearest integer value.

Similarly, given that the colour-difference signals are to occupy 225 levels and that the zero level is to be level 128, the decimal values of the colour-difference signals, $\overline{C}_R$ and $\overline{C}_B$, prior to quantization are:

$$\overline{C}_R = 224\,[0.713\,(E'_R - E'_Y)] + 128$$

and

$$\overline{C}_B = 224\,[0.564\,(E'_B - E'_Y)] + 128$$

which simplify to the following:

$$\overline{C}_R = 160\,(E'_R - E'_Y) + 128$$

and

$$\overline{C}_B = 126\,(E'_B - E'_Y) + 128$$

and the corresponding level number, after quantization, is the nearest integer value.

The digital equivalents are termed Y, C_R and C_B.

It has been pointed out in [CCIR, 1982-86d] that further consideration of the relationship between analogue video levels and quantization levels may be necessary in the light of current operational margin requirements.

Note. – The quantization and encoding for the construction of Y, C_R, C_B from signals other than luminance and colour difference signals are considered in § 2.4 of Annex II to Recommendation 601.

"Digital coding in the form of Y, C_R, C_B signals can represent a substantially greater gamut of signal values than can be supported by the corresponding ranges of R, G, B signals. Because of this it is possible, as a result of electronic picture generation or signal processing, to produce Y, C_R, C_B signals which, although valid individually, would result in out of range values when converted to R, G, B. [Devereux, 1987] explains that it is both more convenient and more effective to prevent this by applying limiting to the Y, C_R, C_B signals than to wait until the signals are in R, G, B form. Also, techniques are described by which limiting can be applied in a way that maintains the luminance and hue values, minimising the subjective impairment by sacrificing only saturation.

3.1.2 *For composite signals*

The sub-Nyquist technique can be applied by sampling the PAL composite signal at a rate of twice the sub-carrier frequency [Devereux and Phillips, 1974]. The digital codec employing such sampling uses filtering which introduces minor losses of diagonal luminance resolution and vertical chrominance resolution. However, further filtering of this nature in any subsequent sub-Nyquist sampling process should not cause any further resolution impairment [Stott and Phillips, 1977].

For system M/NTSC there is a tendency to use a sampling frequency of three or four times the colour sub-carrier frequency. However, [CCIR, 1974-78f] describes studies of a coding system which uses a sampling frequency that is an integer multiple of line frequency. The sub-Nyquist sampling technique has also been used with NTSC signals [Rossi, 1976].

Patel [1980] describes the effects of low-pass filtering on the analogue composite signal of system I/PAL. It is concluded that chrominance ringing is dominant and that improved delay correction can mitigate the resulting impairment.

3.1.3 *Compatibility between composite and component signals*

In [CCIR, 1974-78c] the EBU draws attention to the need for compatibility between the proposed methods for composite and component coding of 625-line signals.

EBU experiments [CCIR, 1978-82b] have shown that good quality analogue PAL to digital *YUV* coding and decoding, when using line-locked sampling, can be achieved provided a sophisticated codec is used.

In [Clarke, 1986], details of digital techniques are given for generating, from a line-locked sampling frequency, quadrature subcarrier signals for use in composite colour encoders and for locking these signals to the incoming reference burst in colours decoders. This allows the advantages of more stable, better defined performance produced by digital implementation to be obtained in coders and decoders without the need for sample rate conversion. The description also includes the modifications necessary to provide operation with NTSC signals.

Further, in [Clarke, 1988], a number of filtering methods for achieving high quality separation of the luminance and chrominance components of a PAL signal are described, primarily for obtaining digital Y, C_R, C_B signals from PAL in a digital studio context. These range from filters using relatively simple line-delay combs to three-dimensional comb filters using multiple line, field and picture delays. The results of subjective tests comparing the different methods indicate that, while a modest degree of temporal filtering can improve performance significantly, greater use of this technique can lead to impairments to moving objects.

3.1.4 *Change of sampling frequency*

Within a given system (using either composite or component coding) it may be necessary to change the sampling frequency.

A method is described in [CCIR, 1974-78g] which may be used with system M/NTSC for changing the sampling frequency from 4 to 3 times the NTSC sub-carrier frequency and vice versa.

In [CCIR, 1974-78h], which proposes the possible use of two sampling frequencies in the digital PAL studio, it is pointed out that a signal sampled at $4 f_{sc}$ may be very easily converted to a signal sampled at $2 f_{sc}$ and vice versa. However, when the sampling frequency is changed from $2 f_{sc}$ back to $4 f_{sc}$ the minor impairments associated with $2 f_{sc}$ sampling remain; nevertheless, the effect upon resolution is not cumulative.

3.1.5 *Sampling frequency tolerance*

The sampling frequencies used should comply with the requirements of associated television systems. In particular the tolerance for component signal sampling frequencies should be equal to that for line frequency in the relevant colour television standard [CCIR, 1982-86e, f].

In cases where the sampling frequencies are generated from the reference synchronization signal arriving from a distant main synchronization generator, special centralized synchronization signals containing reference frequency packets may prove useful for the purpose of increasing the phase stability of the generated frequencies [CCIR, 1986-90d].

3.2 *Linear PCM*

The basic form of digital coding is linear PCM, where the value of each digital "word" represents the uniformly quantized amplitude of a sample of the baseband signal [CCIR, 1970-74a and b].

Preliminary results of an experiment using 7 PCM codecs in cascade when coding NTSC composite signals are presented in [CCIR, 1974-78i].

[CCIR, 1978-82q] describes experiments to determine the picture impairments introduced when up to 10 codecs are used. Composite NTSC signals were coded using various numbers of bits per sample and sample frequencies of 3 f_{sc} and 4 f_{sc}. The signal-to-noise ratio of the source was high.

A study on PCM codecs using 8 bits per sample [CCIR, 1982-86g; Devereux, 1983] draws attention to the importance of the performance of both the basic coder/decoder and associated circuitry in determining the performance of a cascaded chain of codecs. Of particular importance are: pre- and post-filters; blanking-level stabilization; quantization distortion, particularly on signals with high rate-of-rise (or fall); timing jitter on clock pulses; line-time non-linearity. In a well-designed codec where the foregoing have been taken into account, quantization noise is likely to be the dominant impairment, and this is shown to be about 2 dB worse than theoretical in the codecs tested. A cascaded connection of 8 codecs is shown to increase the quantization noise by approximately the expected 9 dB.

Experience suggests that, within PCM signal processing equipment, more than 8 bits per sample should be retained to avoid a rapid accumulation of quantizing disortion from repeated rounding after each arithmetic process. However, 8 bits per sample has been found satisfactory for interconnections between equipment using digital Y, C_R, C_B signals coded according to Recommendation 601, provided that effective rounding is applied when converting from a higher number of bits to 8 bits at the equipment output. [Croll, Devereux and Weston, 1987] describe a suitable form of rounding, called error feedback, in which those lower significance bits truncated from one sample are added to the following sample before truncation thus accumulating, rather than discarding, lower significance residues. With 8 bits per sample, rounding signals in this way causes higher frequency quantizing distortions which are not visible, whereas simple truncation can cause visible contouring.

4. Bibliography

In addition to the references explicitly cited in this Report, a Bibliography of several publications on the subject of digital television is appended. The referenced papers are not repeated in the Bibliography.

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[1978-82]: **a.** 11/36 (United Kingdom); **b.** 11/14 (EBU); **c.** 11/15 (EBU); **d.** 11/330 (EBU); **e.** 11/328 (USSR); **f.** 11/285 (EBU); **g.** 11/292 (USA); **h.** 11/339 (OIRT); **i.** 11/342 (Canada); **j.** 11/344 (Japan); **k.** 11/31 (USA); **l.** 11/16 (EBU); **m.** 11/114 (France); **n.** 11/33 (USA); **o.** 11/343 (Japan); **p.** 11/278 (Germany (Federal Republic of)); **q.** 11/80 (Japan); **r.** 11/87 (Japan); **s.** 11/248 (Japan).

[1982-86]: **a.** 11/22 (Japan); **b.** 11/90 (USSR); **c.** 11/81 (United Kingdom); **d.** 11/23 (Japan); **e.** 11/46 (EBU); **f.** 11/135 (OIRT); **g.** 11/65 (United Kingdom); **h.** 11/19 (Japan); **i.** 11/26 (Japan).

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REPORT 962-2

THE FILTERING, SAMPLING AND MULTIPLEXING FOR DIGITAL ENCODING OF COLOUR TELEVISION SIGNALS

(Question 25/11, Study Programme 25H/11)

(1982-1986-1990)

1. Introduction

Report 629 provides a brief introduction to the subjects of bandwidth and sampling as relevant to the process of encoding component signals into digital form.

In order to ensure that the total bit rate of the digital signal is not excessive, it is clearly necessary to determine the bandwidths of the luminance and colour-difference signals which are adequate to provide high-quality broadcasting signals (which may be in the analogue composite form). Further, when considering the filtering and sampling of component signals, it is also necessary to bear in mind that proposals have been made to use such signals in digital form for purposes which could be more demanding than conventional broadcasting (see § 2.3). In particular, attention must be paid to the constraints imposed by modern programme production techniques, taking into account the quality margin required by the increasing demand for picture-processing operations [Akrich and Zaccarian, 1981].

In choosing the sampling parameters to be used for component signals, the sampling frequencies are, clearly, closely related to the bandwidths of the component signals, but other parameters are concerned with the picture sampling structure or structures (see § 3).

The number of bits necessary to describe each sample is discussed in § 4.

In order to handle a single byte stream in the studio when component coding is used, time-multiplexing of the three byte streams is required. Some possible arrangements are discussed in § 5.

2. Bandwidths

This section is divided in three sub-sections, the two following sub-sections outline the results of subjective tests aimed at establishing the overall luminance and colour-difference signal bandwidths, respectively. The third sub-section discusses the implications with regard to these bandwidths, taking into account the needs of studio signal-processing operations.

2.1 *Luminance-signal bandwidth*

[CCIR, 1978-82a and b] give the results of tests by members of the EBU, to determine the relationship between subjective quality and the bandwidth of the luminance component, using a 625-line system and monochrome display. The tests were carried out using a method described in Report 405, using the impairment scale and pictures slightly more critical than average, as required by Recommendation 500.

The main conclusion indicates that bandwidth-limiting to 4.5 MHz (at −3 dB) using sharp cut off low-pass filtering introduces an impairment which is imperceptible to 50% of the observers at a viewing distance of four times the picture height (see Fig. 1a). The results indicate that the effects of filtering on electronically-generated captions are less critical than those on the pictures. These studies did not show the expected advantage for the use of a comb filter (with sub-Nyquist-sampling) when compared with a low pass filter cutting off at half the sampling frequency.

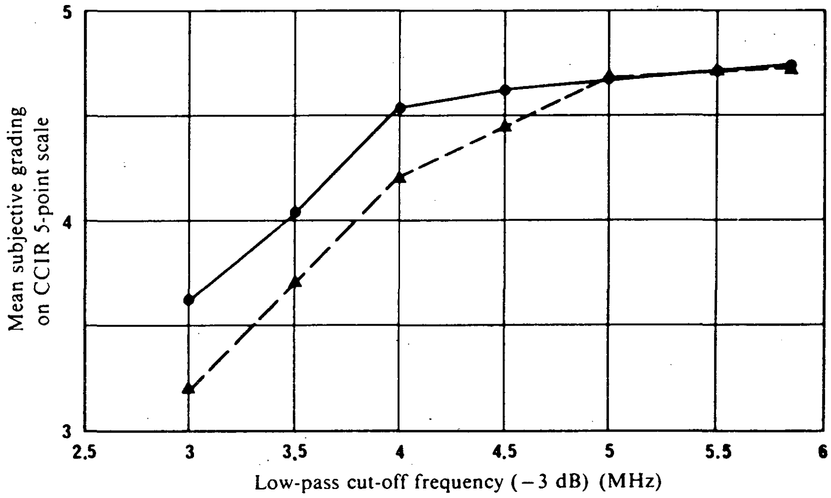

FIGURE 1a – *Low-pass filtering. Mean values of the results obtained in seven laboratories, using 625-line test pictures*

—●— viewers at a distance of six times picture height

—▲— viewers at a distance of four times picture height

The subjective test results obtained in these EBU tests have been analyzed in accordance with the method described in Annex III of Report 405 and this work is described in [CCIR, 1978-82c]. The result of the analysis is presented in Fig. 1(b). The same document discusses the substantial effect of the choice of picture material and the large spread of the results which can occur when Recommendation 500 is not followed. It also expresses the view that an impairment criterion of $I = 0.05$ (corresponding to grade 4.8 in a five grade scale) is appropriate and that consequently the minimum bandwidth of the luminance signal should be 5.8 MHz.

Tests carried out in Poland, and described in [CCIR, 1978-82d] also indicate that the luminance-signal bandwidth should not be less than 4.5 MHz for 625-line systems.

[CCIR, 1978-82e] describes work by the U.S.S.R. which concludes that the appropriate bandwidth for the luminance signal is 6.0 MHz.

The relationship between picture quality and luminance-signal bandwidth, for 525-line systems, has been investigated in Japan [CCIR, 1978-82f]. Separate tests were carried out, using colour pictures, for two different values of colour-difference signals bandwidth; the filters used in the luminance and colour-difference channels were of the Thomson type (i.e. relatively slow cut-off). The results of the tests indicate that a luminance-signal bandwidth of 5.6 MHz is suitable.

2.2 *Colour-difference signal bandwidth*

Tests in Poland [CCIR, 1978-82d] indicate that, for 625-line systems, the bandwidth of each colour-difference signal should be not less than 1.5 MHz, a result which agrees with that given in [CCIR, 1978-82e] from the U.S.S.R.

The work described in [CCIR, 1978-82f] also included tests to determine the colour-difference signal bandwidth appropriate to 525-line systems. The relationship between picture quality and colour-difference signal bandwidth was determined by separate tests, using colour pictures, in which two different values of luminance-signal bandwidth were involved. From the results it is concluded that the colour-difference signal bandwidth should have a value of approximately 2.8 MHz (Fig. 2).

Experiments conducted in France [Sabatier and Sallio, 1981; Sabatier and Chatel, 1981] show very similar results for 625-line systems.

Investigations to establish the optimum characteristic for limiting the bandwidth of colour-difference signals are outlined in [CCIR, 1978-82g]. These studies, carried out in the Federal Republic of Germany, were made assuming that the maximum bandwidth available (the Nyquist limit) was 2.0 MHz.

Studies involving subjective tests have been made to determine the optimum characteristics for a filter, also with a bandwidth of 2.0 MHz; these studies are described in [CCIR, 1978-82h].

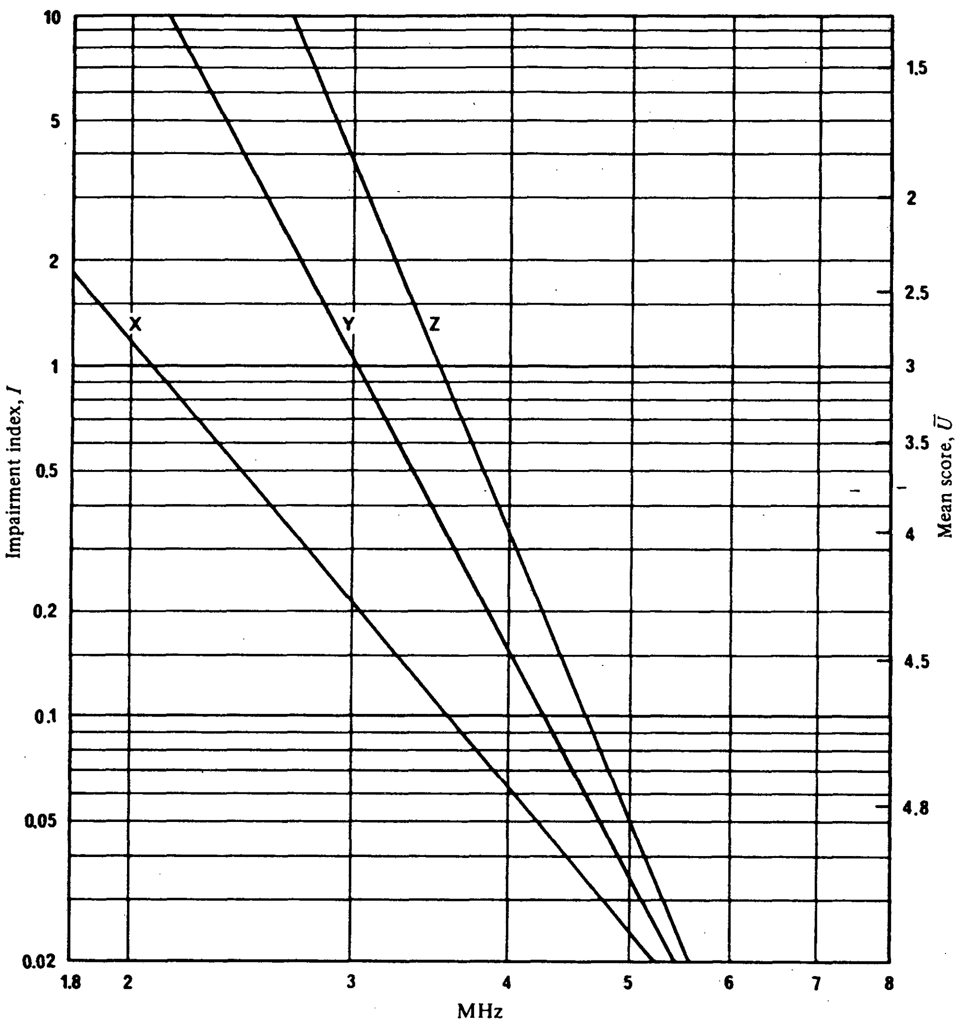

FIGURE 1b – *Impairment characteristics for bandwidth restriction, from EBU experiments: spread of results from different laboratories. Viewing distance is 4 times picture height*

Curves X: laboratory A (the least critical)
Y: average of results from 7 laboratories
Z: laboratory B (the most critical)

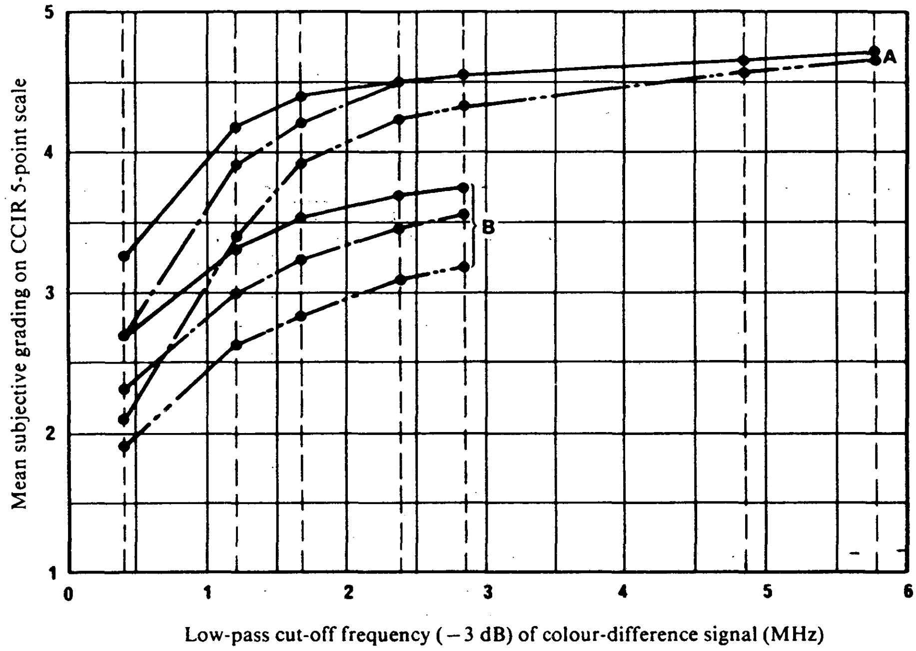

FIGURE 2 – *Relationship between colour-difference signal bandwidth and picture quality (525-line systems)*

Curves A: *Y* signal bandwidth 5.8 MHz (−3 dB)
B: *Y* signal bandwidth 2.9 MHz (−3 dB)

——— viewers at a distance of 6 times picture height
—·— viewers at a distance of 4 times picture height
—··— viewers at a distance of 2.5 times picture height

2.3 *Bandwidth requirements for studio signal-processing applications*

It must be borne in mind that the values of the luminance-signal bandwidth arrived at in § 2.1 and 2.2 are those regarded as desirable when considering the overall signal chain prior to the broadcast transmitter. [CCIR, 1978-82i] discusses the need for increased luminance and colour-difference signal bandwidths when considering signal processing in the studio. It is pointed out, first, that the luminance bandwidth must be adequate to permit a reasonable amount of picture recomposition, without causing a perceptible impairment of the output picture. Secondly, [CCIR, 1978-82i] argues that the bandwidths of the colour-difference signals must be sufficient to enable good results to be obtained with chroma-key (colour-matte). [CCIR, 1978-82h] also discusses colour-difference signal bandwidth requirements in the context of the chroma-key (colour-matte) process. It expresses the opinion that a colour-difference signal sampling frequency of 6 to 7 MHz (half that used for the luminance signal) is satisfactory with regard to both picture quality and chroma-key (colour-matte) requirements, provided that the filtering characteristic shows 12 dB attenuation at half the sampling frequency; further, the frequencies at which the attenuation values are 12 dB and 3 dB should be related by the ratio 1.25 : 1.

The general problem of the design of the band-limiting filters used in the digital coding of television signals has been studied in Italy [CCIR, 1978-82j]. Computer simulations were used to investigate the influence of several design parameters on the amplitude of overshoot and the amount of aliasing.

Experiments in the People's Republic of Poland are reported in [CCIR, 1982-86a] on the luminance filtering characteristics preferred for an environment where the luminance bandwidth of 6 MHz is used for conventional composite systems. A 6 MHz passband, insertion loss tolerance ± 0.05 dB, attenuation 15 dB at 6.75 MHz, and 40 dB at 7.5 MHz are suggested.

[CCIR, 1982-86b] reports studies in the USSR which, taking into account the circumstances above, and additional practical design considerations, propose a 5.75 MHz passband, insertion loss tolerance 0.1 dB, attenuation 20 dB at 6.75 MHz and 40 dB at 7.5 MHz for the luminance filter.

In Italy [CCIR, 1982-86c] a study was made using computer simulation of pre- and post-filter characteristics based on minimization of the weighted influence of over-shoots and aliasing. The study provided valuable preliminary data, which subsequently led to support for luminance and colour-difference filtering characteristics of the kind in [CCIR, 1982-86d].

A careful study of the performance of a cascaded chain of PCM codecs [CCIR, 1982-86e, f; Devereux, 1982] has shown that after minimizing the instrumental deficiencies of the codecs, the most important avoidable impairment which remains is due to the passband amplitude and phase responses of the analogue pre- and post-filters, and proposals for these characteristics are made in the above documents.

The OIRT [CCIR, 1982-86g] has studied the proposal to use a cut-off frequency of 5.75 MHz for the luminance signal in the digital 4 : 2 : 2 standard. This is nearer to the value of the 6 MHz cut-off frequency for the video signals specified by standards D, K, Kl and L (see Report 624). The value of 6 MHz for the band-limiting filter is also being studied.

Based on the results of the studies mentioned above, and an examination of the problems of the practical realization of efficient filters to meet the requirements of all administrations, the characteristics given in Fig. 1 of Annex III to Recommendation 601 were drawn up.

The study has been continued [CCIR, 1982-86d, f; Devereux, 1984] to determine specifications for filters for the colour-difference signals for the 4 : 2 : 2 coding standard of Recommendation 601. In these studies special attention has been given to:

(a) the need to maximize the usable bandwidths of both luminance and colour-difference signals;

(b) the need to ensure negligible impairments due to passband tolerances when a number of filter pairs are cascaded in a transmission chain;

(c) complementing (b) above, the need to avoid unnecessarily stringent values and tolerances;

(d) the need for the specifications of both analogue and digital filters to be capable of being met in production at reasonable cost.

Resulting from these studies, the specification for analogue filters for colour-difference signals sampled at 6.75 MHz are given in Fig. 2 of Annex III to Recommendation 601. The specification for a corresponding digital filter for sampling rate conversion between signals sampled at 13.5 MHz and signals sampled at 6.75 MHz is given in Fig. 3 of Annex III to Recommendation 601.

Some guidance on the practical implementation of the filters recommended in Annex III to Recommendation 601 is given in the following paragraphs.

In the proposals for the filters used in the encoding and decoding processes, it has been assumed that, in the post-filters which follow digital-to-analogue conversion, correction for the (sin x/x) characteristic is provided. The passband tolerances of the filter plus (sin x/x) corrector plus the theoretical (sin x/x) characteristic should be the same as given for the filters alone. This is most easily achieved if, in the design process, the filter, (sin x/x) corrector and delay equalizer are treated as a single unit.

The total delays due to filtering and encoding the luminance and colour-difference components should be the same. The delay in the colour-difference filter (Fig. 2 of Annex III to Recommendation 601) is double that of the luminance filter (Fig. 1 of Annex III to Recommendation 601). As it is difficult to equalize these delays using analogue delay networks without exceeding the passband tolerances, it is recommended that the bulk of the delay differences (in integral multiples of the sampling period) should be equalized in the digital domain. In correcting for any remainder, it should be noted that the sample-and-hold circuit in the decoder introduces a flat delay of one half a sampling period.

The passband tolerances for amplitude ripple and group delay are recognized to be very tight. Present studies indicate that it is necessary so that a significant number of coding and decoding operations in cascade may be carried out without sacrifice of the potentially high quality of the 4 : 2 : 2 coding standard. Due to limitations in the performance of currently available measuring equipment, manufacturers may have difficulty in economically verifying compliance with the tolerances of individual filters on a production basis. Nevertheless, it is possible to design filters so that the specified characteristics are met in practice, and manufacturers are required to make every effort in the production environment to align each filter to meet the given templates.

Subjective assessments of the visibility threshold for colour signal ringing were carried out in Japan. The results show that the visibility threshold is reached with 2.5% or less, for electronically generated patterns and characters, and with 5% or more, for general pictures. Based on the results of the assessments, a colour-signal shaping-filter was designed, for which the total disturbance due to ringing and aliasing was less than 2.5%. This characteristic can be realized by a digital transversal filter [CCIR, 1982-86h].

The specifications given in Annex III to Recommendation 601 were devised to preserve as far as possible the spectral content of the Y, C_R, C_B signals throughout the component signal chain. It is recognized, however, that the colour difference spectral characteristic must be shaped by a slow roll-off filter inserted at picture monitors, or at the end of the component signal chain.

2.4 Bandwidth and filtering for conversion between different sampling rates

[CCIR, 1986-1990a] considers the digital filtering and interpolation characteristics necessary to interface between the 4:2:2 signals of Recommendation 601 and signals conveyed using lower sampling frequencies, and gives examples of filters, designed to preserve the information content, of reasonable complexity. Only horizontal filtering is considered.

[CCIR, 1986-1990b] describes subjective tests carried out using the above characteristics implemented by computer simulation. It was found that for natural pictures, the effects of sub-sampling are more visible in coloured areas, but some impairment was introduced by sub-sampling the luminance component of electronically generated pictures. The former conclusion led to consideration of quincunx sub-sampling for chrominance signals.

3. Sampling parameters

The sampling process is determined by three basic factors:

- the sampling structure, i.e. the relative position of the samples in space and time;
- the number of samples per line;
- the filtering process, which may be one-, two-, or three-dimensional.

The sampling structure mentioned above may, or may not, be repetitive with respect to the picture. Likewise, the number of samples per line may, or may not, be constant from line to line. In all the examples given below the sampling patterns were picture-locked.

A general theoretical survey is given in [Kretz and Sabatier, 1981].

Some comparisons between orthogonal and quincunx sampling patterns are given in [CCIR, 1978-82d]. These indicate that the orthogonal pattern has some advantages.

3.1 *Sampling rates*

The EBU has studied the problem of defining a standard set of essential coding parameters for television studio equipment. The work was carried out with four main objectives:

- to eliminate, in the production area, the differences between the existing 625-line systems;
- to ensure that the picture quality obtained is as high as, or higher than, that obtainable with good modern practice using analogue techniques;
- to ensure that the standard is suited to technology that is available at present, or is likely to be available in the near future;
- to arrive at parameter values which take into account the needs of picture processing in the studio.

In a first series of studies [CCIR, 1978-82k] orthogonal sampling was used with sampling rates of 768 f_H (line frequency) for the luminance signal and 256 f_H for the colour-difference signals; the colour-difference samples were co-sited and each pair of colour-difference samples was co-sited with a luminance sample.

These studies indicated that further work was necessary, with particular regard to the influence of picture-processing requirements on the choice of sampling rates.

The sampling parameters discussed in [CCIR, 1978-82k] are considered in [CCIR, 1978-82l] with regard to their suitability for digital-signal transmission at a rate of 140 Mbit/s. The view is expressed that signals based upon these sampling parameters would be of higher quality than those now provided by analogue transmissions.

The EBU has carried out a further series of studies relating to sampling rates. This work included experiments to assess the picture quality available using a number of parameter-set values within the range 12 : 4 : 4 to 14.3 : 7.15 : 7.15 where the numbers in these ratios correspond to the sampling frequencies (in MHz) used for the luminance signal and for the two colour-difference signals, respectively. Apart from the 12 : 4 : 4 set, all the parameter sets assessed had a ratio of 2 : 1 between the luminance and colour-difference sampling frequencies. [CCIR, 1978-82m; EBU, 1981] outlines these investigations and discuss the results obtained with each of the parameter-set values, with regard to a number of attributes.

First, concerning the picture quality obtained after one analogue *RGB* to digital *YUV* conversion, the results indicate, in broad terms, that the 12 : 6 : 6 parameter set gives a perceptibly better performance than the 12 : 4 : 4 set. However, they also indicate that the performance of the 14.3 : 7.15 : 7.15 set, in this regard, is not significantly better than that obtained using the 12 : 6 : 6 set.

Secondly, with regard to the quality of chroma-key (colour-matte) obtained, the results indicate that, while the 12 : 6 : 6 set clearly provides a better performance than the 12 : 4 : 4 set, a relatively steady improvement in performance can be noted as the luminance and colour-difference sampling frequencies are further increased to their maximum values, i.e. conforming to the 14.3 : 7.15 : 7.15 set.

Thirdly, it was found that, in tests involving a moderate amount of horizontal picture expansion, no aliasing could be observed, using natural (non-electronically generated) test pictures, for all luminance-signal sampling frequencies within the range 12 : 6 : 6 to 14.3 : 7.15 : 7.15. However, using an electronically generated horizontal-frequency sweep, aliasing decreased with increasing sampling frequency; the decrease was most noticeable in the range 12 to 13 MHz.

Finally, with regard to bit-rate reduction, the studies show that it is possible to reduce the bit-rate of a signal conforming to the 14.3 : 7.15 : 7.15 set so as not to exceed 140 Mbit/s, without affecting the picture quality or the potential capability for chroma-key (colour-matte) processing.

Some of the above-mentioned results were derived from work undertaken in the UK, which is described in detail in [CCIR, 1978-82n]. This work included tests on two parameter sub-sets, in order to investigate the properties of systems possibly qualifying as lower members of the family of compatible digital coding standards. In one of the sub-sets the luminance- and colour-difference signal sampling frequencies were related by the ratio 4 : 1.

The subjective tests involved in this work were carried out using the "double-stimulus" method described in the Appendix I of Recommendation 500 and reference pictures derived by digitally coding the input signals according to the 14.3 : 14.3 : 14.3 parameter set. The detailed subjective-test results obtained during the above-mentioned tests have been analysed by the method described in Annex III of Report 405, and the results of the analysis, described in [CCIR, 1978-82o], are given in terms of the impairment index I and the mean score $\overline{U}$. From the analysis it can be concluded that, with regard to basic picture quality the 13.5 : 6.75 : 6.75 parameter set is characterized by an impairment index I of 0.03 at 4 H (i.e. a mean score greater than 4.8) and that the corresponding results related to chroma-key (colour-matte) performance are $I = 0.3$ and $\overline{U} = 4.0$.

In the USSR consideration has been given to the sampling parameters suitable for standards D and K. Early work included the study of a system in which the luminance signal was sampled orthogonally at a rate of 800 f_H (12.5 MHz), and each of the colour-difference signals were similarly sampled at 200 f_H (3.125 MHz); the investigation is outlined in [CCIR, 1978-82e]. In studies described in [CCIR, 1978-82p] the sampling parameters for digital TV studios were revised as it was found desirable to increase the sampling frequencies to about 13 to 13.5 MHz and 6.5 to 6.75 MHz for the luminance and colour-difference signals respectively.

[CCIR, 1978-82q] reports the results of comprehensive subjective tests which were carried out with the objective of determining the relationship between the reproduced colour-picture quality and the sampling frequencies and sampling structures used for the luminance and colour-difference signals.

A standard, designed to be a member of the family of digital coding standards below that recommended as the main studio standard is described in [CCIR, 1978-82r]. In this standard the luminance signal is sampled at 10.125 MHz and the useful bandwidth extends to 5 MHz. The colour-difference signals are sampled at a frequency equal to 3.375 MHz, and have a bandwidth of 1.5 MHz. Further studies are necessary to select the best sampling structure for this system. The system is known as a 3 : 1 system, owing to, first, the particular ratios used to calculate the sampling frequencies from the frequencies recommended for the main studio standard and, secondly, the use of line-sequential coding of the colour-difference signals. It is claimed that the picture quality obtained from this system is at least equal to that obtained using a conventional analogue PAL codec.

A system for coding a television signal at a bit rate of 70 Mbit/s using the DPCM method (folded quantization with 5 bit/sample) is described in [CCIR, 1982-86i; Wengenroth, 1982]. The sampling frequencies for luminance and colour-difference signals are derived from the studio standard by means of a digital filter which gives a conversion of the sampling frequency in the ratio 6 : 5. Line-sequential transmission is foreseen for the two colour difference signals.

Extensive subjective tests, using a method described in Report 405, Annex IV, were carried out in the USA using digitally coded component signals conforming to the 525-line standard; these are outlined in [CCIR, 1978-82s; SMPTE Journal, 1981]. The tests covered luminance-signal sampling rates corresponding to 768, 864 and 912 samples per total line and ratios of luminance-signal to colour-difference signal bandwidth of 4 : 4 : 4, 4 : 2 : 2, 4 : 1 : 1 and 2 : 1 : 1. Tests were carried out with regard to basic picture quality and on the properties of the various parameter sets with regard to production processes such as picture expansion, chroma-key (colour-matte), multi-generation digital recording and digital decoding from, and encoding into, analogue M/NTSC composite colour signals.

These tests confirm the selection of the 4 : 2 : 2 parameter set as the one preferred as a studio standard, and showed that a small but rising picture quality was obtained with increase of sampling rate.

Subjective tests with similar sampling parameters were carried out in Japan, and these are described in [CCIR, 1978-82t]. The tests included digital chroma-key (colour-matte) processing for parameter sets with luminance-signal sampling frequencies of 12.1, 13.6 and 14.3 MHz. The two main results can be summed up in the following way: first, the picture quality decreases gradually as the sampling frequency of the colour-difference signals decreases from a value equal to that used for the luminance signal, to a quarter of that value and, secondly, the picture quality obtained using the chroma-key (colour-matte) process decreases significantly as the sampling frequency used for the colour-difference signals is reduced; this decrease is more marked when the sampling frequency is reduced from half that used for the luminance signal to a quarter of that value.

[CCIR, 1982-86j; Khleborodov, 1983] contain a theoretical study of picture distortions in line-sequential transmission of colour-difference signals with a two-field cycle.

[CCIR, 1982-86k] describes results of subjective assessments of picture quality obtained with 4 : 1 : 1, 4 : 2 : 0, 2 : 1 : 1 and 3 : 1 : 0 coding, including the effects of line- and field-offset sub-sampling, and of line-sequential processing of the colour-difference signals; these tests used stationary test pictures. The results showed that the picture quality for 2 : 1 : 1 with field-offset sub-sampling was superior to that of the other members with a similar bit rate for most of the pictures tested.

[CCIR, 1982-86l] reports subjective tests on a 2 : 1 : 1 system employing field-offset sub-sampling which suggests that satisfactory portrayal of movement can be achieved.

3.2 *Changing the sampling rate*

Sampling rate changing is a process required in many picture processing operations. One example is that involved in converting the signals conforming to one member of the family of compatible coding standards to another. [CCIR, 1978-82u] describes a filtering process, based on comb filtering of the upper part of the signal spectrum, which enables signals to be converted easily between various members of a binary-related family (4 : 4 : 4; 4 : 2 : 2; 2 : 1 : 1). [CCIR, 1978-82t; Nishizawa *et al.*, 1981] include the description of a very sophisticated interpolation low-pass filter intended for the same purpose.

Change of sampling rate is also required when the family of compatible digital coding standards is not based upon binary ratios. [CCIR, 1978-82v] indicates that the design of the interpolating filter need not be unduly complicated, provided that the change of sample rate involves a ratio described by a rational number.

In [CCIR, 1982-86m] it is shown how various source coding procedures and bit-rate reduction techniques can be used to adapt the various members of the family of compatible digital coding standards to suitable levels of the transmission hierarchy based on 2048 kbit/s.

In order to avoid quality losses due to sampling frequency conversions and coding procedures in tandem and to eliminate the need for transcoding equipment to be set up at all transmission network nodes operating at different bit-rates, it is desirable to carry out bit-rate conversion at the television studio in accordance with the bit rate of the circuit section having the narrowest bandwidth.

Thus signals transmitted through a point-to-point link consisting of the tandem connection of sections of different capacity should be coded in conformity with the section having the smallest capacity, unless it is necessary for a signal of higher quality to be available at an intermediate point.

4. Uniformly quantized PCM

The basic form of digital coding is uniformly quantized PCM, where the value of each digital "word" represents the uniformly quantized amplitude of a sample of the baseband signal.

In all the examples given above, 8 bits per sample uniform quantizing is proposed for the luminance signal and for the colour-difference signals [CCIR, 1978-82e, k, l and w].

5. Multiplexing methods

The single-channel transmission of digitally encoded component signals requires that the three separately encoded signals, describing the luminance and two colour-difference signals, respectively, be combined together in time-multiplex form.

[CCIR, 1978-82x] compares two forms of multiplex. In the first, the three digital words describing each picture element are grouped together; in the second the words describing the luminance-signal values of all the picture elements in one line are grouped together, and this group of words is followed by two groups each describing the corresponding colour-difference signal values. The comparison concludes that the first arrangement is more economic but that the second is more advantageous with regard to monitoring.

[CCIR, 1978-82k] discusses a multiplexing structure identical to the first of those described above.

The work on the digital encoding of component signals carried out in the U.S.S.R. and described in [CCIR, 1978-82e], includes a multiplex arrangement in which the signals are transmitted in the order Y, D_R, Y, Y, D_B, Y, where Y represents a luminance signal value and D_R and D_B represent colour-difference signal values.

[CCIR, 1982-86n] describes a multiplexer which combines two signals, each having a bit rate of approximately 70 Mbit/s, to produce a signal at the fourth order of the hierarchical level, namely 139 264 kbit/s. Each 70 Mbit/s tributary may contain either one digital television signal or two signals of 34 368 kbit/s. The frame alignment signal and the net bit rate of the two tributaries are adjusted to the requirements of both telephony and television. Accordingly, it may be possible for digital television signals to be adapted to other hierarchical bit rates. The insertion of a frame alignment signal at the interface between the television studio and the transmission system would considerably facilitate the transmission of television signals in the integrated services digital network (ISDN).

[CCIR, 1982-86o] describes the results of studies on a bit-parallel transmission method which permits easy transcoding both to and from a bit-serial format having a bit rate of 108 Mbit/s using two channels, and also to and from a 216 Mbit/s single channel format. [CCIR, 1982-86p] gives some details on the 2 × 108 Mbit/s parallel-serial and 216 Mbit/s serial interfaces.

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[1982-86]: **a.** 11/393 (Poland (People's Republic of)); **b.** 11/327 (USSR); **c.** 11/348 (Italy); **d.** 11/292 (IWP 11/7); **e.** 11/65 (United Kingdom); **f.** 11/276 (United Kingdom); **g.** 11/424 (OIRT); **h.** 11/31 (Japan); **i.** 11/13 (Germany (Federal Republic of)); **j.** 11/90 (USSR); **k.** 11/22 (Japan); **l.** 11/415 (Japan); **m.** 11/14 (Germany (Federal Republic of)); **n.** 11/15 (Germany (Federal Republic of)); **o.** 11/24 (Japan); **p.** 11/136 (OIRT).

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REPORT 1209

MEASURES FOR THE AVOIDANCE OF POSSIBLE INTERFERENCE GENERATED BY DIGITAL TELEVISION STUDIO EQUIPMENT

(1990)

1. INTRODUCTION

With the advent of digital picture processing, the problems of spurious radiation from such apparatus has had to be considered. Equipment built to operate on the CCIR Recommendation 601 digital video standard utilizes a luminance sampling frequency of 13.5 MHz, the ninth harmonic of which coincides exactly with an international distress frequency, namely 121.5 MHz. In addition, 243 MHz, or the 18th harmonic of the luminance sampling frequency, is also reserved for international distress use.

The international distress frequencies, 121.5 MHz and 243 MHz are used by Emergency Location Transmitters (ELT) in the aeronautical service and Emergency Position Indicating Radio Beacons (EPIRB) in the marine service. The methods of operation are similar and an emergency is indicated by the radiation of a carrier with AM "chirp" modulation. The signals may be received on fixed receivers but are usually detected by aircraft or satellite receivers. Sophisticated processing is required to detect these signals reliably due to noise, interference and frequency variations due to misalignment and Doppler shifts over a bandwidth of 25 kHz. [Chung and Carter, 1987] outlines the processing involved in the SARSAT (Search And Rescue Satellite Aided Tracking) program of Canada, USA, France and USSR.

In view of the need to eliminate harmful interference, the design, construction and operation of digital equipment must take this into consideration, as a high priority. This Report describes electrical and mechanical measures, methods of measurement and some results of measurement.

2. Circuit Design Methods

Whenever feasible, the circuit board should be partitioned by logic speed, frequency and function. This technique reduces track lengths and helps to isolate high-frequency digital signals from analogue signals and also input and output lines. Impedance matching should be employed for high-speed logic devices. Balanced ECL circuits are frequently used.

The use of multi-layer printed circuit boards with power and ground distribution planes is recommended, as the planes act as feed-through capacitors at high frequencies. Analogue and digital power busses should be isolated. When the printed circuit board is being designed, the power distribution system should be considered first, followed by the signal distribution arrangements.

Decoupling capacitors with low effective series resistance and inductance should be placed close to IC power pins to reduce power supply radiating loops. Decoupling capacitors should also be employed at the point where the power supply enters the board. Surface mounted components should also be used where practical.

3. Electro-Magnetic Considerations

The following techniques may be employed for the minimisation of electro-magnetic radiation from equipment:

- use of connectors that are shielded and earthed to the equipment chassis.
- shielding and compartmentalising of components or sub-assemblies
- shielding and minimising the length of internal wiring.
- bringing earths and shields to a common point.
- use of multilayer boards with ground-planes for extender modules
- use of RF-screened chassis.

It has been reported that shielding is effective only if all inputs and outputs are filtered.

Electro-magnetic radiation can occur from ribbon cables. Possible means of minimising this radiation are by using "twist-n'-flat" and shielded cable, as well as by specially designed circular cables. Additional information on aspects of electro-magnetic shielding is contained in [Jerse and Terrien, 1986].

4. Measurement Methods

CISPR publications 16 and 22, on which the methods recommended by the standards associations of many administrations are based, give detailed specifications and procedures for measuring electromagnetic radiation. When measuring the radiation from a particular item of equipment, the real-life operational conditions of the equipment must be adhered to as far as possible. In particular, all external connections must be present.

5. Acceptable levels of radiation

CISPR Publication 22 recommends that the electro-magnetic radiation limits for Class A equipment (non-domestic low voltage equipment) should conform with the limits given in Table I.

TABLE I - Limits of radiated interference field strength at a test distance of 30m for Class A equipment

Frequency Range (MHz)	Quasi-peak limits dB(μV/m)
30 to 230	30
230 to 1000	37

Some administrations however recommend the limits given in Table II

TABLE II - Limits of spurious emissions (CSA Class A)
Maximum field-strength in dB(μV/m) at 30m

Frequency (MHz)	Maximum field-strength dB(μV/m) at 30m
30 to 88	30
88 to 216	34
216 to 1000	37

In [CCIR, 1986-1990 a] useful information is provided that may be used in making comparative judgements regarding the level of interference from digital equipment.

6. Measurements of radiated interference levels

Measurements of the levels of radiated signals at 121.5 MHz for a prototype digital PAL-RGB/YC_RC_B decoder based on Recommendation 601 have been conducted in Australia using a measurement technique conforming with CISPR publication 22. [CCIR, 1986-90 b] At a distance of 30m from the decoder field strength levels of up to 46 dB(μV/m) were measured. With cables removed levels of 37 dB(μV/m) were measured.

Similar measurements were carried out in the UK [CCIR, 1986-1990 c], again on experimental processing equipment conforming to Rec. 601, and adhering closely to the measurement technique outlined in BS 6527: 1984 (which is in accord with CISPR Rec. 22) in order to ensure repeatable results. The equipment under test was mounted on a remotely controlled turntable, and the measuring antenna was adjustable in height and polarisation so that worst case measurements could be obtained, field strength levels (referred to 30m) of up to 39 dB(μV/m) were measured. However, when the equipment was enclosed in a wire mesh cage a value of 24 dB(μV/m) (referred to 30m) was obtained.

These measurements on prototype equipment demonstrate that a potential problem exists. Careful attention needs to be paid to the electromagnetic compatibility of equipment based on Recommendation 601 in design, manufacture and use.

In Japan, measurements of the radiation from commercially produced digital video equipment having a sampling frequency of approximately 14.3 MHz have been conducted [CCIR, 1986-1990 d]. While this equipment does not conform to Recommendation 601 the levels of measured 9th harmonic (128.7 MHz) radiation may provide a useful guide to the levels that could be obtained from commercially produced equipment conforming with Recommendation 601. The level of 9th harmonic radiation measured was 22 dB(μV/m), referred to 30m.

Results reported in [CCIR, 1986-90e] carried out at an experimental digital television studio in France gave mean field strengths which at 30 m would amount to between 29 dB (μ V/m) and 37.8 dB (μ V/m). If an attenuation of 20 dB to the concrete construction of the studio is taken into account, the resultant field strength would certainly be below the appropriate CISPR limit which is 30 dB (μ V/m) at 30 m.

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REPORT 1088-1

INTERFACES FOR DIGITAL VIDEO SIGNALS IN 525-LINE AND 625-LINE TELEVISION SYSTEMS

(Question 25/11)

(1986-1990)

1. Introduction

CCIR Recommendation 656 specifies interfaces for digital studio equipment, in conformity with the basic parameter values contained in Recommendation 601.

This Report summarizes the contributions received on digital video interfaces which provided the basis for Recommendation 656, it includes supplementary information on the subject, and indicates areas in which further studies are required.

2. Definitions

Interface is a concept involving the specification of the interconnection between two items of equipment or systems. The specification includes the type, quantity and function of the interconnection circuits and the type and form of the signals to be interchanged by these circuits.

A parallel interface is an interface in which the bits of a data word are sent simultaneously via separate channels.

A serial interface is an interface in which the bits of a data word, and successive data words, are sent consecutively via a single channel.

A parallel-serial (hybrid) interface is an interface in which portions of a data word are sent consecutively via separate channels.

3. Primary encoding format

There are features of the basic data organization which are common to the three types of interface defined above and which are the subject of Part I of Recommendation 656. They comprise:

- the organization of the video data into words and blocks;
- the timing reference codes providing video synchronization;
- ancillary data signal structure;
- data signals during blanking intervals;
- details of the multiplexing.

3.1 *Blanking and synchronization considerations*

[CCIR, 1982-86a, b and c] agreed on the form and use of timing reference signals. Each timing reference signal consists of a four-word sequence. The first three words are a fixed preamble. The fourth word contains information defining:

- first or second field identification;
- state of field blanking;
- state of line blanking;
- error protection data.

[CCIR, 1982-86d] proposed that only one timing reference signal should be used, located at the end of each line-blanking period. This identification signal includes a clock burst (for a bit-serial interface), indication of the initial point of the data frame, field-blanking period and first and second field periods. End-of-line information will be obtained by counting clock pulses.

The EBU [CCIR, 1982-86e] suggested that additional codes be included in the data stream and that the beginning and end of the digital active line will be identified in the demultiplexed Y, C_R, C_B data streams. It further proposed that these codes be included at the 4 : 4 : 4 level for both Y, C_R, C_B and R, G, B signals in digital form.

[CCIR, 1982-86f] stated that the timing reference (digital synchronization) codes inserted into the parallel code should be easily usable in a serial code.

Proposals for 525-line and 625-line differ in their definition of digital field-blanking intervals. [CCIR, 1982-86b, c, and d] stated that only 9 lines in both fields 1 and 2 belong to the field-blanking interval. [CCIR, 1982-86a and f] specify the digital field-blanking interval of 24 lines (field 1) and 25 lines (field 2). It may be advisable to shorten the digital field-blanking interval so as to allow for complex vertical filtering, though this problem needs further study.

Amongst other considerations [CCIR, 1982-86g] drew attention to the fact that "timing reference signals" should be referred to as "timing reference codes".

In those data words occurring during digital blanking intervals that are otherwise unspecified, the OIRT [CCIR, 1982-86e] proposed that the digital codes equivalent to blanking level for Y, C_R, C_B be included in the appropriate locations in the multiplex.

3.2 *Ancillary signals*

Provision is made for ancillary data signals to be inserted synchronously into the video multiplex during both horizontal and vertical blanking intervals. It is noted that digital video tape recorders (Rec. 657) do not record any of the horizontal blanking intervals nor some lines in the vertical blanking intervals. For that reason the EBU has allocated only four vertical blanking lines for ancillary signals. The unrecordable blanking periods can be used to transfer data between other studio equipment if required.

[CCIR, 1982-86 d and f] contain some details of the ancillary signals. [CCIR, 1982-86a, b and c] propose the ancillary data signal format.

Time-code is an essential ancillary signal for control of post-production processes and the synchronization of video and audio. Four formats are currently recognised, IEC format [IEC Pub. 461] in the vertical interval and longitudinal forms, audio time code in accordance with Recommendation 647 and time code associated with the R-DAT audio recording format. Ancillary data formats to include this information in the vertical interval are a current study in a number of Administrations and offer possibilities to maintain the synchronism of video and audio through various processes [CCIR, 1986-1990a].

Recommendation 656 specifies only a timing reference code ANC; the data field following the ANC is left unspecified. There have been discussions about various packet formats for the ancillary data.

Some information with higher priority and predetermined format might have a fixed data packet length and probably also a fixed time slot in the data stream. Less important ancillary data not having a predetermined format might have variable packet length.

[CCIR 1986-1990b] mentions digital line numbers as possibly useful information which should be considered as an ancillary signal. The document contains a proposal for two modes of digital line numbering. In addition one method for introduction of respective code words into the video data is proposed.

The study of the requirements for sound signals is included in Decision 60 to ensure that any possible effects upon the associated sound signals caused by the video interface parameters will be duly considered. Except for the need to control the relative delay between the video and the sound, no such effects have been identified.

4. Parallel interfaces

A number of proposals [CCIR, 1982-86a, b, c, d and f] suggested using eight conductor pairs, where each should carry, in NRZ format, a multiplex stream of bits (of the same significance) of each of the component signals, namely, Y, C_R, C_B. The eight pairs should also carry timing reference information and may carry ancillary signals that are time-multiplexed into the data stream during video blanking intervals. A ninth pair would provide a synchronous clock at 27 MHz. These proposals, with [CCIR, 1982-86e], contributed to the preparation of Recommendation 656 (see also [EBU, 1983]).

The signals on the interface may be transmitted using balanced conductor pairs for a distance of up to 50 m without equalization and up to 200 m with appropriate equalization [CCIR, 1982-86a].

Appropriate coding of the clock signal, such as the use of an alternating parity (AP) coding, has been shown to extend this distance by reducing the effects of cable attenuation [CCIR, 1982-86h].

5. Serial interfaces

[CCIR, 1982-86d] gives an example of a data sequence using 216 Mbit/s multiplexing. Particular attention is paid to ease of clock extraction and word synchronization by the inclusion of words within the data stream which generate clock bursts.

[CCIR, 1982-86f] refers to channel coding and states that transmission should be effected via 75 Ω coaxial cables for distances up to 1 km.

[CCIR, 1982-86e] contains a detailed consideration of the special requirements for a serial interface and proposes in Annex I a draft Recommendation for a bit-serial interface for the 4 : 2 : 2 level of Recommendation 601. This contributed to the preparation of Recommendation 656 (see also [EBU, 1985]).

In [CCIR, 1982-86e] the transmission of signals is considered in both electrical form, using coaxial cable, and in optical form using an optical fibre. The special requirements for bit-serial signal transmission between studios, or between equipments in a studio are given as:

- low cost and low complexity coupled with high reliability;
- very low intrinsic error rate in the transmission due to the very short distances;
- multiple outputs for monitoring and distribution;
- rapid recovery from errors introduced by switching of the transmission path, the video source or signal interruptions;
- full compatibility with the format of the bit-parallel interface and signal code commonality of both electrical and optical implementations of the bit-serial interface;
- usable over a range of distances from zero to at least 500 m, with a minimum of adjustments and extremely low error rates;
- applicable to a range of cable types.

These requirements are confirmed in [CCIR, 1982-86i], which also points out that in the implementation of a digital video installation, preference would normally be given to the parallel interface for short connection lengths and that recourse would be made to the serial interface mainly in the case of long or complex connection paths, where the cost of the interface terminal equipment would not override the saving in the physical support of the connection itself. Coaxial cables would probably be preferred for connections of medium length, while preference would go to optical fibres for very long connection lengths.

This contribution also suggests that the code used should be structured so as to permit the redundant bits to be employed to implement a system for measuring the bit error ratio (BER) at the receiving end of the connection and thus automatically monitoring its performance.

It further suggests that in a fully integrated digital installation or system it may be useful for all interconnections to be transparent to any appropriate digital stream, irrespective of the message content. Thus, although the interface will be used to transmit a video signal, it should be "transparent" to the message content, i.e., it should not base its operation on the known structure of the message itself.

[CCIR, 1982-86e] reviews the characteristics of transmission media, including interference susceptibility and describes the proposals received for source encoding, channel encoding and error management.

Two methods of source encoding have been proposed. [CCIR, 1982-86j] suggests the use of a parallel scrambler with the addition of a parity bit for synchronization and limited error detection purposes. According to a preliminary investigation, it appears that the sending end, at least, of such an interface could be integrated in a single gate-array chip.

A second method [CCIR, 1982-86e] providing spectrum control, clock and word synchronization by an 8-bit to 9-bit adaptive mapped code, is adopted in Recommendation 656.

In relation to these methods of source encoding, two different approaches to channel encoding have been proposed. In the scrambled system the channel coding is the AMI (Alternate Mark Inversion) for coaxial cable, and NRZ for optical fibre. The AMI code restricts the required bandwidth. In the bit-mapped system the encoded bit-stream, in NRZ format, is suitable for feeding both transmission media.

The bit-parallel interface defined in Recommendation 656 includes the possible addition of two bits to each word, thus enhancing the accuracy of the sample from 8 bits to 10 bits. In some applications, such as computer graphics, this improvement has been found advantageous. In the case of the serial interface of Recommendation 656, this extension is not feasible, thus limiting the application of the serial interface in both its electrical and optical forms. Certain Administrations are studying methods to convey a 10-bit word length in the serial interface, based on scrambled NRZ coding techniques.

6. Parallel-serial (hybrid) interfaces

[CCIR, 1982-86d and f] also discuss an alternative solution in which signals are divided into multiple channels of 108 Mbit/s each in order to reduce the bit rate per channel. This method also enables various members of the extensible family of compatible coding standards to be accommodated within a multi-channel arrangement. However, as stated in [CCIR, 1982-86k], the main advantage advocated for the hybrid interface is that it reduces the bit rate sent on each of the parallel cables, but if 2 parallel cables are used, which is the most frequent proposal, then the bit rate is halved but the new bit rate is still too high to be implemented by means of much cheaper technologies.

On the other hand, the use of a hybrid interface involves complications at the sending and receiving ends, where circuits are needed to multiplex and demultiplex the bit stream, and also to phase the bit streams received on the cables.

These complications, and the cost of the additional cable (or cables) in the hybrid interface, appear overwhelmingly to militate in favour of a fully serial interface, rather than a hybrid interface, in those cases when the parallel interface cannot be used.

7. Optical interfaces

Work has been reported concerning the optimum characteristics of an optical fibre interface for use in the studio, [CCIR, 1986c, d, e]. The use of a single-mode fibre driven by a laser or LED at a wavelength of approximately 1300 nm is suggested. Appendix 1 contains a draft text, as yet incomplete, to form the content of section 7 of Recommendation 656. Administrations are invited to make studies and contributions to complete this section in the current study period.

[CCIR, 1986-90f] describes a new approach to the switching and routing of digital signals by optical means within a large studio centre. An arrangement is suggested in which the central routing switcher is eliminated by conveying all of the signals to every destination along a single optical fibre. The signals are assembled by a combination of time-division multiplexing (TDM) to a bit rate of the order of 2 Gbit/s, and optical wavelength-division multiplexing. The use of TDM means that the system is applicable to a wide range of bit rates including those required for digital HDTV. If this approach proves successful, appropriate interface specifications will be required.

Document [CCIR, 1986-90g] described a method, applicable also to HDTV systems, for the transmission of three analogue wideband (up to 60 MHz) signals (R, G, B) through three optical fibres. The method used consists of the linearization of the characteristics of the optical device. The same document details the advantages of serial digital optical transmission at 1.15 Gbit/s for HDTV on a single fibre.

8. Practical implementation of interfaces

[Grimaldi et al, 1986] describes the all-digital studio in final implementation in France. Although some functions are still analogue (e.g. cameras) the system uses a large number of pieces of digital equipment, in particular a mixer/switcher, video tape recorders and miscellaneous other functions. This equipment is connected by coaxial cables using the serial interface of Recommendation 656, with some minor differences due to the early implementation. An optical link using the same signal format is operative over 6 km. A discussion of the solutions adopted is included.

[Baraclough et al, 1987] provides information on practical experience in the design, installation and operation of an experimental digital television production centre in the United Kingdom employing the parallel interface of Recommendation 656. The solutions adopted for problems encountered are given, incuding, for example, those associated with multiple equipment interconnections, synchronization and timing.

Further contributions on this subject are invited.

9. **Interference with other services**

Processing and transmission of digital data, such as digital video signals, at high data rates produces a wide spectrum of energy that has the potential to cause cross-talk or interference. In particular, attention is drawn in Recommendation 656 to the fact that the ninth and eighteenth harmonics of the 13.5 MHz sampling frequency (nominal value) specified in Recommendation 601 fall at the 121.5 and 243 MHz aeronautical emergency channels. Appropriate precautions must therefore be taken in the design and operation of interfaces to ensure that no interference is caused at these frequencies. Permitted maximum levels of radiated signals from digital data processing equipment are the subject of various national and international standards, and it should be noted that emission levels for such related equipment are given in CISPR Recommendation: "Information technology equipment – Limits of interference and measuring methods" Document CISPR/B (Central Office) 16.

In the case of the bit-parallel interface [CCIR, 1982-86l] states that according to studies and experiments effected at the Canadian Broadcasting Corporation (CBC), with a correct shielding of the cables, no interference problem with other services is to be expected. This contribution recommends that radiation levels should comply with the limits given in Table I [CSA, 1983]. These limits are equivalent to those of the FCC in the United States of America.

TABLE I – *Limits of spurious emissions (CSA Class A)*

Frequency (MHz)	Maximum field strength dB(μV/m) at 30 m
30 to 88	30
88 to 216	50
216 to 1000	70

In relation to the bit-serial interface [CCIR, 1982-86e] states that transmission by optical fibres eliminates radiation generated by the cable and also prevents conducted common-mode radiation, but the performance of coaxial cable can also be made near-perfect. It is believed that the major portion of any radiation would be from the processing logic and high-power drivers common to both methods. It adds that due to the wideband, random nature of the digital signal, little is gained by frequency optimization.

Note.- See Report 1209.

10. Further studies

Further studies are required:

- on interfaces for the 4 : 4 : 4 level, and for lower members of the family of digital coding standards;
- to establish the types of ancillary signals to be carried, including their characterization and location in the data stream, and to propose international standards as necessary;
- to determine what special provisions may be necessary in relation to the associated sound channels, for example, to avoid excessive relative time delays;
- on the practical methods required to ensure acceptably low levels of radiated interference from the digital signals;
- on optical interfaces for bit-serial signals.

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[1982-86]: **a.** 11/126 (EBU); **b.** 11/61 (United States of America); **c.** 11/94 (Canada); **d.** 11/24 (Japan); **e.** 11/291 (IWP 11/7); **f.** 11/136 (OIRT); **g.** 11/336 (Italy); **h.** 11/347 (Italy); **i.** 11/335 (Italy); **j.** 11/356 (Italy); **k.** 11/354 (Italy); **l.** 11/385 (Canada).

[1986-90]: a. IWP 11/7-257 (Australia); b. IWP 11/7-186 (OIRT); c. IWP 11/7-115 (United Kingdom); d. 11/112 (Canada); e. 11/124 (Canada); f. IWP 11/7-141 (United Kingdom); g. 11/28 (Thomson-CSF).

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Appendix 1

Proposed draft additions to Recommendation 656 concerning an optical interface

7. Characteristics of the Optical Interface

7.1. Source Characteristics

7.1.1. Output Wavelength

1300nm nominal

Maximum spectral line width 150nm between half power points.

7.1.2. Output Power

Maximum 0dBm

Minimum −25dBm

7.1.3. Logic Convention

Maximum power output corresponds to the signalling of a logical 1.

7.1.4. Rise and Fall Times

To be decided.

7.1.5. Jitter

To be decided.

7.1.6. Isolation

Transmitter must withstand 10% of its output power returned by reflection.

7.2. Optical Fibre Link

FIBRE (compatible with optical fibre specified in CCITT Rec. G.652)

Fibre type	- single mode
Dimensions: mode field dia.	- 9-10 um +/-10%
cladding	- 125 um
Operating window	- around 1300 nm
Mode field concentricity	- < 3 um
Cladding non circularity	- < 2%
Cut-off wave length	- 1100-1280 nm
Attenuation at 1300 nm	- < 1 dB/km
Max. dispersion (1270-1340 nm)	- 6 ps/nm.km

CONNECTOR

Type	- biconical

7.3. Destination Characteristics

7.3.1. Sensitivity

Input power for a mean bit error rate of 1 in 10^9 -35dBm.

Maximum input power -20dBm.

7.3.2 Maximum Input Power

Receiver shall operate with a mean bit error rate better than 1 in 10^9 up to a power Level of -20 dBm.

REPORT 1219

SYNCHRONIZING SIGNALS FOR THE COMPONENT DIGITAL STUDIO

(Question 25/11 and Study Programme 25N/11)

(1990)

1 Introduction

Close synchronisation of signal sources and of signal processing is required in a television studio of any kind and this is particularly true in the digital studio or in studios operating in a mixed analogue and digital manner. Synchronisation is required at various levels: for the sample clock (13.5 MHz in the case of Recommendation 601), and the scanning line, field and frame, to a high degree of accuracy and stability so as to allow the freedom of mixing, effects and processing demanded in television programme production. Synchronisation is thus a basic function and its accuracy and stability are fundamental to successful television broadcasting.

Two requirements for synchronisation can be identified:-

(a) Input Synchronisation the synchronisation of the internal clocking of a process with the input signal. This is generally achieved by locking the clock generator to the input signal directly through a phase-locked loop, thus minimising jitter and drift.

(b) Output Synchronisation the synchronisation of two or more signals with each other, by locking their respective generators to a common reference signal, as is generally done with cameras and telecines.

2 Possible Synchronising Signals

For the case of input synchronisation of an equipment processing a component digital signal, it is clear that the reference can only usefully be the digital signal itself as defined in Recommendations 601 and 656. For the case of output synchronisation a wider choice is possible including:

- A digital black signal;
- A digital picture signal;
- An analogue black signal;
- An analogue picture signal;

- A special signal in analogue or digital form.

Here the digital signals would conform to Recommendations 601 and 656, and the analogue signals to Recommendation 470 and Report 624.

The essential requirement is that the signal should carry picture synchronisation information (line, field and frame) and that the sample clock can be derived in a simple and precise manner. It is further desirable that the signal be usable with analogue equipment in component and possibly composite form, and in both 525-line and 625-line standards.

Studies by broadcasters in both 525-line and 625-line standards have concluded that, to cater for a mixed analogue/digital environment, satisfactory performance, flexibility and commonality are achieved by the use of the analogue black signal modified slightly in respect of the tolerances on rise-time and jitter. [EBU, 1988] [SMPTE, 1989].

It is also appropriate to provide for the fully-digital environment by allowing for the use of a digital signal conforming to Recommendation 656 as a synchronizing reference.

3 Signal Decoding

The synchronising elements of the digital video signal described in Recommendation 656 can be derived from the synchronising signal either directly, or by means of the phase-locking of a generator of higher accuracy and stability, if an improved level of performance is required. The equivalent of a studio-level synchronising pulse generator (SPG) may be required. Derivation is as follows:

Sample Clock - 858 times the line frequency (525-line systems) or 864 times the line frequency (625-line systems).

EAV and SAV Timing References - directly or indirectly from line synchronising clocked by the sample clock.

V and F Flags - directly or indirectly from vertical synchronising, clocked by the sample clock.

Digital Blanking - as EAV/SAV and V, F flags.

4. Alternative signals

The use of a composite video signal in place of the specified analogue signal has been studied but is not recommended, as variations in average picture level (APL) can cause timing drift and jitter following synchronizing separation.

Further studies are invited on alternative methods of studio synchronization which make full use of new digital techniques.

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SMPTE [1988]. Recommended Practice RP 154-1988: Reference signal for the synchronisation of 525-line component digital video equipment.

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REPORT 1211

USER REQUIREMENTS FOR DIGITAL TELEVISION TRANSMISSION

1. Introduction (1990)

In the Study Period 1982-1986, IWP 11/7 of CCIR Study Group 11 assembled data on bit-rate reduction techniques, for the most part those which could be used to reduce the net bit-rate of signals originally conforming to CCIR Rec. 601 . This information represents a reference work on bit-rate reduction techniques and is contained in Report 1089.

In Section 2, the functions and purposes which digital television links will serve are discussed. In Section 3, assessment methods are considered. Section 4 concerns performance in the presence of transmission errors and Section 5 presents systems requirements for systems at about 140,, 68 and 34 Mbits/s. Section 6 considers the requirements of associated sound channels. Section 7 concerns bit-budgets for 140 Mbit/s and 34 Mbit/s systems and Section 8 makes comments on source formats and criteria for 34 Mbit/s systems. Section 9 concerns encryption and Section 10 sound-vision timing.

Annex 1 contains specific comments on the failure mode for the television multiplex.

2. Functions and purposes of digital television networks

Digital transmission networks carrying television signals will need to transport vision and accompanying sound signals. It is possible to categorise the purposes for which the received signal will be used. This is something of a generality which remains to be precisely defined, but nevertheless, it may be useful in understanding the different requirements associated with different access levels, etc.

The overall system objectives can be classfied as given in (a) and (b) below.

(a) Systems for contribution purposes

A contribution circuit is a circuit at the end of which there may be a need for high-quality picture processing (e.g. inter-studio links). This means that the transmission system should not (ideally) limit the processing possibilities that can be performed on the signal.

(b) Systems for distribution purposes

A distribution circuit is a circuit at the end of which there is likely to be little or no need for high-quality picture processing (e.g. studio-transmitter links). This means that the emphasis in the design of the system is on the highest subjective picture quality.

For all systems however, the source requirement is the same and is specified as follows:-

The video source standard for bit-rate reduction systems considered in this document is the 4:2:2 standard defined in CCIR Rec. 601. For the video signal, the digital transmission system must be able to carry all the active picture period, defined as follows, to the extent that it has an effect on the desired quality or processing capability of the signal.

	625-lines	525-lines
- active lines/frame	576	488
- active luminance samples/line (Y)	720	720
- active colour difference samples//line (C_R, C_B)	360 x 2	360 x 2
- no. of bits/sample	8	8
This corresponds to a total bit-rate of (Mbit/s)	165.88	168.48

In general, three facets of bit-rate reduction system performance are of importance to their function. These are given below in (1), (2) and (3).

(1) The basic picture quality of the system

The picture quality in the absence of visible errors.

(2) The failure characteristic

The characteristic of picture quality versus bit error-rate taking into account the likely error distribution pattern of the link.

The performance of the system after an interruption and from cold-start.

(3) The downstream processed quality

The quality after the signal has been through one or more of the following processes before being displayed:

- colour matte
- picture expansion and compression
- successive decoding and encoding
- slow motion.

In general, the requirements in each of these cases will be weighted depending on the degree to which the circuit will be used for contribution purposes and the degree to which it is used for distribution purposes.

3. Assessment methods for bit-rate reduced systems

IWP 11/4 (now JIWP 10-11/6) is studying the choice of methodology of quality assessment for bit-rate reduction systems and their report is given in Report 1206 [CCIR 1986-90a]. Their report considers the choice of method for subjective quality assessment for the particular environment of digital codecs, and also discusses objective quality assessment methods.

In general, the impairment level associated with the basic picture quality is likely to be small, because systems which exhibit substantial impairments will have been discarded by simple visual inspection. However, there will be occasions when the full range of grades is to be explored, for example, in the failure characteristics. Digital systems in general, however, have steep failure characteristics. Therefore, it may be that the area between grades 4 and 5 is likely to be the most important, and the method used should aim for high stability of results in this region in particular, although this would not be to undervalue high stability throughout the grade range.

The objective is that results, derived independently in a number of laboratories throughout the world, can be fairly compared. However, at the present time, the most completely reliable method of evaluating the ranking order of high-quality codecs is to assess all the candidate systems at the same time under identical conditions [CCIR, 1986-90a].

Arguably, the biggest single factor affecting the consistency and relevance of subjective assessment results is the choice of test material. In line with normal CCIR procedures, this should be arranged to be "critical but not unduly so" for the system in question.

IWP 11/7 believes that the most immediate need is to define the test material for the evaluation of 30-33 Mbit/s codecs, because studies on such systems are at an advanced stage. An initial list is contained within Report 1213.

Several types of downstream processing must be considered in the evaluation of picture quality. These processes, such as colour matting or chromakeying, depend on decision-making that is based on signal content, such as precise level sensing or hue selection in a narrow colour bandwidth. They are thus critically sensitive to impairments such as edge noise, bandwidth reduction or slew rate limiting. For the moment, these processes are difficult to specify objectively, although such a definition would be desirable for consistency of the results and would also permit computer simulation. In these circumstances, picture quality evaluations can only be carried out by means of a specific reference process, using for example, a wideband analogue RGB chromakey unit.

Report 1213 also includes pictures that can be used for the assessment of characteristics in the presence of errors.

Document [CCIR, 1986-90b] describes methods of generating high quality moving sequences from still pictures. Various types of movement are considered: straightforward interpolating methods are suitable for some, and Fourier transform techniques are applicable to others. It is also suggested that in some applications it is helpful to reverse the movement process, after passing the signal through the equipment under test, in order to make various artifacts more readily visible (since they are now seen to be moving against a background of stationary picture material).

4. Performance in the presence of digital errors

It is necessary to ensure that bit-rate reduction systems are adequately rugged in the presence of errors introduced on digital links. This means that at the error rates and with the distribution of errors likely to be encountered in practice, the decoded pictures should have acceptable quality, both when viewed directly and when subjected to further ("downstream") processing such as picture expansion and colour matte.

The errors that will be seen are, of course, those that remain uncorrected after the action of any error protection circuits built into the receiving terminal. The characteristics of such errors will depend on the precise mode of operation of these and subsequent receiving terminal circuits, and therefore it is difficult to make general statements about what level of performance is acceptable. Nevertheless, some work has been done in the United Kingdom [CCIR, 1986-90c] to assess the visual impact of random error in individual bits of linearly coded Y, C_R, C_B signals. This work, the broader aspects of which are being considered by IWP 11/4 as possible material for inclusion in Rec. 654, concluded that directly viewed errors were more serious in the luminance channel than in the colour difference channels, and that bits of high significance were much more susceptible than those of lower significance. The following error ratios were found to give grade 4.5 on the impairment scale:

TABLE I: ERROR RATIOS FOR GRADE 4.5 ON THE IMPAIRMENT SCALE

Component	Bit significance	Just perceptible	
		Events/second	Bit-error ratio
Y	MSB	1	10^{-8}
Y	MSB-1	100	10^{-6}
Y	MSB-2 to MSB-7	$>10^4$	$>10^{-4}$
U/V	MSB	10	10^{-7}
U/V	MSB-1	10^3	10^{-5}
U/V	MSB-2 to MSB-7	$>10^4$	$>10^{-4}$

Errors in the colour difference channels were found to be much more serious, however, and much less dependent on bit significance, when downstream chromakey processing was used. The corresponding error rates were as follows:

TABLE II: ERROR-EVENTS-PER-SECOND FOR GRADE 4.5 ON THE IMPAIRMENT SCALE WITH CHROMAKEY PROCESSING

Channel	MSB	MSB-1	MSB-2	MSB-3	MSB-4 to MSB-7
U	3	10	30	2×10^3	$>10^4$
V	2	30	3×10^3	$>10^4$	$>10^4$

It was thus concluded that where downstream processing such as chromakey is envisaged, these processes should set the standard for acceptable error rate.

Practical systems may be expected to incorporate error correction techniques, and therefore the acceptable error-rate as measured on the link will be greater than the above figures would suggest. Studies are in hand to determine the acceptable limits to be applied to links carrying digital television signals; the likelihood is that it will be necessary for the BER to be maintained better than 10^{-4} measured over an integration period of 10 ms.

A suitable method for measuring the error performance of suggested systems is as follows:

(1) Forward error correction disabled

Using the EBU method, obtain mean impairment grade for a random presentation over the range of bit-error rates required for investigation (e.g. possibly 10^{-3} to 10^{-9}). The tests should be conducted for all sources and results presented as a curve of picture quality versus bit-error rate. Doc. [CCIR, 1986-90d] discusses error characteristics.

(2) Forward error correction enabled

The above procedure is repeated to obtain a comparative results graph.

The results of the first of the above tests must be interpreted with care, since they relate to conditions which will not normally be met in practical situations (though they do roughly simulate a situation in which the error corrector is overwhelmed by an extremely high error rate on the link). Moreover the second test will only be practicable at very high error rates. These two tests will nevertheless provide useful information on error performance.

Further tests will be needed to establish the time taken by the system to recover from gross errors causing a complete loss of signal to the decoder.

The recovery time can be measured as the number of fields of delay that is required between the connection of signal to the decoder, and switching the picture monitor input from a grey level signal (or a suitably delayed non-processed signal) to the decoder output signal such that no picture disturbance can be observed.

A similar procedure should be adopted to assess the recovery time associated with bit-slips, as might occur following, for example, a non-sync cut.

5. Target system requirements

5.1 User requirements

User requirements for distribution and contribution codecs are shown in Tables IIIa and IIIb.

All quality assessment ratings in this section are carried out by following the procedures given in Recommendation 500 and Report 1206 using the subjective assessment methods indicated.

TABLE IIIa

Requirements for distribution codecs

Bit rate for which compatibility is required	60-70/140 Mbit/s: CCITT hierarchy levels 139.264 Mbit/s and ISDN H3/H4 30-45 Mbit/s: CCITT hierarchy levels 34.368/44.736 Mbit/s and ISDN H21, H22
Source signals	4:2:2 with potential for full spectral occupancy
Destination signals	4:2:2
Sound capacity	Under study
Auxiliary and data capacity	Under study
Maximum sound-vision delay	± 2 ms per codec
Basic quality	Number of codecs tested: 60-70/140 Mbit/s: 3 codecs in tandem[1] 34-45 Mbit/s: Single codec Quality difference $\leq$ 12%[2][3] with DSCQS[5] method using: mobile and calendar (sequence), rotating disk (sequence)[4] diva with noise (sequence)[4]
Failure characteristic/ error performance	BER $\leq 10^{-4}$ including error bursts $\leq$ 30 bits Impairment $\leq$ 1 grade with DSIS[6] method using: toys against blackboard (still) mobile and calendar (sequence)
Recovery time	$\leq$ 160 ms after a break of 50 ms
Change in overall delay after signal interruption	As small as possible (in Report 1235 a value of $\pm$ 20 μs is suggested, for further study)

TABLE IIIb

Additional requirements for contribution codecs

Basic quality	34-35 Mbit/s 2 codecs in tandem[1] Quality difference ≤ 12%[2][3] with DSCQS[5] method using: mobile and calendar (sequence) Kiel Harbour with zoom (sequence) rotating disk (sequence)[4] diva with noise (sequence)[4]	140 Mbit/s 3 codecs in tandem[1]
Quality after colour matte	Quality difference ≤ 18%[2] with DSCQS[5] method using: Popple (foreground) + limbs of tree_(background) old masters pair[4] between two codecs	
Quality after modification to picture geometry	Quality difference ≤ 18%[2] with DSCQS[5] method using: flower garden (sequence) between two codecs	
Quality after slow motion	Quality difference ≤ 18%[2] with DSCQS[5] method using: moving Kiel Harbour (sequence) 10:1 slo mo between two codecs	

Notes:

1) It is appreciated that there are problems in estimating or measuring the characteristics of codecs in tandem, practically if a number of different codecs have to be considered. These quality criteria assume that direct codec tandem connections are entirely digital. For contribution applications downstream processing should be inserted between codecs.

2) The quality specification only applies to the test material indicated. With less critical material a lower quality difference should be obtained.

3) In reporting the results of tests, it is desirable to identify separately those relating to high activity sequences; this matter is under study.

4) These scenes may be replaced or augmented by others.

5) Double stimulus continuous quality scale.

6) Double stimulus impairment scale.

5.2 Use for conveying composite signals

Although primarily designed to carry signals conforming with Rec. 601, the system will also be required to carry signals derived from a composite signal. The latter will be decoded into components at the sending terminal and reassembled into composite form at the receiving terminal.

In such applications, it is desirable to use a complementary separation and recombining process. For such a process, separation of luminance and colour-difference may not be complete and cross components may exist, even though the overall process may be transparent. It is essential therefore that the digital codec should transmit the cross components with minimum distortion and the capability for conveying a level of cross components should be specified.

In addition, an auxiliary data capacity should be provided within the multiplex channel to signal subcarrier phase and V-axis switch information. Investigations are proceeding to determine the data rate required for the data signal and a standardized interface may prove desirable; the ancillary data capacity specified in Section 2.5 of Rec. 656 is thought adequate for the inclusion of PAL encoding data.

When used in this manner, the system will not be suitable for long distance transmission with mixed analogue/digital links, and does not have to be transparent to vertical interval test signals.

5.3 Conditional access

Bit-rate reduction processes are based on the systematic elimination of redundancy in the signal in several dimensions. Signals that are already scrambled for conditional access will have reduced spatial and temporal correlation and hence the performance of the coding process and the resulting signal quality at the decoder may not be suitable at this bit-rate for signals that have already been scrambled. Therefore, in case additional security of transmission is required, an arrangement for the additional scrambling of the transmitted data stream is desirable.

5.4 Upward extensibility

Consideration should be given to coding algorithms which are modular in concept and that could be applied for other applications e.g. HDTV.

5.5 Other applications

It would be convenient if some parts of the transmission codec could be adapted for use in other applications, e.g. digital recording.

5.6 System complexity

The complexity of the codec should be such that it can be implemented with available technologies at a cost reasonably related to the transmission costs for the intended application.

5.7 System availability

Any relevant patents should be available without discrimination worldwide on equitable terms.

6. Requirements for sound signals in a digital multiplex which includes television sound

The study of digital sound transmission is being undertaken by CCIR Study Groups 10 and the CMTT, but IWP 11/7 has been asked to take account of sound requirements and therefore the following note has been included in this report. It is not intended to provide a definitive text, which should be provided by Study Groups 10 and CMTT, but rather to ensure that the requirements for sound are not overlooked.

The CCIR has approved Recommendation 647 for a digital audio interface for use within studio centres. This is primarily intended to carry mono or stereo signals with a 48 kHz sampling frequency and with a resolution of up to 24 bits/sample. In this mode, with normal stereo operation, the net bit-rate required is 3.072 Mbit/s. As this interface is intended to operate in the studio environment, there would normally be no need for error protection other than a simple parity check, and indeed none is included in the Recommendation. Conceivably, however, some could be included in the 4 least significant bits of the sample word, if needed.

In general, this interface allows audio signals which have a margin for subsequent processing (without audible loss of quality), and in a sense therefore has a parallel with the concept of a 'contribution' quality in vision terms.

Note must also be taken of Rec. 660 concerning digital sound circuits. This specifies 384 kbit/s per channel including data and any error correction, based on a sampling rate of 32 kbit/s. Studies for other sound formats at higher levels of quality are in the process of being made in the region of 480 kbit/s per channel.

In the selection of the channel capacity assigned to digital sound, consideration must be given to the quality balance between picture and sound, as picture-quality in the region of 30 Mbit/s is likely to be very sensitive to small changes in data rate. Further discussions must take place with Study Groups 10 and CMTT, but, provisionally the following is proposed:-

1) An allocation of 960 kbit/s for sound (corresponding to one high-quality stereo pair), should be considered for the H2 level. The need for possible additional channels, or their feasibility at the H2 level requires further study.

2) For transmission at the H3 and H4 access levels, which may be more attractive for contribution networks, a higher data rate may be required to achieve higher quality, the necessary processing headroom, and facilities. Coding simplicity and flexibility indicate that a close alignment with Rec. 647 is desirable. Study Group 10 and CMTT must study this question, and that of the required number of channels as soon as possible, considering also the desire for a minimum number of coding formats in current and future broadcast chains.

7. Guidelines for bit-budgets

7.1 Contribution systems at bit-rates around 140 Mbits/s.

The EBU has indicated that, for 625 line television long distance transmissions, its general requirements would be:-

- Video, coded at approximately 6 bits/sample for the active picture only (plus necessary video framing): 125 Mbit/s

- Error protection for video, based on a BER of 10^{-3} for a period of greater than 10 seconds (corresponding to complete failure of the digital network) * : 8 Mbit/s

- Ancillary data lines: 3 per field and 8 bits/sample: 2 Mbit/s

- Sound/data/ancillary signal multiplex : 4 Mbit/s

Present indications are that, in the case of a future broadband ISDN, the total bit-rate available to the user may be reduced. It has been suggested that it may be as low as 135168 kbit/s. In this case, it will be necessary to accept a compromise and, in particular, fewer bits can be made available for error-correction, sound and data.

7.2 Distribution systems at bit-rates around 34 Mbit/s

The CCITT has not yet defined the bit-rate that will be provided by the H_2 level in the ISDN. On the assumption that the bit-rate will be near the corresponding existing hierarchical level, proposals have been made as follows:

	Approx. Mbit/s
Coded video signal with teletext and forward error-correction :	32.5
Coded sound signal :	1.0
Ancillary data	0.5

* Other proposals for error-rate objectives are being considered, as discussed in § 4 of this Report.

8. Source formats and criteria for 34 Mbit/s systems

In Decision 60-1, IWP 11/7 is requested to work in close collaboration with Interim Working Party CMTT/2, taking account of Decision 18, and is required to draft Reports and Recommendations on the methods of encoding 525-line and 625-line television in component form for transmission. The following principles are suggested to IWP CMTT/2 by IWP 11/7 to assist it in its work.

1. The encoding method selected should achieve a balance between performance and complexity for the anticipated application.

2. The encoding algorithm should transmit still pictures and pictures of low difficulty at, or near, the source quality level and move smoothly to lower quality levels for pictures of increasing difficulty. Documents [CCIR, 1986-90 e, f and g] express the opinion that coding systems should preferably handle a full 4:2:2 sampling pattern rather than including pre-filtering and sub-sampling to lower levels, e.g. 3:1:1. The algorithm should avoid sudden failures on any picture sequence within the limits of the source standard.

3. Increasing levels of uncorrected transmission errors should, where possible, result only in contamination of small areas of the picture.

4. The complexity of the codec should be such that it can be implemented with available, or near available, technologies at a cost reasonably related to the transmission costs for the intended application.

5. Operation of the algorithm should be feasible over a small range of data rates to allow for differing audio channel multiplexes and future decisions affecting precise channel data rates.

6. Consideration should be given to coding algorithms that are "modular" in concept and that could be applied at higher levels of transmission bit-rate.

Several techniques have been identified and are under study which might meet these objectives, but a firm decision by IWP 11/7 requires further study.

9. Encryption

Document [CCIR, 1986-90h] points out that the data requirements for encryption should be taken into account in the allocation of data for auxiliary signals. All suitable encryption systems use a PRBS generator in the receiver, and therefore an encrypted version of the PRBS initialisation word is required in the multiplex. In addition, user addressing data might be needed. The amount would be related to the number of addressable decoders needed for the system. The above contribution suggests that suitable data allocations for the above would be 6 kbit/s for distribution applications and somewhat less for contribution applications.

10. Relative timing of sound and vision

Subjective tests indicate that delays between the instant at which an action is seen to take place and its corresponding sound are disconcerting to observers. Specifications on tolerable timing differences between sound and picture can be found in Report 1081. Further study is required taking into account CCIR Recommendation 265 and the use of codecs in tandem.

REFERENCES

CCIR Documents

[1986-90]: a. 11/75 (IWP 11/4); b. IWP 11/7-140 (United Kingdom); c. IWP 11/7-109 (United Kingdom); d. IWP 11/7-134 (EBU); e. 11/29 (France); f. 11/137 (EBU); g. 11/170 (Spain); h. IWP 11/7-139 (United Kingdom).

ANNEX I

COMMENTS ON FAILURE MODE FOR THE TELEVISION MULTIPLEX

Discussions within IWP 11/7 on this question have led to the items listed in Table IIIa. The following outlines the thinking behind these and other related considerations. CMTT has been asked to provide further information about the likely characteristics of transmission links to enable the user requirements to be refined further.

- Interruptions of any part of the multiplex lasting several seconds or more are intolerable and protection modes would be required.

  With regard to the response to burst errors of short duration, the synchronizing system should have adequate protection so that the effect of the errors on the video, audio or data would not be extended due to the need for resynchronization. By maintaining synchronization through the interruption, the error management systems for the video, audio and data could be independent.

  It is likely that it will not be possible to protect against interruptions of the order of 50 ms. After such events, the decoder circuits will have to relock in a manner similar to that of the initial switch-on. It is suggested that the relocking sequence should be complete within 160 ms.

- It is important that the overall signal delay through the codec should not change markedly under the influence of transmission errors or interruptions. The degree to which the delay should be permitted to change is under study; Report 1235 suggestes that ± 20 μs would be a reasonable maximum.

- There appeared to be general agreement that very short duration defects were less tolerable in the sound than in the picture.

- The degree of protection required for the data is heavily dependent on the application. For example, if the data is being used for system control it could be very critical and require powerful protection.

- Under normal operating conditions there should be no perceptible effect from channel errors in video, sound or data.

- In the design of protection systems to be used when the performance of the link in use deteriorates, the switching to the protection link should not cause a disturbance in the video, sound or data signal.

REPORT 1089-1

BIT-RATE REDUCTION FOR DIGITAL TELEVISION SIGNALS

(Questions 3/11 and 25/11, Study Programmes 3A/11, 25J/11, 25K/11 and 25M/11)

(1986-1990)

1. Introduction

The subject of this Report is bit-rate reduction algorithms and their performance in picture quality, processing capability, and resistance to transmission errors. Such algorithms may find application in a number of areas of broadcasting, but it is clear from contributions received that the particular application of such schemes to long-distance transmission links is of the greatest interest at the present time.

Transmission systems in general are studied by the CMTT, and therefore it is necessary for Study Group 11 to inform the CMTT of its work and, where necessary, to refer questions to the CMTT.

An analysis of potential methods of bit-rate reduction for broadcasting pictures is a formidable task, and a wide range of approaches and techniques for bit-rate reduction have been reported in contributions. An overview of the techniques used is given in § 2 of this Report.

Section 3 of this Report presents an analysis of the available information by grouping systems according to practical application.

To compare alternative systems, it is necessary to agree on the way objectives are set and the way systems should be evaluated. Section 4 describes the kinds of impairments likely to arise in bit-rate reduction schemes and their evaluation, including a reference to subjective methods.

The Report concludes in § 5 with an assessment of future studies which Study Group 11 could undertake.

2. Bit-rate reduction approaches and techniques

Pulse-code modulation (PCM) representation of video signals requires bit rates of approximately 100 Mbit/s and 216 Mbit/s for composite and component signals respectively. There are several sources of redundancies in television signals which make it possible to reduce the bit rate; these are statistical redundancy, spectral redundancy, and perceptual redundancy.

The statistical redundancy results from the high degree of spatio-temporal correlation between adjacent picture samples. Generally, the statistical redundancy can be removed or reduced by a fully reversible process, i.e., no degradations are introduced by this process.

Spectral redundancy results from over-sampling. The video signal is essentially three-dimensional (vertical, horizontal, and temporal). Orthogonal (aligned) sampling patterns are, in general, inefficient in terms of spectrum (bandwidth) utilization. With the use of appropriate sampling patterns and the three-dimensional spectral properties of the sampled signal, the effective sampling frequency can be reduced (sub-sampling). The process of sub-sampling and interpolation results in perturbation of the signal (irreversible).

Properties of the human visual system, i.e., the eye-brain mechanism, create what is known as perceptual redundancy. By exploiting these properties, visibility of impairments caused by bit-rate reduction can be minimized under normal viewing conditions. For example, the visibility of noise varies with the brightness level of the picture. Another example is the masking phenomenon where high spatio-temporal activities in the picture tend to mask coding or processing impairments.

A very important element to be considered in bit-rate reduction systems is the fidelity criterion. Picture quality requirements depend on the intended applications. It is important to recognize that picture quality requirements for display under normal viewing conditions are quite different from those needed for post-processing. Therefore, in selecting bit-rate reduction systems, techniques and parameters, it is important to take into consideration the properties of the receiver, i.e., the human visual system or processing equipment. In general, picture quality requirements for post-processing are more stringent than those for visual display.

A generic video codec for bit-rate reduction can be conceptually segmented into the following main functions:

- analogue interfaces: these perform all analogue pre- and post-processing functions. They also include the analogue-to-digital and digital-to-analogue operations. In cases where input or output signals are in digital format (e.g. conforming to Recommendation 601) they are by-passed;
- digital pre- and post-processing functions: these include operations such as noise reduction, digital pre- and post-filtering, sub-sampling, etc.;
- bit-rate reduction functions: these include the implementation of bit-rate reduction algorithms and techniques to reduce the bit rate to the desired level. The inverse of these functions is performed at the decoder to reconstruct the signals;
- peripheral functions: these include all other functions such as channel interfaces, channel encoding, multiplexing, framing, etc.

2.1 *Pre- and post-processing techniques*

Pre-processing techniques are applied to video signals in order to condition the signal for efficient encoding and minimization of signal impairments. They generally involve linear or non-linear digital filtering for reduction of aliasing prior to sub-sampling. They are also used for noise reduction. Post-processing techniques include interpolation or enhancements filtering, and in some cases, they may include noise reduction at the output.

2.1.1 *Multi-dimensional pre-filtering*

One of the techniques used in bit-rate reduction is spatio-temporal sub-sampling. This involves reducing the effective sampling frequencies spatially and/or temporally. In order to minimize the impact of aliasing, one- or multi-dimensional low-pass filters are used. Alias components affect picture quality and reduce the efficiency of bit-rate reduction systems which again translate to lower picture quality.

The design and selection of the appropriate pre-filtering technique is closely tied to the sampling pattern used. For orthogonal sampling patterns, pre-filtering is carried out in the direction of sub-sampling. This will generally require reducing the picture resolution as the alias components will coincide with the baseband components. In the case of non-orthogonal sampling patterns, e.g. line-quincunx or field-quincunx patterns, multi-dimensional pre-filtering may be required. For a carefully chosen sampling pattern, the alias components do not overlap with the baseband components. In this case they can be removed by post-filtering.

2.1.2 *Noise reduction*

Traditionally, noise reducers have been used in broadcast television in order to improve picture quality for certain types of video material. In the low bit-rate environment where large compression ratios are required, e.g. 4 : 1 or 8 : 1, noise reduction may be necessary. The benefits of using noise reduction are not limited to the improvements in picture quality but are helpful for efficient bit-rate reduction operations.

Examples of such systems can be found in [CCIR, 1986-90a and Drewery et al., 1984], which set out the findings of theoretical and experimental studies and the methodology of calculating the effectiveness of noise suppression.

2.1.3 *Spatio-temporal interpolation*

In cases where sub-sampling techniques are utilized for bit-rate reduction, spatio-temporal interpolation is required. The design of the interpolation filters is closely tied to the specific sampling pattern used.

2.2 *Predictive coding techniques*

In predictive coding techniques, a prediction of the current picture sample is obtained using previously coded picture samples (generally referred to as DPCM). The prediction error, i.e. the difference between the current sample and prediction value, is quantized, coded and transmitted. At the receiver, the inverse of these operations is performed to reconstruct the signal.

A large body of literature dealing with predictive coding techniques already exists. A classification of the various methods is usually done according to the origin of the information used to form the prediction. They can be divided as "intrafield" techniques in which the information used to form the prediction belongs only to the current field, and as "interfield" techniques, in which information from previous fields (and possibly from the current field) is used to form the prediction.

2.2.1 *Intrafield predictive coding techniques*

Intrafield techniques can be classified as one- or two-dimensional. In one-dimensional techniques the prediction signal is formed using previously coded samples from the current line only. The simplest form is the previous element predictor where the previous sample (sometimes weighted by a factor less than unity) is used to form the prediction.

One-dimensional predictors have the advantage of simplicity of implementation. In addition, channel-error propagation is limited to the line where any error occurred. However, the achievable compression ratio is relatively moderate, unless loss of picture quality is tolerated [Systems 12, 15, 26 and 36]. (In order to provide quick cross-references, particular bit-rate reduction systems are referred to under the system numbers (applicable only in this text). These numbers are the same as the relevant Interim Working Party 11/7 contributions.)

In two-dimensional predictive coding techniques the prediction is formed using previously coded elements from current and previous lines from the same field [Systems 11, 13, 21, 30 and 42]. In general, two-dimensional techniques are more efficient than one-dimensional.

Hybrid PCM/DPCM techniques have also been reported [System 42] and [CCIR, 1982-86a]. They involve periodic transmission of PCM samples and anchoring the prediction on those transmitted PCM samples. This approach provides a certain degree of channel-error immunity.

2.2.2 *Interfield coding techniques*

While the intrafield coding techniques discussed in the previous section exploit the spatial properties of the signal, interfield techniques exploit both temporal and spatial properties. In essence, these techniques exploit the three-dimensional nature of television signals and are essential for situations where higher compression ratios are required, while maintaining good picture quality. Interfield prediction techniques can be classified into two main categories, i.e. standard interfield techniques and motion-compensated techniques.

2.2.2.1 *Standard interfield techniques*

In these techniques previous and current field elements can be used to form the prediction. The predictor configuration and prediction coefficients are fixed. They generally perform extremely well in stationary areas of the picture; however, their performance deteriorates in the moving or changing areas of the picture.

2.2.2.2 *Motion-compensated techniques*

The basic idea of motion-compensated interfield prediction techniques involves estimating the motion of different objects from one field (or frame) to the next and performing the prediction in the direction of motion [Systems 4, 7, 8 and 9].

A key element in this approach is the method of displacement (motion) estimation. Several approaches have been presented in the literature. Among these are the pattern matching approach and the picture-element (pel) recursive approach.

The displacement estimation can be carried out prior to coding in which case the displacement vectors will have to be transmitted to the receiver. Segmentation methods identify areas of the picture pertaining to the same motion vector in order to limit the extra bit rate needed. Alternatively, motion estimation can be carried out based on previously coded information. In this case, the displacement estimates need not be transmitted as they can be regenerated at the receiver.

Several levels of segmentation complexity are suggested in [CCIR, 1986-90b].

2.2.3 *Adaptive (switched) predictive coding techniques*

Any prediction process assumes a certain image model. One-dimensional (intraline) predictors assume that the image consists mostly of horizontal edges or flat areas. Two-dimensional predictors extend this model slightly to the second dimension.

Standard interfield techniques assume that images consist mostly of stationary areas. Obviously for television imagery an accurate image model does not exist. Therefore, the performance of fixed-prediction schemes will vary depending on how far the local picture properties are from the implicitly assumed properties.

In order to improve the performance of predictive coding techniques, adaptive (or switched) predictors have been used [Systems 4, 5, 14, 15, 22, 31 and 37]. In this approach, two or more predictions are formed. The predictor which gives the lowest prediction error is selected. In this way the prediction process can be adapted to local picture properties.

Predictor switching can be carried out on a pel-by-pel basis or on a group of pels. Since the receiver has to know which predictor has been used at the transmitter, the predictor-selection rule has to be conveyed explicitly or implicitly. Explicit switching rules require transmission of necessary overhead information to indicate which predictor has been used. Implicit rules are based on previously coded information and generally do not require the transmission of such overhead, at the expense of some loss of performance.

2.3 *Transform coding techniques*

In transform coding techniques, the signal is segmented into one-, two- or three-dimensional blocks. Each block is transformed using one of the known orthogonal transforms, e.g. Discrete Cosine, Hadamard, ... etc. The resulting transform coefficients are quantized, coded and transmitted. At the receiver, the inverse of the above operations is performed to reconstruct the signal [Systems 18, 20, 38, 44 and 51].

2.4 *Hybrid predictive/transform techniques*

These techniques combine both transform and predictive coding approaches. This hybrid coding process can take one of several forms. One approach is to perform a spatial two-dimensional transform on the image blocks, then code the resulting transform coefficients by an interfield predictive coding technique. A second approach involves performing an interfield predictive coding in the pel domain. The prediction error is transform encoded inside the predictive coding loop. Obviously an inverse transformation is also carried out within the feedback loop. The transform coded prediction error is transmitted to the receiver [System 27].

2.5 *Miscellaneous coding approaches*

In addition to the basic techniques described in the previous sections, other approaches have been reported in the literature. These include group coding, interpolative coding, contour coding, stored pattern transmission [System 43] and block truncation coding (BTC) [CCIR, 1982-86b].

2.6 *Techniques for bit-rate reduction*

All the methods previously described do not reduce the bit rate by themselves, but rather tend to obtain a new signal more suitable to be encoded using fewer bits per sample than the original one. However, it should be pointed out that the amount of redundancy reduction achievable, without any loss of information, is usually very small. Higher compression ratios are only obtainable by cutting out a certain amount of non-redundant signals. The way in which these techniques work is by elimination of the part of information which is less necessary to the correct reproduction of the picture, meaning that the resulting impairment is of low visibility or not visible at all.

A number of techniques which are used to achieve the actual bit-rate reduction are listed below.

2.6.1 *Synchronization and blanking intervals removal*

Removal of the highly redundant synchronization and blanking intervals gives an appreciable bit-rate saving without introducing any impairments to picture quality and is relatively easy to implement. This technique is applicable to all television coding systems.

2.6.2 *Sub-sampling*

Spatio-temporal sub-sampling is the most obvious method of bit-rate reduction. In general, loss of signal resolution results from this process. However, with the use of an appropriate sampling pattern, coupled with a corresponding pre-filtering operation, the impact of the sub-sampling process on picture quality can be minimized [Systems 4, 7, 8, 9, 13, 19, 21, 22, 36, 37] and [CCIR, 1982-86c].

Sub-sampling can be carried out over the whole picture or it can be restricted to specific areas of the picture. For example, in multi-mode coders, spatio-temporal sub-sampling can be used in higher modes of operation. Alternatively, temporal sub-sampling is applied to the stationary areas and spatial sub-sampling is applied in the moving areas. Obviously conditional sub-sampling requires accurate image characterization, e.g. segmentation into moving or stationary areas.

Document [CCIR, 1986-90c] provides subjective test results for some sub-sampling filters and shows that critical pictures can be impaired by sub-sampling. The document suggests that, in order to meet the requirements of high quality programme exchange, bit-rate reduction methods which involve sub-sampling should be avoided in a digital television.

2.6.3 *Quantization*

Effective quantization involves reducing the number of bits representing each sample. Both uniform and non-uniform quantizers can be used. In the majority of bit rate reduction systems, several quantizers are used. The switching between quantizers can be based on which mode of operation the coder is running [Systems 4, 5, 9, 10, 11, 13, 14, 15, 28 and 42], or the switching can be based on local picture properties [Systems 21, 22 and 30].

Another approach is given by the sliding quantizer [System 36], in which the quantization law is chosen depending on the signal level. It is based on the consideration that the video signal cannot be outside a certain value range. Thus, depending on the predicted value, the prediction error is limited. Hence, the selection of the more suitable quantizer will be made from time to time on the basis of the prediction value.

The quantization process need not be carried out on a pel-by-pel basis. It can be simultaneously applied to a group of adjacent pels. Examples of this process include vector quantization and block quantization techniques.

Orthogonal transforms perform some kind of spectral analysis. As the eye sensitivity decreases with frequency, the visibility of quantizing noise affecting transform coefficients is minimum when the quantizing steps increase with the coefficient order. An equivalent approach consists of scaling the transform coefficients according to their order and to use the same quantizing step for all coefficients. Such modified transforms have been called perceptual. Optimum scaling factors, for which the weighted quantization noise power is minimized, are given in [CCIR, 1986-90d].

2.6.4 *Change of thresholds and isolated pel noise suppression*

In predictive coding the prediction error falling below a given threshold is classified as insignificant and is set to zero. By changing this threshold, the number of bits needed to represent the quantized prediction error will vary. The change of threshold provides a relatively fine control over the bit rate.

In addition, isolated prediction error samples that can be classified as noise can be suppressed (set to zero) [Systems 7 and 9]. This will improve the efficiency of variable word-length, run-length, and block encoding processes that will be discussed later.

2.6.5 *Temporal filtering*

This process involves processing the prediction error signal through a linear or non-linear function. In its simplest form, the prediction error is multiplied by a value α less than unity. The result of temporal filtering is a reduction in the magnitude of prediction error. Generally, a reduction in temporal resolution and other impairments result from this process.

2.6.6 *Variable word-length encoding*

Variable word-length encoding (sometimes referred to as entropy encoding) exploits the statistical properties of the quantized prediction error signal or quantized transform coefficients. This is achieved by assigning a lower number of bits for signal values with high frequency of occurrence and a larger number of bits for signal levels with low frequency of occurrence. This results in a variable-word length representation of the signal, e.g. Huffman code representation. This leads to a reduction of the bit rate [Systems 4, 5, 10, 11, 14, 15, 19 and 28].

An alternative approach based on universal quasi-universal binary codes is proposed in [CCIR, 1986-90e]. These codes achieve a high efficiency in coding long binary words delivered by a memoryless source. For this purpose groups of N DCT blocks (e.g. N = 90 corresponding to 8 lines) are formed. The input words to the coder consist of the N bits of a given order taken in the N coefficients of a given order. The advantage of this approach is that entropy coding is made independent of picture statistics.

2.6.7 *Run-length and block encoding*

This approach involves partitioning the quantized prediction error or transform coefficients into groups of pels, i.e. either "runs" or "blocks". The behaviour or the shape of the signal is encoded and transmitted [Systems 18, 27, 38, 43 and 44].

Studies [CCIR, 1986-90f] have shown that matrix or block operations can, in effect, approximate many of the processes that are involved in digital signal processing, such as filtering or subsampling, as well as transform coding. This may be particularly useful because matrices can be readily combined. This concept could allow a family of systems to be defined and implemented.

2.7 *Multi-mode coding*

In video coders utilizing variable word-length, run-length or block encoding, video data is generated at a variable rate. Since the transmission bit rate is generally fixed, buffering of data is required. In order to prevent the buffer memory from overflowing or underflowing, multi-mode operation is required. The coder will have several modes of operation.

The modes of operation are indicated by M_0, M_1, ... M_n. Each mode represents a specific choice of coding parameters (sampling rates, quantizer levels, thresholds, etc.). R_{ij} represent mode transition rules (e.g. buffer memory occupancy changes from below T_i to above T_i). In general, most transitions are not permitted, and transitions are between adjacent, or nearly adjacent modes.

M_1 is referred to as the main mode of operation, designed for "typical" image statistics, and giving full available resolution and best picture quality. M_0 is an "underflow" mode, which ensures that the buffer does not empty, perhaps by transmitting full resolution 8-bit PCM. A refresh mode may also be considered in order to limit the propagation of channel errors. Modes M_2, M_3, ... M_n are referred to as "overflow" modes, invoked successively in periods of increased picture quality. In order to prevent the coder from oscillating between two modes, a hysteresis is built in the mode transition rules.

The art of designing multi-mode coders involves optimization of both coding parameters and mode transition rules. This process is carried out by subjective evaluation of picture quality over a large input data base.

2.8 *Channel error management*

It is well known that channel errors caused by interference and other channel impairments will adversely affect the final picture quality. In PCM systems, channel errors do not propagate beyond the pel where they occurred. However, in systems utilizing bit-rate reduction techniques, errors propagate beyond the pel where they occurred. Generally, three techniques have been used to alleviate the impact of channel errors on picture quality. These are:

2.8.1 *Forward error correction* (FEC)

By adding a small controlled amount of redundancy to the coded information, limited protection against channel errors is provided by detecting and correcting a given number of errors per block [Systems 4, 5, and 13]. Several codes have been reported in the documents. They include BCH (239, 255) double error correcting code, Reed-Solomon (63, 59) code and Wyner Ash (15, 16) code. These codes can handle random error effectively. However, in order to deal with burst errors, interleaving techniques are used.

2.8.2 *Error detection and concealment*

This class of techniques involves error detection followed by concealment which involves replacing the corrupted picture pels by information extracted from surrounding pels. This class has been extensively used in PCM systems.

In predictive coding systems (DPCM) their use has been mainly directed to cases where one-dimensional (intraline) predictors are used. This is largely due to the error propagation properties in such systems. In the case of two-dimensional spatial predictors, errors propagate in a way that may affect the whole field. Therefore, implementation of concealment techniques may require several field memories. In the case of interfield predictors, concealment techniques may not be practical as the errors will propagate in the temporal direction.

The problem of error propagation in DPCM systems can be greatly alleviated by adding a stability constraint to the criteria of predictor design [System 13]. This can be achieved by introducing a deliberate "leak" to the prediction process (leaky predictor). Therefore, impairments caused by error propagation will decay rapidly and hence are less obtrusive.

2.8.3 *Periodic refresh*

In order to limit the propagation of channel errors, periodic PCM refresh is used. This involves periodically transmitting some of the picture samples in PCM format. This also has the effect of removing residual picture impairments caused by coding. Alternatively, in coders utilizing several predictors, periodic refresh can be achieved by enabling only the intraline predictor and disabling the remaining predictors, i.e. DPCM refresh.

In bit-rate reduction systems, the information transmitted to the decoder includes coded visual information as well as overhead and control information, e.g. line identification, field identification, mode of operation, etc. Generally, control information requires a larger degree of protection than coded visual information. This can be achieved by adding more redundancies to the control information and using the same FEC techniques used for visual information. Alternatively, a different FEC technique can be used for control and overhead information.

3. Bit-rate reduction systems for various applications

It should be noted in the following descriptions of bit-rate reduction systems that, for convenience, they have been categorized into ranges of bit rate. Some coding algorithms, reported here at particular bit rates, could also be used in applications involving other bit rates.

Table I summarizes the main features of the systems on which contributions were made in the current study period as answers to questionnaires issued by Interim Working Party 11/7 [CCIR, 1982-86d]. Certain features of these systems are outlined below.

TABLE I – *Summary of bit-rate reduction systems*

System No.		19	12	13	26	42	76	13	13	21	30	36	22	31	37	28	20	38	51	74	4	18	44	27	75	43	13	14	13	15	15	10	11	5	8	9
Contributor		D	FNL	G	I	G	OIRT	G	G	D	D	F	D	D	F	D	D	F	BEL	OIRT	J	CHN	EGY	I	OIRT	EGY	G	J	G	J	J	J	J	J	CAN	J
Status	Study															*		*				*	*	*		*									*	
	Experimental	*	*	*	*	*		*	*	*	*		*	*	*		*		*	*					*				*				*			*
	Practical					*	*					*									*						*	*		*	*	*		*		
Component	140 (155) Mbit/s	*	*	*	*	*																														
	50-70 Mbit/s				*		*	*	*																											
	30-34 Mbit/s									*	*	*	*	*	*	*	*	*	*	*	*															
	6-20 Mbit/s																				*	*	*	*	*	*										
PAL	68 Mbit/s																										*	*								
	34 Mbit/s																												*							
NTSC	44 Mbit/s																													*	*					
	30-32 Mbit/s																															*	*	*		
	15-20 Mbit/s																																		*	*
Blanking removal	Line-blanking	(1)		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*					*		*	*	*	*	*	*
	Field-blanking	(1)			*			*	*		*	*		*	*	*		*		*	*			*					*				*	*	*	*
Quantization	Linear	*			*					*			*															*		*					*	
	Non-linear		*	*		*	*	*	*		*	*		*	*	*		*		*							*	*	*	*	*	*	*	*		*
Sub-sampling	Horizontal	(1)						*	*		*	*	*	*	*	*	*		*	*	(2)						*		*						*	(3)
	Vertical	(1)						(4)	(4)		(4)	(4)	(4)	(4)	(4)	(4)			*		(4)															
	Temporal											(4)													*											
PCM		*				*																														
DPCM	Intrafield		*	*	*	*	*	*	*	*	*	*	*		*	*					*						*	*	*	*	*			*		*
	Interfield							*	*				*		*	*					*			*			*		*	*				*		*
	Intraframe													*																		*	*			
	Interframe												(5)	*		*					*			*											*	*

TABLE I *(cont.)*

System No.		19	12	13	26	42	76	13	13	21	30	36	22	31	37	28	20	38	51	74	4	18	44	27	75	43	13	14	13	15	15	10	11	5	8	9
Contributor		D	FNL	G	I	G	OIRT	G	G	D	D	F	D	D	F	D	D	F	BEL	OIRT	J	CHN	EGY	I	OIRT	EGY	G	J	G	J	J	J	J	J	CAN	J
Transform	2-D																*	*	*			*		*												
	3-D																						*													
Entropy	Variable word-length				*					*			*			*	*				*							*		*		*	*	*	*	
Miscellaneous																				*					*	*										
Adaptive control	Quantizer									*	*	*	*		*	*	*	*			*							*		*		*	*	*	*	*
	Predictor												*	*	*	*					*							*		*				*		*
	Motion-compensation																				*														*	*
	Transform coefficients																			*		*														
Error correction										*		*				*				*	*	*					*	*	*	(6)				*	*	
Application	Contribution			*		*																														
	Distribution	*	*		*			*	*	*	*	*	*	*	*		*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*			*
	Satellite															*					*													*	*	

(1) C partly, depending on sampling rate.
(2) Y and/or C partly, depending on sampling rate.
(3) Partly, depending on the mode selected.
(4) C only.
(5) In combination with intrafield prediction only.
(6) Optional.

3.1 Bit-rate reduction methods for HDTV signals

Studies are being carried out on the aspects of the digital transmission of high definition television signals, for which bit-rate reduction is an essential process. This work is able to build upon the results of the studies into methods for transmission of the 4:2:2 level of Recommendation 601 reported in the following section and on the related work on standard algorithms and codec specifications for 34, 45 and 140 Mbit/s transmission.

Studies are being aimed at both contribution and distribution networks, and take account of Decision 18. A distinction between these applications is not always easy to make. Broadly speaking, contribution applications are those for inter-studio traffic requiring signals of such fidelity that they can withstand studio post-processing after passage through a digital coding/decoding operation. In distribution to viewers, coding is applied to signals which may have already been coded into analogue or digital formats, and it forms the final method of delivery to the home. Often the choice of distribution to viewers will be influenced by the economics of a low-cost decoder in the home.

3.1.1 Contribution (distribution between broadcasters)

a) Document [CCIR, 1986-90g] describes a source coding algorithm based on DPCM with noise shaping for HDTV contribution applications using 565 Mbit/s transmission rate. It assumes a sampling frequency of 72 MHz for the luminance and 36 MHz for the two colour-difference signals, and a total of 1152 Mbit/s that will have to be reduced by about a factor of two; DPCM with 2D-prediction (fixed positive coefficients 1/2, 1/4, 1/4) and fixed quantization (5 bits for luminance, 4 bits for colour-difference) is sufficient for the required high picture quality. For a compact codec realization dedicated 1.5 μm-CMOS-chips are being implemented.

b) Document [CCIR, 1986-90h] describes the outline of a 120/140 Mbit/s HDTV coding system, which has already been implemented by a compact hardware for practical applications. This system is designed for the purpose of transmitting HDTV signals via the 72 MHz bandwidth transponder of an Intelsat satellite, or via the 4th CCITT digital hierarchy of an optical fibre cable. The principal bit-rate reduction techniques employed are:

- removal of blanking intervals and line-alternative processing for two colour components,
- a 1/2 sub-Nyquist sampling with a line offset structure, and
- intrafield DPCM with an adaptive noise shaping filter and an adaptive quantizer.

c) Document [CCIR, 1986-90i] describes some preliminary results obtained using the DCT algorithm. It is concerned with HDTV signals with parameter values as proposed in Document [CCIR, 1986-90j] employing progressive scanning and resulting in a bit rate of 2304 Mbit/s. It refers to the intensive work carried out during the present study period aimed at the specification of a contribution 34/45 Mbit/s codec for conventional digital signals conforming to Recommendation 601. It states that the promising results obtained have led several organizations to apply such bit-rate reduction techniques to HDTV signals, the target being HDTV contribution codecs at 140 Mbit/s. It points out that simple extrapolation of these results is not appropriate since a) a higher compression ratio is required, b) progressive scanning yields a richer information content, and c) because of the high data rate, specific algorithm restraints must be taken into account in order to make the algorithms implementable in compact hardware.

The extra studies required to adapt the conventional codecs to HDTV are being presently addressed by some European cooperative projects. Simulations are being performed based on the DCT coding algorithm proposed by a DCT Expert Group. Whilst some further work has to be carried out, it states that extension of the algorithm has yielded promising results for both interlaced and progressive scan HDTV formats. Its conclusion is that 140 Mbit/s can be considered a possible channel for the transmission of HDTV in both formats, enabling all the benefits of progressive scanning to be retained in transmission.

d) Document [CCIR, 1986-90k] gives a summary on NI-DPCM sound decoding systems, which could find application in studio facilities too. A 48 kHz, 16-to-11 bit NI-DPCM and a 32 kHz, 15-to-8 NI-DPCM are reported to be capable of reproducing about the same quality as 48 kHz, 16 bits linear PCM and 32 kHz, 14-to-10 NI-PCM used in Japanese satellite broadcasting, respectively.

3.1.2 Distribution (to viewers)

a) A bit-rate reduction codec for HD-MAC signals has been developed within the European Eureka-95 project and is described in Document [CCIR, 1986-90 l]. The technique employs a hybrid of 8-bit PCM and 5-bit DPCM with a reflected quantizer, to reduce the bit rate of a HD-MAC multiplex to the H4 transmission level of about 140 Mbit/s. The method has a simple implementation, is rugged in the presence of transmission errors and can convey HD-MAC signals while still in their scrambled form. Such a codec was demonstrated at IBC-88 in Brighton, United Kingdom, where digitized HD-MAC was transmitted over 2 kms of optical fibre.

b) An alternative HD-MAC coding approach also developed within the Eureka-95 project is given in Document [CCIR 1986-90m]. This approach demultiplexes the MAC/packet signal into vision and sound/data components and codes the two components separately.

For the vision signal non-adaptive hybrid DPCM combining Van Buul techniques with a folded quantizer is used. To reduce further the sensitivity to transmission errors given by the coding method, the 7-bit DPCM code words at every ninth sample are replaced by the 8-bit PCM input code words.

For the sound/data packets, binary (1-bit) transmission of the decoded duobinary information is used. This coding could also be done in the presence of the scrambled form of the two components.

The multiplexing of the coded HD-MAC signal is chosen for transmission so that the complete signal will fit into the video channel of the TV Container which is described in Document [CCIR, 1986-90n].

c) Document [CCIR, 1986-90o] contains an overview of digital transmission of the MUSE signal (see Report 1075, Annex II, for details of the MUSE signal). The digital transmission system described is considered to be an advantageous one especially when the destination requires a MUSE-encoded signal only. The document states that the digital transmission of the MUSE signal is possible with a bit rate of around 135 Mbit/s by the MUSE-DPCM scheme. Further refinement and implementation are under way.

d) Document [CCIR, 1986-90p] describes HD-MAC bandwidth reduction coding principles for the emission of HDTV pictures derived from the proposed 1250/50/1 standard and is a status report on the studies in the Eureka-95 project. It states that HD-MAC is optimized to allow the introduction of HDTV services on WARC-77-BS channels while preserving compatibility with the MAC/packet system. The methods of bandwidth reduction employed are discussed, including the DATV (digitally-assisted television) concept and multi-branch coding. Some design trade-offs are highlighted, and reference is made to the subjective assessments which have led to the system being adopted by the Eureka project.

e) In Document [CCIR, 1986-90q], different subjective effects of the bit errors depending on three different coding schemes for HDTV still picture transmission are reported. For linear PCM component signals, for a sub-sampled PCM signal and for a sub-sampled DPCM signal, relative values of bit error rates, at which the subjective impairments are judged to be equal, were found to be 1, 1/6 and 1/10 respectively, in terms of the just perceptible limit of the impairment.

3.1.3 Conclusion

Studies which have been reported show that various bit-rate reduction techniques exist which will enable digital HDTV transmission to be effected at about 140 Mbit/s. Practical work currently in progress on codecs for the 4:2:2 level of Recommendation 601 should yield further relevant information. Final decisions as to standard methods can be expected to depend on the digital parameters chosen for the studio and for the international exchange of high definition television programmes.

3.2 Bit-rate reduction for 4:2:2 component signals

3.2.1 140 Mbit/s systems

The majority of these systems fully maintain the spatial and temporal resolution of the television signal according to Recommendation 601, hence, they meet the performance requirements of contribution links where downstream processibility is required. Some general aspects on the choice of coding parameters for contribution links are given in [CCIR, 1982-86e].

Three different techniques have been applied to the coding of component signals at 140 Mbit/s: PCM coding, DPCM coding and hybrid DPCM coding.

Coding proposals for a future local-area distribution network using uniformly quantized 8-bit PCM for both luminance and colour-difference components have been reported in [System 19] and [CCIR, 1982-86f]. Bit-rate reduction is obtained using line-blanking removal combined with horizontal and/or vertical sub-sampling of the colour-difference signals.

A DPCM system is described in [System 12], in which the sampling rates are unchanged with respect to the 4 : 2 : 2 coding, while previous sample prediction is applied to both luminance and colour-difference signals using 6-bit quantization for the *Y* signal and 4-bit quantization for the *U*, *V* signals. [System 13] describes a non-adaptive DPCM scheme with a 9-element, two-dimensional predictor for *Y* and a previous sample predictor for *U* and *V* using 6 bits/sample for both luminance and colour-difference signals. A further study [System 26] for verifying optimum colour-matte performance utilizes a real-time simulator to derive the best quantization characteristics and optimum variable-length coding.

A hybrid DPCM (HDPCM) approach is reported in [System 42]. Every fourth source sample in a line-quincunx structure remains as an unmodified 8-bit PCM sample and the values of these samples are then used as a basis of two-dimensional predictor/interpolators for the intervening DPCM samples.

A further proposal is described in [CCIR, 1982-86a]. By using a folded quantizer characteristic and a hybrid DPCM proposed by Van Buul [Van Buul, 1978], picture quality degradation due to overload effects can be significantly reduced. In addition, sensitivity to transmission errors comparable to systems with PCM representation can be obtained. Some implementation aspects based on the use of table memories in order to give a high degree of freedom in optimizing the coding scheme are given in [CCIR, 1986-90r].

For the particular case of point-to-point transmission at bit rates of around 140 Mbit/s, when the main system requirements are broadcast picture quality, the preservation of 4:2:2 downstream processing capability and moderate coder complexity, the EBU has outlined the main characteristics of such a system in [CCIR, 1986-90s and t]. This is the reference system referred to in Report 1234. A specification of a coding system based on that reference proposal is given in Table II. Hardware implementation is progressing in the Federal Republic of Germany [CCIR, 1986-90u] and in France [CCIR, 1986-90v].

Recommendation 721 describes bit-rate reduction codec characteristics for 140 Mbit/s.

TABLE II: OUTLINE SPECIFICATION OF A YUV CODING SYSTEM FOR USE AT 140 MBIT/S

Video input/ output	Standard	625-line digital video in component form
	Coding	4:2:2 signals according to Rec. 601
	Interface	Bit-parallel or bit-serial in accordance with Rec. 656
Pre-processing	Blanking	Removal of horizontal and vertical blanking intervals
	Sub-sampling	None
	Pre-filtering	None
Coding	Predictor	Two-dimensional intra-field $X = \frac{A+C}{2}$ C ——X— A X —X——O— for luminance and colour-difference components
	Adaptive control of predictors	None
	Motion compensation	None
	Quantizer characteristics	Folded quantizer combined with Van Buul technique
	Bit/sample	6, each for luminance and colour-difference components
	Variable-length coding	None
Post-processing		None
Video data rate		124416 Kbit/s

3.2.2 50-70 Mbit/s systems

Signals with no loss of picture quality and negligible loss in colour-matte quality compared to 4 : 2 : 2 signals can be achieved at the hierarchical bit rate of 140 Mbit/s. Using the next lower standardized level, 34 Mbit/s, picture quality is generally equivalent to that of existing analogue component signals whereas the processing capability is reduced with respect to that of 4 : 2 : 2 signals. Some administrations believe that a non-hierarchical bit rate of about 68 Mbit/s may be an attractive compromise between possible link costs and available operating capabilities bearing in mind that bit rates of the order of 50 to 60 Mbit/s may also be available via future communication satellites [System 17].

A DPCM system using 5 bits/sample is described in [System 76] with an overall bit rate of 70 Mbit/s including auxiliary signals. It is based on a 4 : 1 : 1 sampling ratio with line-sequential colour-transmission together with horizontal blanking removal.

[CCIR, 1986-90w] includes some specification of a system for operation at the rate of approximately 68 Mbit/s as well as brief information on two possible alternatives. This specified system does not involve subsampling-of the 4:2:2 source, and is based on DPCM with multi-element fixed prediction, adaptive quantization and variable length coding.

Bit-rate reduction of *YUV* component signals to about 52 Mbit/s using multi-element non-adaptive DPCM with a two-field prediction algorithm and a 32-level non-linear quantizing has been investigated for broadcast-quality applications in two different approaches [System 13].

In the time-division multiplex approach, the luminance sampling frequency is reduced to 10.125 MHz and colour-difference sub-sampling is involved by reducing the horizontal sampling frequency to 3.375 MHz and halving the vertical sampling frequency (line sequential colour-difference). In the frequency division multiplex approach, the colour-difference components are added to the luminance component on an out-of-band sub-carrier at half the sampling frequency of 6.75 MHz. For both cases, the picture quality was found to be comparable with, or better than, analogue composite-coded signals; some reduction in processing capability relative to the 4 : 2 : 2 source signal was introduced because of the reduced bandwidths of the colour-difference components.

3.2.3 30-34 Mbit/s systems

The data rate of 30-34 Mbit/s is of special interest for terrestrial and satellite transmission of television programmes. It has been claimed in [CCIR, 1982-86g] that a good distribution quality could be obtained at this bit rate. The quality attainable at 34 Mbit/s and its relationship with the quality required for contribution links is still to be determined.

For transmission with 34 Mbit/s various systems have been proposed which utilize non-adaptive prediction, fixed or switched quantizing together with sample-rate conversion thus introducing sub-Nyquist sampling and a ratio of 4 : 1 between the sampling frequencies for the luminance and colour-difference components.

Examples of DPCM coding schemes with fixed prediction using sampling frequencies of 9 MHz for the luminance and 2.25 MHz for the colour-difference signals are presented in [Systems 21 and 30].

A further approach [System 36] starts with an initial picture coding of 12 : 6 : 6 MHz. After line- and field-blanking removal a two-stage coding technique is provided by the use of line-quincunx sub-sampling.

In [System 22], an adaptive DPCM coding scheme using sampling frequencies of 9 MHz for luminance and 2.25 MHz for colour-difference signals is described where interframe or interfield prediction is performed when the picture content is still and intrafield prediction takes place when the content is moving.

Other approaches using adaptive predictor selection between interfield and intrafield, interframe and intraframe or intrafield and interframe have been made, in which sampling rates of 10.125 MHz for the luminance and 3.375 MHz for the colour-difference signals are used together with either alternate-line transmission of the C_R, C_B signals [Systems 31 and 37] or simultaneous transmission of the C_R, C_B signals including variable-length coding [CCIR, 1986-90x].

In [System 28], an interframe/intraframe DPCM codec is presented which enables transcoding between different data rates standardized for different ITU regions without prior reconstruction into the PCM level. By selecting the quantizing characteristics and the associated variable-length code words up to the capacity of the output buffer memory and by signalling predictor changes to the decoder, the concept allows the picture quality achievable in higher-rate transmission systems to be largely retained.

A DPCM method of 34 Mbit/s using variable length coding and transmission of the residual length in the horizontal blanking period is described in [CCIR, 1982-86h].

An adaptive DPCM system using 4:1:0 sampling is described in [CCIR, 1986-90y] to achieve a bit rate of about 30 Mbit/s for the picture. It makes use of several intrafield and an interframe predictors. Quantization is also adaptive; activity functions control all adaptivity. All luminance samples are processed, but colour differences are sub-sampled by two horizontally and by two temporally. The output of the DPCM loops are fed to variable-length encoders, and the buffer condition is fed back to adaptivity control for regulation. The system was implemented in simulation with preliminary hardware developments.

[System 4] presents a universal codec for either 525-line or 625-line systems which is applicable to the bit rates of the third PCM hierarchy levels recommended by the CCITT (32, 34 and 44 Mbit/s) without any significant modification in the hardware configuration and which has input/output interfaces conforming to Recommendations 601 and 604. This codec employs a new adaptive prediction scheme, MAP (median adaptive prediction), based on a combination of motion-compensated interframe, interfield and intrafield prediction which allows the transmission of broadcast TV programmes at 30 Mbit/s.

[CCIR, 1986-90z and aa] describe the activity of the Expert Group in IWP CMTT/2 and the considerations undertaken in an effort to establish a reference system derived from two practical codecs for the bit rates corresponding to the H2 CCITT access level, in view of a future draft Recommendation in this CCIR study period. This system employs 3:1:1 prefiltering after the 4:2:2 interface, which was seen as a good compromise between resolution and coding noise, and a motion-compensated interframe, interfield and intrafield adaptive prediction, adaptive quantizer and variable-length coding to achieve the quality objectives stated in [CCIR, 1986-90ab]. As to the channel error protection, a (255, 239) BCH double error correcting code is used in the system.

Formal subjective tests have been carried out in Sweden [CCIR, 1986-90ac] with a hardware implemented algorithm described in [Bengtsson et al., 1986] using 30 Mbit/s net video bit rate. This algorithm is close to the coding system described in [CCIR, 1986-90ad].

The tests were carried out according to the EBU method. Six test scenes were used with 4:2:2 as the reference.

The results of this test show that this coding method clearly meets the quality requirement of mean impairment grade 4.5 for basic picture quality for the test material used.

In respect to the 4:2:2 reference, the difference in quality grade was between 0.0 and 0.25 at 6H, and the grades were between 4.46 and 4.81 for the coded picture and for the 4:2:2 reference, between 4.75 and 4.88.

At 4H, the results were that the difference in quality grade was between 0.1 and 0.4, and the grades were between 4.28 and 4.91 and for the 4:2:2 reference, between 4.55 and 4.97.

After further consideration by the Expert Group of IWP CMTT/2 and to comply with the wishes of many administrations, the sub-sampling has been removed from the system so that it operates directly on a 4:2:2 source. As compared with the earlier technique, the new approach features more elaborate motion compensation and incorporates conditional replenishment. A detailed description of the new system is to be found in [CCIR, 1986-90ae].

Transform coding has also been applied to the transmission of component signals. [System 20] proposes a coding method using a modified *M*-transformation for transmission at 34 Mbit/s. Here, a redundancy and irrelevance-reducing encoding is carried out in three parallel channels by processing and quantizing the spectral value, the average value and the activity of a vector which represents a block of 4 × 4 pels.

A further application of transform coding to the luminance component of separate component signals is described in [System 38], using a Walsh-Hadamard transform having blocks of 4 lines by 8 pels with adaptive quantization for each block.

Another 34 Mbit/s system [System 51] makes use of a Hadamard transform in combination with sub-sampling performed by two-dimensional interpolation (decimation).

[CCIR, 1986-90af] contains information about the parameters of the system based on intrafield bi-dimensional discrete cosine transform (DCT) which has been implemented in Italy for transmission at 34 Mbit/s. The bit-rate reduction is obtained by transforming blocks of 8 x 8 pels, without any pre-filtering or sub-sampling processes, scaling the coefficients in relation to buffer filling, and coding them using a variable length code. The protection from transmission errors is obtained by a BCH (511,493) code. A detailed description of the system may be found in [CCIR, 1986-90ag].

[CCIR, 1986-90ah] describes subjective assessments carried out using the above system implemented by computer simulation. Six items (three still pictures and three moving sequences) have been used with 4:2:2 as the reference. Expressed in grades of the impairment scale at 6H the difference was between 0.0 and 0.49 and the values were between 4.46 and 4.96 for the coded pictures and between 4.75 and 4.96 for the 4:2:2 reference pictures. At 4H, the difference was between 0.0 and 0.76, and the values were between 4.16 and 4.97 for the coded pictures, and between 4.80 and 4.98 for the 4:2:2 reference pictures. These results show that the DCT coding method can meet the basic quality requirements for the test material used.

In [CCIR, 1986-90ai], a system using a DCT transform to encode 4:2:2 video into about 30 Mbit/s is described. The blocks are 8 x 4, and may be processed as such or as interframe differences. Coefficients are selected by means of thresholds, then classification, quantization and bit allocation are carried out. Intra- or inter-mode is selected as giving the lower bit rate, and the decision together with classification and bit allocation is transmitted in the block header. The system was only implemented in simulation. Indications on its performance appear in [CCIR, 1986-90aj], where a comparison is made with the system of [CCIR, 1986-90x] to which it is concluded to be superior.

An informal comparison of several coding methods is made in France using only one test sequence [CCIR, 1986-90aj], where the performance of two DPCM based [CCIR, 1986-90x and y] and one DCT based [CCIR, 1986-90ai] codecs are compared. It is concluded that codecs using a 4:2:2 or 4:1:0 sampling scheme offer at least as high a quality as the one using a 3:1:1 scheme (in particular the DCT based codec) and that the choice of sampling frequencies lower than 4:2:2 is an unnecessary restriction.

[CCIR, 1986-90ak] presents a coding technique for a 30-34 Mbit/s access level. The method used is a hybrid of predictive and interpolative coding which combines the advantages of predictive coding which combines the advantages of predictive coding to exploit human visual characteristics, with the ability to provide full 4:2:2 resolution when the channel capacity and image activity permit. There is no fixed sub-sampling involved, but the coder contains adaptive filtering which slightly reduces the resolution in moving detail when it is strained by active picture sequences. Features of the system include a highly adaptive ROM-based predictor which can respond to luminance contours, while being rugged in transmission errors, and a simple receiver implementation. The technique is being optimized by simulation and hardware is planned.

A statistical DPCM system, [CCIR, 1986-90al] employing a 4:2:2 interface, has the feature of field-sequential sub-sampling of the colour-difference signals prior to the encoding process. The full luminance component is encoded by an adaptive interframe/intrafield prediction controlled by a motion detector, and one of three quantizers selected according to a statistical activity measure determined in the locality of each picture sample. The sub-sampled colour-difference components are encoded with fixed spatial predictors and fixed quantizers. Both luminance and colour-difference quantizer outputs are assigned variable length codewords for transmission. To ensure robustness against channel errors periodic replenishment is employed and an error correction strategy based on a FIRE code with four-times interleaving.

This codec can handle up to four CCITT Recommendation J.41 sound channels and is now available as a commercial equipment.

Block truncation coding (group coding) has also been successfully used at 34 Mbit/s with high picture quality and having an error protection system able to withstand a bit error ratio of up to 10^{-5} [System 74] and [CCIR, 1982-86b].

[CCIR, 1986-90am] presents an EBU view that the development of a codec which meets the quality and processing objectives for 30-34 Mbit/s systems should be encouraged within the present CCIR study period. However, until the quality and processing capacity of possible systems is clearly known, and until current studies are complete, it would be unwise to adopt a draft Recommendation. The EBU believes that the study of a range of techniques should be encouraged (DPCM, hybrid systems, DCT), and that a system which does not involve systematic sub-sampling (e.g. to 3:1:1) should be possible and produce higher overall quality. However, if this does not prove to be substantiated, there could be a strong case for consideration of a 3:1:1 codec.

In the IWP CMTT/2 a system based on hybrid DCT plus variable length encoding is under discussion. [CCIR, 1986-90an] describes subjective assessments carried out using a computer simulation of the above algorithm. The double stimulus continuous quality scale was used: 16 observers at 6H assessed 3 critical sequences coded at 4 different bit rates. The overall results, expressed as a mean difference score on a scale of 1 to 100, were 3.2 for 30 Mbit/s, 8 for 15 Mbit/s, 15 for 12 Mbit/s and 22.8 for 10 Mbit/s. Although only an approximation, a score of 25 would equate with about one grade difference in the CCIR five-grade scale.

These results indicate that a subjective quality comparable with the 4:2:2 reference is obtainable at 30 Mbit/s for the test material and conditions used. The performance at lower bit rates suggests that the same algorithm can have a large field of applications, e.g. bit-rate reduction for distribution purposes and for digital HDTV.

One system under study in CMTT/2 based on Hybrid DCT is being developed in Italy and Spain. The advantages in terms of efficiency and robustness against channel errors of the Variable Length Code (VLC) and the video framing structure being implemented are reported in [CCIR, 1986-90ao]. Based on such considerations an updated annex on VLC of the system being specified by CMTT/2 is proposed in [CCIR, 1986-90ap] and a video framing structure based on fixed length packets is proposed in [CCIR, 1986-90aq]. The coding algorithm is also suitable for digital HDTV and [CCIR, 1986-90ar] gives the development schedule for the prototype hardware of both 4:2:2 and HDTV codecs which should be available for testing at the end of 1989.

Recommendation 723 describes bit-rate reduction codec characteristics for 32-45 Mbit/s.

3.2.4 6-20 Mbit/s systems

It may be necessary to reduce the transmission bit rate to 15-20 Mbit/s or lower in order to accommodate up to four channels per satellite transponder. Coding efficiency must be substantially improved to obtain this reduction. In this context, movement-compensated prediction, three-dimensional transform coding or hybrid DPCM/transform coding may offer promising approaches.

The codec of [System 4] is also used for the transmission of ENG programmes at 15 Mbit/s. In this 15 Mbit/s system a 2 : 1 : 0 sampling ratio is adapted.

An adaptive image transform coding using fast Hadamard transformation is described in [System 18]. The adaptivity is provided by finding so-called activity factors for each transform block and assigning more bits to the more active parts of the picture and fewer bits to the less active parts of the picture.

In [System 44], a method for achieving substantial saving in bit rate has been reported in which the correlation between consecutive frames in the form of a three-dimensional transformation is introduced. In this method, the rate distortion function is calculated for a vector of 64 pels, a square of 8 × 8 pels, and a cube of 4 × 4 × 4 pels using in each case Karhunen-Loeve, Hadamard and Slant transformation in the one- and three-dimensional form.

First results of an investigation on a 16 Mbit/s hybrid coding scheme, a combination of predictive and transform coding, are discussed in [System 27]. The system uses a linear three-dimensional predictor which samples the previous 3 frames according to a grid of 5 × 5 pels surrounding the point to be predicted.

A group coding system using 4 × 4 pel blocks for the luminance signal and 2 × 4 pel blocks for the colour-difference signals is presented in [System 75]. For transmission at 18.5 Mbit/s, every other field is dropped and reconstructed by temporal linear interpolation at the receiving end.

In [System 43], a new approach called stored pattern transmission (SPT) is applied for bit-rate reduction. The SPT depends on selecting a finite number of patterns to cover the different variations normally occurring in a picture. These patterns are stored with the same addresses at both the transmitting and receiving ends. The bit rate can be reduced to 6 Mbit/s with this system.

3.3 Bit-rate reduction systems for PAL signals

3.3.1 68 Mbit/s systems

A technique involving sub-Nyquist sampling combined with non-adaptive intra/interfield DPCM is described in [System 13]. By the action of a digital comb-filter, the original 4 f_{sc} (see Note) sampling structure of the PAL signal is reduced to a $2f_{sc}$ sampling structure. A fixed multi-element DPCM algorithm using several samples taken from the present and previous field in combination with a non-linear 64-level quantizer enables the difference signal so formed to be sent at a video bit rate of about 53 Mbit/s.

A coding principle based on a reversible predictive coding followed by entropy coding is reported in [System 14]. In order to generate a constant transmission rate, PCM bit truncation prior to predictive coding is introduced.

Note .– f_{sc} denotes the colour sub-carrier frequency.

3.3.2 34 Mbit/s systems

[System 13] describes a 34 Mbit/s DPCM coding system using a non-adaptive 14-element intra/interfield predictor and a 22-level non-linear quantizer combined with the removal of both line- and field-blanking intervals and sub-sampling at twice the colour sub-carrier frequency.

3.4 Bit-rate reduction systems for NTSC signals

Various studies have been carried out on bit-rate reduction of NTSC signals with bit rates in the range 30-44 Mbit/s using predictive coding techniques in fixed or adaptive form, sampling frequencies of 8.9 MHz or 10.7 MHz, and in some cases, variable word-length coding.

3.4.1 44 Mbit/s systems

[System 15] presents two different approaches in high-order predictive coding and describes its application to codecs encoding NTSC colour TV signals at a transmission rate of 44 Mbit/s. The first approach is based on reversible predictive coding followed by entropy coding. In the second approach, the digitized NTSC signal sampled at 8.9 MHz with 8-bit precision, is encoded into a 5-bit fixed word-length code by using a non-adaptive intrafield DPCM followed by a 31-level non-linear quantizer.

3.4.2 30-32 Mbit/s systems

For the transmission of NTSC signals within the third-order PCM hierarchy bit rate in Japan, a DPCM approach utilizing either fixed prediction schemes together with a sampling frequency of 8.9 MHz ($= 2.5f_{sc}$ or $566f_h$), or adaptive prediction schemes combined with a sampling frequency of 10.7 MHz ($= 3f_{sc}$), can provide sufficient data rate reduction.

[System 10] describes an intraframe combinational-difference coding method for use as an LSI-oriented coding algorithm in which two predictive coding circuits with identical configurations are connected in sequence and to which a quantizer is added.

The composite DPCM prediction method reported in [System 11] is based on the principle that luminance and colour-difference components are predicted individually. The composite prediction value is then determined by the sum of these two prediction values. A 4-bit and 8-bit dual word-length code assigning the 4-bit words to 15 quantizing levels which correspond to small prediction error amplitudes and the 8-bit words to 15 other quantizing levels which correspond to large prediction error amplitudes provides an average word length of 4.4 bits/sample.

A further approach to composite coding of NTSC colour TV signals using an inter/intrafield adaptive prediction method in combination with blockwise conditional replenishment control, is proposed in [System 5]. For "insignificant" blocks where the error sum does not exceed a certain threshold value, the prediction errors are assumed to be zero and only the block mode information of 2 bits transmitted, whereas the prediction errors of "significant" blocks are quantized and transmitted together with the block mode information.

3.4.3 15-20 Mbit/s systems

[System 8] presents the coding algorithms and simulation results of multi-mode movement-compensated interframe video coders operating at 15 Mbit/s and 20 Mbit/s. To reduce the bit-rates to the desired levels, various techniques such as sub-sampling from $4f_{sc}$ to $2f_{sc}$, temporal filtering, isolated pel noise suppressing, switched quantizing, block encoding, and variable word-length coding, are used in different modes which are controlled by the buffer memory status.

A second approach making adaptive use of interframe, interfield and intrafield prediction for coding of NTSC colour TV signals is presented in [System 9]. Whereas the motion-vector detection for a segment of the picture is carried out by using only the luminance signal, both the luminance signal and the two baseband components of the chrominance signal are motion-compensated in order to displace the picture segments of the previous frame according to the motion-vector which is detected.

3.5 Bit-rate reduction systems for the MAC family of signals using 140 Mbit/s

One bit-rate reduction codec for the MAC family of signals (D, D2-, or HD-) has been developed in the European Eureka-95 project and is described in [CCIR, 1986-90 l]. The technique employs a hybrid of 8-bit PCM and 5-bit DPCM with a folded quantizer, to reduce the bit rate to about 140 Mbit/s. The method has a simple implementation, is rugged in the presence of transmission errors and can convey MAC family signals while still in their scrambled form. Such a codec was demonstrated at IBC-88 in Brighton, United Kingdom, where digitized HD-MAC was transmitted over 2 kms of optical fibre.

An alternative coding approach also developed within the Eureka-95 project is given in [CCIR, 1986-90m]. This approach demultiplexes the MAC/Packet signal into vision and sound/data components and codes the two separately. For the vision signal non-adaptive hybrid DPCM, combining Van Buul techniques with a folded quantizer, is used. This coding could also be done using the scrambled form of the two components. The multiplexing of the coded MAC/Packet signal is chosen for transmission such that the complete signal will fit into the video channel of the TV Container which is described in [CCIR, 1986-90n].

3.6 Secondary distribution (See Note 1)

The issue of secondary distribution codecs is addressed by [CCIR, 1986-90as], which reports on subjective assessments carried out in simulation on four DCT based codecs. Two of these use a 30 Mbit/s video bit rate with intrafield and intraframe coding respectively, and two have 15 Mbit/s video bit rate with different forms of motion compensation. The assessments were carried out using CCIR test sequences and basic methodology; the analysis was made using confidence intervals. Low anchorage (PAL) as well as high anchorage (4:2:2) was provided. The results show that all algorithms have almost comparable quality and are clearly better than PAL quality, although not equivalent to 4:2:2 quality. It is concluded that these bit rates and types of algorithm are suitable for secondary distribution and possible for primary distribution.

Note 1 - The term secondary distribution has recently been proposed within CMTT ——— Recommendation 604 ————— to cover the transmission of television signals directly to the consumer. These developments in CMTT may create a corresponding need within Study Group 11 to explore the related quality criteria, bit rates and other matters.

3.7 Error protection methods

As for channel-error protection methods, several forward error correction (FEC) codes, such as Reed-Solomon (63, 59) code, Wyner Ash (15, 16) code and BCH (239, 255) code, have been applied in bit-rate reduction coding systems [Systems 4, 5, 8, 13, 14, 21, 28, 36, and 79]. As an example of a channel-error protection method employed in a codec, the BCH (239, 255) code in combination with periodic DPCM refreshing and line-reset is described in [System 79].

3.8 Network economics and performance

[CCIR, 1986-90at] makes some fundamental considerations of future network economics and performance based on experience in the United Kingdom. It suggests that with single mode optical fibre, the cost vs. bit-rate characteristic is not linear and that optimal economic transmission may be on the basis of 140 Mbit/s per channel. Impairments affecting digital transmission systems are examined and it is found that scaling parameters from 64 kbit/s Recommendations are not appropriate to specify vision service performance, which should be assessed subjectively. A single parameter "percentage of centiseconds with a BER worse than 10^{-4}" or alternatively two parameters with different values of BER and averaging interval, are offered for further consideration.

3.9 Multiplexing schemes

Two different approaches have been made to build up an appropriate multiplex for the transmission of component coded video signals for contribution quality applications.

The first approach, described in [CCIR, 1986-90n] makes use of a so-called TV Container with a data rate of 138 240 kbit/s that is able to convey different video source signals with data rates of 135 000 kbit/s and audio/data signals with data rates of 2048 kbit/s. Although the main interest of this TV Container is directed to Y, CR, CB contribution signals according to [CCIR, 1986-90m], other component or composite signals are applicable. By means of stuffing or mapping techniques, this TV Container could be adapted to the channel framing of different transport media; in particular, the TV Container will fit into a channel framing according to CCITT Recommendation G.751 as well as those of CCITT Recommendations G.707 to G.709.

A second approach [CCIR, 1986-90v] starts from the need expressed by some broadcasters for the transmission of two stereo pairs of high quality sound in addition to the video. Two 2048 kbit/s (effective capacity 1920 kbit/s each) channels are then provided for sound transmission. The general structure of the frame is in accordance with CCITT Recommendation G.751 with respect to frame length, alignment and organization. Video and audio justification is provided such that the jitter of the recovered clock is maintained within the limits specified by CCIR Recommendation 656. One important application of this multiplex is the connection of digital video recorders (one 4:2:2 video signal and two stereo pairs of sound encoded according to the AES/EBU standard) for which experiments have already been completed.

4. Methods of evaluation of picture quality for bit-rate reduction systems

4.1 *Scope and objectives of evaluation techniques*

The ultimate criteria for a bit-rate reduction system is the subjective quality of the resulting pictures, in the context of the bit rate achieved.

An overall evaluation must include the performance of the coding system itself (the basic quality), the performance after any subsequent processing has been carried out (the downstream processed quality), and the way transmission errors affect the system (the failure characteristic) and must take into account the critical nature of the test picture sequences used to evaluate the system.

In order to decide on the merits of a particular system, it is necessary to consider the relative importance of all these factors, and to establish criteria for acceptability in each case. An example of such an approach is given in [Inoue and Hishiyama, 1984].

The evidence of the current contributions to the CCIR is that predictive coding (DPCM) is likely to provide the best method for coding high-quality video with current, practically achievable, equipment. In addition, it may be noted that many proposals use sampling-frequency reduction (compared to the source 4 : 2 : 2 sampling frequencies).

4.2 *Evaluation of basic quality*

It is possible to classify the types of impairments associated with intrafield coding broadly as follows:

- slope overload (where the rise-time of the original signal cannot be matched, and therefore edges are blurred);
- edge busyness (where the precise continuity of an edge in the original signal cannot be matched, and therefore edges appear noisy);
- contouring (where the uniformity or monotonicity of the original signal cannot be matched and therefore a layering effect occurs);
- granular noise (where finely detailed portions of the picture, for example those below a threshold level, are not available, and the picture therefore has a noisy appearance).

For interframe or interfield coding, the following types of impairment may occur due to temporal prediction inaccuracy:

- temporal slope overload (where, because of the rate of movement, moving edges cannot be matched, and therefore become blurred during movement);
- granularity and edge busyness (where, for fine detailed areas in movement, the above granular noise effect and edge busyness effect occur).

For interframe or interfield coding, the following types of impairment may occur due to temporal sub-sampling:

- jerkiness (where the smoothness of movement cannot be matched and therefore there are discontinuities in moving sequences);
- temporal aliasing (where high temporal frequency components are folded back);
- loss of resolution in moving pictures (where spatial resolution is reduced during movement).

4.3 *Evaluation of downstream processed quality*

4.3.1 *Types of downstream processing to be considered*

Four types of processing operations principles need to be considered. These are as follows:

- colour matte (a process which combines colour-keying and the addition of signals to produce a single picture giving the impression that two sources (the foreground and the background) are part of the same picture);
- picture expansion and compression (a process which produces a new picture based on the original but either larger (expansion) or smaller (compression));
- successive decoding and encoding (a process of generating an analogue or digital signal in a different format, perhaps for intermediate use, before subsequent encodings, etc.);
- slow motion (reproduction of the picture signal at reduced rates of motion by repetition of frames).

4.3.2 *Types of impairment associated with bit-rate reduction systems*

4.3.2.1 *Colour matte*

– edge effects on foreground edges (where the matting becomes apparent because the transition from foreground to background has a visible halo).

4.3.2.2 *Picture expansion and compression*

– aliasing (where repeat or interference patterns manifest themselves in areas where there was originally fine detail in the picture);
– lack of picture sharpness and detail in the expanded picture.

4.3.2.3 *Successive encoding and decoding*

– a general reduction in picture quality caused by loss of frequency response, noise, etc.

4.3.2.4 *Slow motion*

– lack of picture sharpness, shape or position deformation, or position judder.

4.4 *Evaluation of failure characteristics*

The passage of the reduced bit-rate signal through the transport media, transmission line, video tape recorder, etc. may cause bit errors, which may occur independently or in bursts. The ability of a system to tolerate such errors, including either uncorrected or corrected channel errors, and the way that the resulting impairments manifest themselves, should be a part of the evaluation of a system for a given transport medium [Matsumoto *et al.*, 1985].

In general, the bit errors will manifest themselves as noise on the picture, although there could be other effects depending on the type of techniques, such as concealment, which were used. The errors can spread spatially and temporally depending on the coding technique which was used.

4.5 *Test material*

In general, intrafield systems do not limit motion portrayal, and therefore still-picture test material can be used for their assessment. (However, still-picture stores may not be sufficient because of noise effects.) For interframe coding, moving picture sequences are required.

4.6 Subjective evaluation methods

The bit-rate reduction schemes under consideration are likely to provide high quality pictures, therefore assessment procedures are needed which provide greatest accuracy above mid-opinion. Recommended assessment procedures are given in Recommendation 500. Report 1205 gives information on methods of analysis and presentation of results and Annex IV of Report 405 (Dubrovnik, 1986) contains some discussions on the comparison of different test procedures.

4.7 *Quantitative evaluation methods*

Studies have been made in Japan which suggest that picture quality impairments, arising from digital coding and transmission, can be classified into several categories of disturbance which are independent of each other in terms of their effect upon subjective picture quality. [CCIR, 1978-82; Kobayashi, 1977] indicate that the physical terms to express the categories of disturbance in intrafield coding can be defined and measured using well known test signals such as the staircase and sawtooth signals. For interframe coding, [CCIR, 1982-86i; Hishiyama and Inoue, 1984] indicate that the impairment introduced can be classified into four kinds of degradation factors and the references also describe objective parameters with which they can be specified. There have been further Japanese proposals to devise analogue and digital methods of measuring distortion (the difference between the output and input signal) and in work by the BBC it has been found useful to use a visual display of the quantizing error, multiplied by a factor to make it visible.

Weston [1982] describes a digital zone plate test-signal generator for testing equipments and systems using two- and three-dimensional signal processing. As in other types of frequency-response measurements, the results are most useful qualitatively; the quantitative results may be difficult to relate to a subjective assessment using real pictures.

A technique which may be more meaningful than RMS error alone has been investigated [CCIR, 1986-90d and au]. This technique is to derive a noise visibility weighted value for the luminance and colour-difference error signal.

5. Results of tests of bit-rate reduced codecs

During the 1986-90 study period, IWP 11/7 tested prototype codecs operating at 34-45 Mbit/s. A report giving the result of these tests and noting issues for further study including the degree of criticality of some material is provided in Annex I.

6. Conclusions and future studies

Both predictive and transform coding in combination with the removal of the line- and/or field-blanking intervals appear to be efficient coding methods for bit-rate reduction, although from a practical point of view, most of the coding equipment developed so far is based on predictive coding.

At 140 Mbit/s PCM, DPCM or hybrid DPCM techniques in combination with non-adaptive prediction schemes allow high-quality post-processing (close to that achieved with 4 : 2 : 2 signals). Component coding at 68 Mbit/s using fixed interfield prediction seems to be applicable to contribution purposes with a reduced colour-matte performance. Data rates of 30 to 44 Mbit/s which correspond to the third level of the different PCM hierarchies are of special interest for programme distribution. Conventional composite analogue picture quality can be achieved at these bit rates with present day bit-rate reduction methods.

At data rates around 30 Mbit/s or lower, the adaptive change of prediction schemes is indispensable for attaining satisfactory picture quality. Furthermore, motion-compensated prediction methods can be applied for coding systems at bit rates of 15 to 20 Mbit/s.

Administrations are encouraged to standardize component-based still picture and moving picture source material for subjective assessments of bit-rate reduction systems. If possible, these should be available on the CCIR 4 : 2 : 2 digital television tape recording format (see Recommendation 657).

It seems that a potentially achievable objective of future studies by the CCIR would be to establish standardized source coding methods for the transmission of digital television signals derived from 4 : 2 : 2 signals (Recommendation 601). Several sets of requirements need to be considered. These may include a level for contribution circuits which would preserve the quality and some or all of the processing capacity of the 4 : 2 : 2 signals, and another which would provide at least the equivalent composite signal quality for distribution circuits.

As may be noted, preliminary indications are that the former may be achieved by DPCM (60-140 Mbit/s) and the latter by adaptive DPCM (34 Mbit/s or less). However, further study is required to determine precise objectives and optimum solutions. In this connection [CCIR, 1982-86j] gives one proposal for a basis of system requirements and implementation of a bit-rate reduction coding system to be applied to distribution circuits or long-distance transmission.

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ANNEX I

TESTS OF DIGITAL TELEVISION CODECS

1. Introduction

According to Decision 60, IWP 11/7 is required to investigate methods of bit-rate reduction for digital television transmission. During the 1986-90 study period, IWP 11/7 undertook to test the coding methods employed in prototype codecs operating at rates of 34-45 Mbit/s on material conforming at source to the 4:2:2 specification of Recommendation 601. In this work, IWP 11/7 was assisted by close liaison with IWPs CMTT/2 and 11/4.

This report gives a brief description of the methods employed, the results obtained, and the lessons learned in the tests.

2. Tests and test methods

2.1 Tests conducted

In accordance with the guidelines given in Reports 1089 and 1211, IWP 11/7 undertook to test all 34-45 Mbit/s codecs then available in terms of: basic quality, downstream processed quality following colour matte and slow motion, and failure characteristics in the presence of random and burst errors and following momentary interruption of data.

As some codec manufacturers could not provide complete equipment in time for the tests, the full study could not be completed as planned in the 1986-90 study period. However, full tests were carried out on a motion compensated inter-frame DCT codec operating at 34 Mbit/s and on a motion compensated DPCM codec operating at 45 Mbit/s. Further, tests of basic quality and of downstream processed quality were carried out on a motion compensated inter-frame DCT codec operating at 45 Mbit/s; failure characteristics could not be assessed for this codec due to non-availability of the decoder.

2.2 Test methods

For quality tests, a variant of the double stimulus continuous quality scale method (Recommendation 500), described in Report 1206, section 5.1.3 was used. For failure characteristic tests, the double stimulus impairment scale method (Recommendation 500) was used. Further details are given in [CCIR, 1986-90a, b, c, d].

2.3 Test materials

In order to test the coding algorithms, it was necessary to develop a library of test pictures and sequences. Such test material was developed specifically for the codec tests, but the material, and the criteria according to which it was prepared, are relevant to tests of other standards. The material was prepared in 4:2:2 format (Recommendations 601 and 656) and recorded on D1 videotape (Recommendation 657). The test material and the criteria according to which it was prepared are described in Report 1213.

2.4 Mode of operation

Material appropriate to the tests planned and adequately critical to stress codec algorithms was selected from the library and used to prepare codec test tapes in D1 format. The D1 videotapes were despatched to the codec laboratories, where they were played back on D1 VTRs interfaced to the codecs according to Recommendation 656. The output from each codec, with and without the insertion of errors, was recorded on a second D1 VTR. The output tapes were subjected to post-processing as appropriate and the recorded, final outputs were used to prepare D1 videotapes for use in subjective tests. The entire operation was a critical demonstration of the capacity of digital recording and interfacing to ensure good interchange of material and to maintain high quality throughout, provided adequate care is taken.

The subjective tests were carried out in Australia, Canada, France, Italy, Japan, Spain, and the United Kingdom.

3. Results

3.1 Low/medium activity sequences

In tests of basic quality, the 34 Mbit/s DCT codec met quality requirements for all but one test sequence. Judgements for this sequence, however, may have been affected by a momentary loss of synchronization during recording of the codec output. The 45 Mbit/s DCT and DPCM codecs both met requirements.

In tests of downstream processed quality, all codecs tested met quality requirements following colour matte and slow motion.

In tests of failure characteristics, none of the codecs tested met requirements for resistance to random and burst errors or for recovery from momentary interruption of data.

3.2 High activity sequences

One very high activity sequence was used in basic quality tests for the 34 Mbit/s DCT codec. This sequence, in which the content was generally consistent with normal production practice, featured a surrounding field of noise progressively encroaching upon the centre portion of the picture. For this sequence, which was not available for tests of the 45 Mbit/s codecs, the 34 Mbit/s codec produced markedly poorer quality judgements.

It should be noted, however, that codec designers may not have been sufficiently aware of the severity of requirements as codecs, test material, and user requirements were developed, to an extent, in parallel. It may be useful to continue review of the quality requirements in light of the existence and use of such highly critical video material.

4. Conclusions

Although a full set of tests could not be done, knowledge gained from the tests was sufficient to provide the basis for an outline specification of a standard for 34-45 Mbit/s codecs. This codec would combine aspects of the different codecs tested and use improved error correction. Given the small problems revealed in tests of the prototype codecs, however, it might be useful to confirm the adequacy of codecs produced according to the new standard.

5. Lessons learned

A number of valuable lessons were learned in the tests. First, the ability of D1 recordings and digital interfacing to maintain high quality and high interchangeability, provided adequate care is taken, was established. Second, the adequacy of the test methods used and their reliability across linguistic groups were demonstrated. Third, the adequacy of the test material used was confirmed. In this regard, the test sequences and the methods by which they were prepared and recorded may prove useful in tests of other scanning standards.

6. Issues for further study

Before confirmatory tests of a codec standard can be undertaken, two issues require further study:

a) the statistics of the random and burst errors to be encountered in real transmission links; and

b) the statistics of the video material to be transmitted. If video material can be adequately characterized with a measure like that in [CCIR, 1986-90e], it may be possible to establish formally a quality requirement which is a function of image criticality. This should ensure that codecs perform well with material of low to moderate difficulty and, yet, do not produce subjectively objectionable results with the most critical material likely to be encountered.

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REPORT 1223

A LAYERED MODEL APPROACH FOR DIGITAL TELEVISION

(Question 46/11)

(1990)

1. Introduction

A description of the basic functions of a television information transfer may be performed in terms of a layered architecture complying with the one defined by ISO and CCITT in the OSI framework [Miceli, 1986; Fierro and Miceli, 1987]. Such an approach may be helpful also in the future, when television signals are going to be transmitted across a broadband ISDN. Furthermore it allows a clear separation of the various problems concerning the definition of a new standard. In particular the information path from the 7th layer to the first may be considered also as an ordered way to face these problems.

In Figure 1, the information transfer at a television interconnection is symbolically expressed in terms of the layered architecture.

This has to be considered as a tentative solution to the problem of putting typical television signals into the abstracted functions of the ISO model.

Particularly, problems may arise as far as the 5th layer is concerned, because it is not totally clear whether the "picture rate" and the "pictures per frame" may be considered at the 5th or as a sub-layer of the 6th level. However, this is a theoretical problem only; what is important is the order or, in other words, the priority of the various functions in the television interconnection. For this purpose a valid assignment of parameters is given in Figure 1.

2. Description of layer functions

A short description of some layer functions is necessary for the sake of clarity.

2.1 The 6th layer

In the layered architecture the 6th layer is concerned with the presentation of the information being transferred from the source to the destination. In the case of a video system, therefore, it deals with the colorimetric aspects of the pixel data and with the geometrical structure of the screen (number of active lines, number of active pixels per line, aspect ratio).

2.2 The 5th layer

The 5th layer is concerned with the number of pictures per second (whose format has been already discussed in the 6th layer) flowing through the system. In order to allow some spatio-temporal processing at the 4th layer (as explained later), it is preferable to consider pictures grouped in "frames". Therefore the same group of pictures, can be considered as a whole and can be coded accordingly. Obviously, the product of the number of pictures per "frame" and the "frame" rate equals the number of pictures per second being processed in the television system.

The "frame" so defined can be interpreted also as a time slot in which a typical periodicity of the video signal can be shown. This periodicity has to be specified in terms of an integer number of pictures, also considering the limit case of one picture per "frame". In a sense this concept can be considered as a generalization of the original meaning of the television frame. In fact, the case of an interlaced system can be interpreted as having 2 pictures per "frame" each coded in a particular way (transmission of one line out of two). In this case the "frame" rate is obviously half the field rate and is also the basic periodicity of the video signal.

2.3 The 4th layer

This layer is concerned with coding and formatting the video information. In that sense it deals with bandwidth compression methods, in order to adapt the video bit rate to the channel bandwidth.

In terms of the layered architectures, interlaced methods of picture transmission should involve typically the 4th layer. In fact it is theoretically possible to obtain an interlaced television signal by vertical subsampling a progressively scanned picture: in a sense, interlacing may be considered as a very simple method for coding pictures at reduced bandwidth.

2.4 The lowest layers (transmission standard)

The lowest layers deal with interface problems as shown in Figure 1.

Interfaces define the physical and logical ways for the information transport across the video chain. Their definition should not have any implication on the main system parameters and may be studied separately. Different interfaces may be defined for various nodes of the video chain in order to comply with local transmission requirements, while a common interface should be adopted for studio interconnections, see Figure 2.

3. OSI versus Recommendation 601 approach to compatibility

The most important characteristic of the OSI model is that the information transfer is transparent as far as the higher layers are concerned. If a standards conversion is necessary it will take place at the lower layers, as for example in Figure 2. Hence, the approach to compatibility is obtained starting from the highest layers and proceeding downwards.

This is the fundamental difference with Recommendation 601 philosophy. In fact, in this case the compatibility is obtained at the lowest 2 layers, while a standards conversion process is necessary for the highest layers, (625 to 525 line conversion and vice versa).

4. An example of a possible application

[CCIR, 1986-90] outlines a possible application of the approach described in section 2. According to the above structure an "asynchronous transport system" can be defined which allows to easily accommodate different scanning formats, such as 50 Hz television, 60 Hz television and motion picture films. Assuming that a commonality on the screen format has been reached at the 6th layer (using an interlaced-to-progressive conversion where required), the next step, at the 5th layer, is the definition of a "frame duration" as a time period that includes an integer number of pictures for all kinds of sources.

In order to accommodate into a "frame", regardless of the original picture frequency, an integer number of pictures, a "frame frequency" is considered, which is the greatest common divisor among the various picture rates, i.e. 2 Hz. Therefore, if the source is represented by a motion picture at 24 pictures per second, 12 pictures will be contained in the "frame period" (T = 0.5 sec). On the other hand, in the cases of 50 and 60 Hz television systems, the number of pictures included in a "frame" will be 25 and 30 respectively (Figure 3).

As far as the data formatting is concerned (4th layer), the "frame" has to be organized in a structure able to carry in the order, the information related to the frame itself, the pictures carried in it and the pixels; overhead data is required for labelling, data protection and synchronization purposes.

As shown in Figure 4 (in the case of a 50 Hz television system) a "frame" can be structured as follows:

- a "frame marker record" (FMR) placed at the beginning of each transmission frame;
- an optional "encryption record" (ER) where a conditional access to the transmitted data is required;
- a "picture marker record" (PMR) for each picture;
- a "pixel data record" (PDR) for each group of pixels (e.g. 8 x 8 square blocks where this is allowed by the screen format);
- a "padding record" (PR) to grant a fixed data rate in all cases.

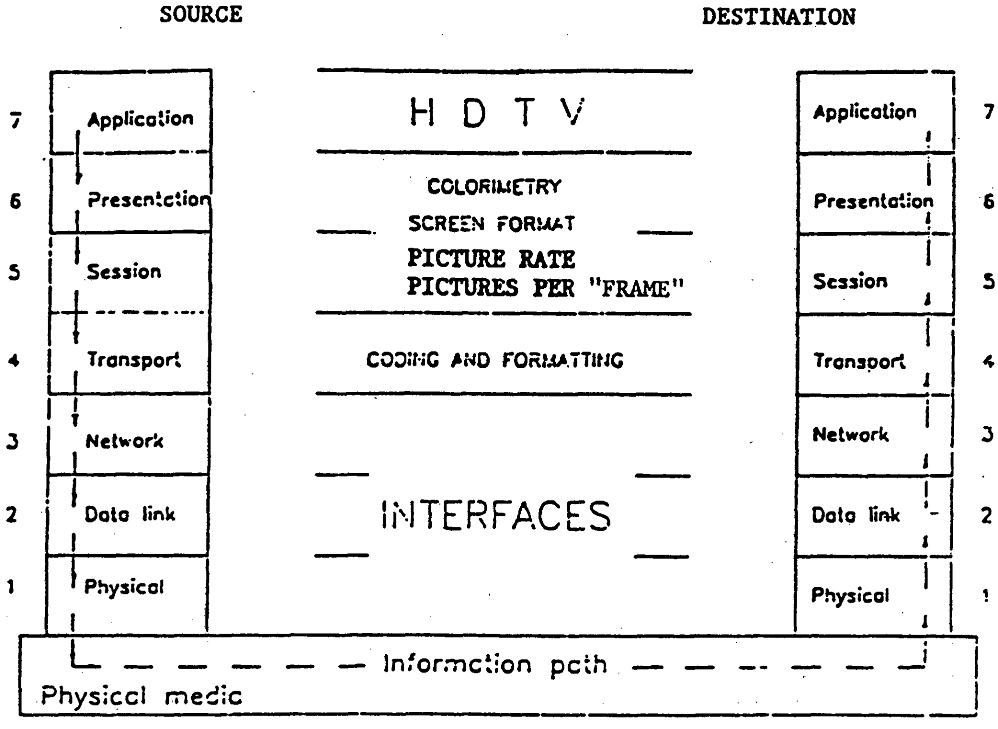


FIGURE 1

Layered architecture for the digital television

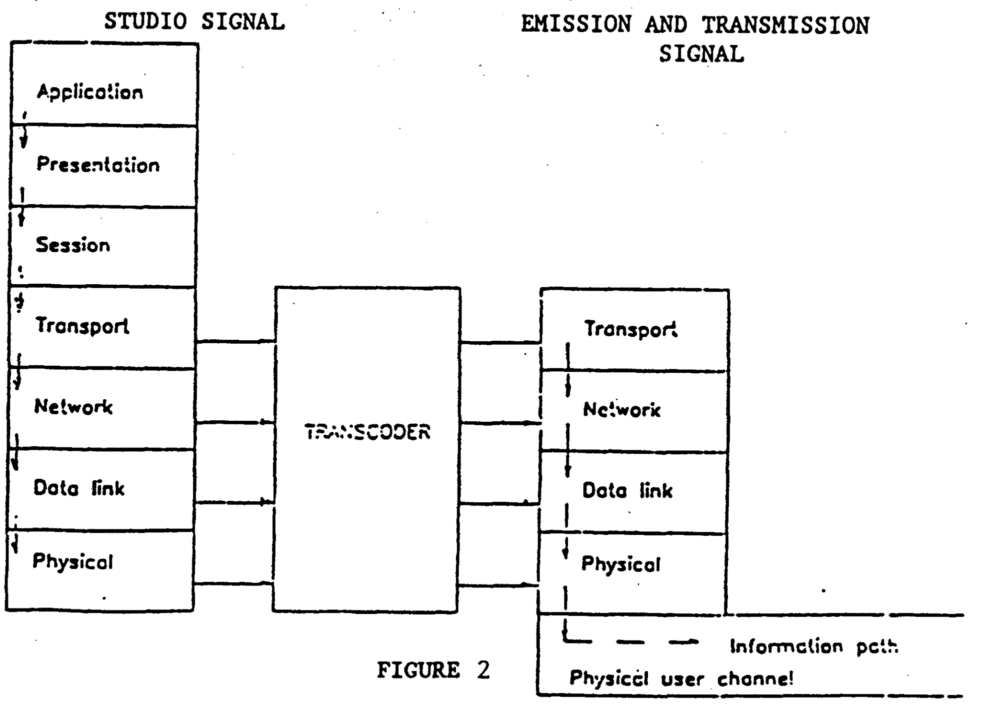


FIGURE 2

Transmission and emission standard generation

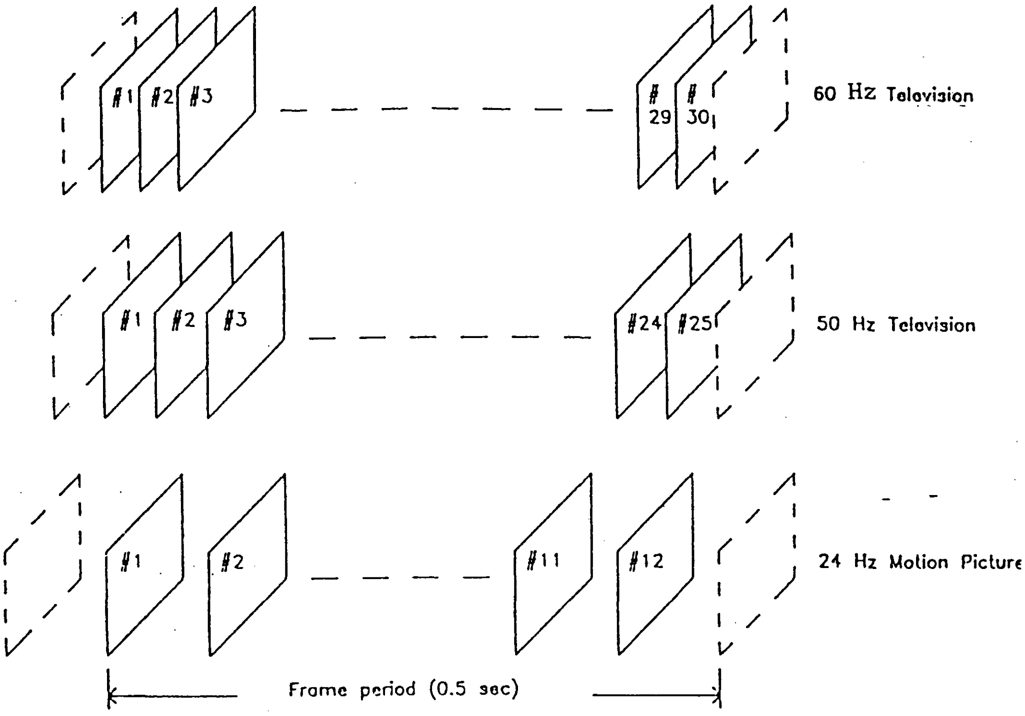
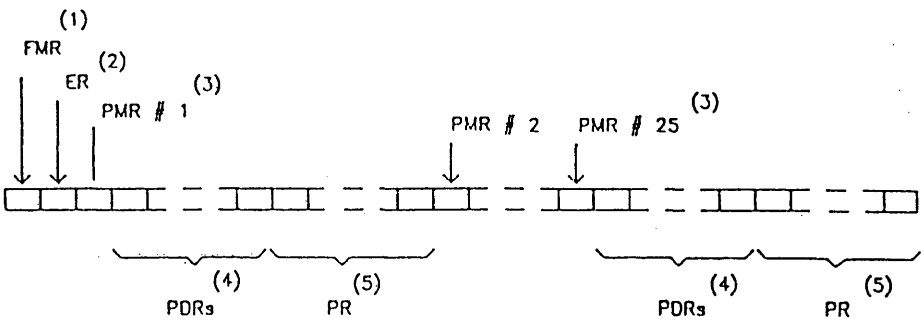


Fig. 3 – Definition of the frame period for the three most used picture rates



(1) Frame Marker Record
(2) Encryption Record
(3) Picture Marker Record
(4) Pixel Data Records
(5) Padding Records

Fig. 4 – Tentative definition of the frame structure (the figure refers to 50 Hz television case)

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REPORT 1212*

MEASUREMENTS AND TEST SIGNALS FOR DIGITALLY ENCODED COLOUR TELEVISION SIGNALS

(Question 25/11, Study Programme 25M/11)

1. Introduction (1990)

Digital television systems operate in very different ways from analogue systems with the consequence that a quite different set of picture impairments may be introduced. Impairments may occur both from the conversions to and from the digital domain (which include filtering, sampling and quantization processes, see Reports 629, 962 and Recommendation 601) and by degradations of the digital signal itself (such as individual digit errors, timing jitter or loss of frame synchronization). In the conversion processes, the impairments may be picture dependent, while errors in the digital domain may be bit-sequence dependent. In the digital domain, an increase in noise or distortion above a certain threshold level can result in a rapid increase in the number of digit errors. Before that level is reached, the error performance can be improved significantly by the use of error correction techniques.

Picture impairments may thus arise from several sources:

a) distortions in the conversion processes from analogue to digital form and from digital to analogue form;

b) errors in the digital channel;

c) distortions introduced by digital signal processing.

Test and measurement methods for the digital television system must therefore include consideration of these separate factors and of the need for both off-line (acceptance and maintenance testing) and on-line (monitoring and diagnostic) requirements.

In the case of picture impairments, either subjective or objective tests may be used. Section 2.1 of this report contains information on subjective test methods and section 2.2 considers objective testing. In either case, care must be taken to consider the effect of two- or three-dimensional signal processing techniques which render many current analogue test signals of little use (in that case because of their line-repetitive nature). Section 2.3 of this report considers the testing of signals in digitally encoded form. In this case,

* This Report should be brought to the attention of the CMTT and of the IEC.

the emphasis is on the measurement of residual bit errors (after any correction has taken place), error distributions and their relation to picture or other information. Objective tests and specialized test equipment may be required.

In digital equipment, advantage can often be taken of the self-test capability of many digital integrated circuits and the ability of the digital circuits to generate well-defined waveforms to test the analogue parts of the conversion circuits.

There is a great deal of work remaining to create adequate measurement and test methods for digital television equipment and administrations are thus invited to make contributions on this subject.

2. Assessment methods

2.1 Subjective assessment

At present subjective assessment is the only technique useful in practice for the evaluation of digital television systems and it is therefore important that the method used should be in accordance with Recommendation 500. Special attention should be paid to the choice of picture material. For example, in [CCIR, 1974-78a], the use of pictures involving either linear or rotational movement is proposed. This document also suggests that slow periodic fluctuations in picture signal amplitude may be useful.

For subjective assessment of interfield or interframe coding methods (which are important for high-efficiency bit-rate reduction of digital television signals), moving test pictures are essential. [CCIR, 1982-86a] describes the factors to be considered in the preparation of such moving test pictures and presents an example set which consists of 26 moving scenes. Report 1206 contains a suggested set of pictures, scenes and sequences for subjective assessments.

2.2 Objective measurements

2.2.1 Measurements on digital television equipments and installations

Studies have been made to define objective parameters, measurements of which could be related to the subjective impairments [CCIR, 1974-78b; Kretz, 1977]. One approach consists of considering separately the various impairments which may affect different types of picture information (e.g. plain areas, contours, fine details). Recent studies [CCIR, 1978-82a] indicate that picture-quality impairments arising from digital transmission can be classified into several categories of disturbance which are independent of each other in terms of their effects upon subjective picture quality. The physical terms to express the respective categories of disturbance for intraframe coding are defined and can be measured using well-known test signals such as the staircase and sawtooth signals. [CCIR, 1982-86b] shows a method for classifying picture quality impairments by using psychological factor analysis, in such cases where the classification procedure cannot take place *a priori*.

Combinations of analogue and digital equipments will continue to be employed in studios before all-digital studios come into operation. In this interim period the video signal will undergo a number of analogue-digital-analogue conversions. Each conversion in either direction is a potential source of picture impairments.

Present analogue test methods are suitable for many measurements of mixed analogue-digital-analogue signal paths in studios, but it is recognised that some measurements provide results which are made unreliable by digital signal processing.

New test signals to ease these difficulties have been proposed. [CCIR, 1974-78a] suggests the use of a sine-squared pulse of half-amplitude duration somewhat less than half the active line period, with superimposed colour sub-carrier, as a test signal for the measurement of quantization noise [Krivosheev, 1976].

[CCIR, 1974-78c] proposes a line-duration sawtooth signal with superimposed colour sub-carrier for the measurement of differential gain and differential phase.

In [CCIR, 1978-82b] a method is suggested for the measurement of distortion introduced by digital processes wherein the processed signal in digital form is subtracted from the original signal also in digital form, thereby providing greater accuracy. Analysis can then be performed on either digital measuring equipments or existing analogue measuring equipments.

Weston [1982] describes a digital test-signal generator for testing equipments and systems using two and three-dimensional signal processing. It produces, *inter alia*, electronic zone plate test patterns which may be stationary (two dimensional) or moving (three-dimensional). The zone plate signals form a powerful diagnostic aid for studying the properties of such processes as spatial and temporal filtering, sub-sampling, interpolation etc., and for optimizing the algorithms used. As in other types of frequency-responses measurements, the results are most useful qualitatively; the quantitative results are difficult to relate to a subjective assessment using real pictures. Nevertheless, tests with zone plate patterns can be used distinctively to reveal particular impairment modes and thus critical real pictures.

[CCIR 1986-1990a] describes the application of a pseudorandom data sequence, generated by a feedback shift register to check the operation of bit-parallel video interfaces corresponding to CCIR Recommendation 656 and the transmission paths between them within the studio. The ranges of values of the quantization levels, in the application described, correspond to the defined range given in CCIR Recommendation 601, however quantization values will occur which lie outside of the RGB signal range.

Although the statistical characteristics (e.g. correlation) of the proposed pseudorandom sequence are not typical of digitized broadcast television, the method described has been used to determine the pulse crosstalk between circuit elements and transmission lines. Results obtained from such determinations should however be interpreted accordingly. The method has also been used to measure bit error rates in, and unwanted radiation from, intrastudio links and the time response of linear and non-linear circuit components, again subject to the reservations of the statistics of the pseudorandom data.

[CCIR 1986-1990b], suggests that conformity tests on the 4-2-2 interfaces must be based on the use of real-time measurement techniques suitable for checking the parameters specified in Recommendation 656 for each item of data transmitted.

In [Lebrat-Fouillet, 1989], it is explained measuring methods based on the use of 4-2-2 test signals:

- The clock jitter on a parallel interface can be measured by producing a signal whose amplitude is proportional to the phase difference between the interface clock and a stable clock obtained by appropriate filtering. Oscilloscopic observation of this signal after calibration provides the amplitude and distribution of the jitter in relation to the structure of the video signal (line, field, etc.).

- The differential transmission delay on a parallel interface can be measured by comparing the data detected by the interface clock with those detected by a number of clock signals obtained by means of a fixed phase shift (gain or lag) in relation to the interface clock. This comparison yields for each item of data the maximum clock gain and lag possible if correct detection is to be maintained, and by combining these results we can measure the differential transmission delay.

2.2.2 Measurements on digital television codecs

Meiseles [1988] describes a method of measurement for objectively determining the effects of the motion prediction algorithms used in some bit rate reduction video codecs. Using the method described, the static performance of the coding system is first measured to find the attributes of frequency response, gain, 2T pulse response, short time waveform distortion (IEEE 511 - 1979 method) and non-linear gain. The results of these tests provide the performance reference for the dynamic tests. The dynamic test pattern with the appropriate test signals, used to measure the static responses, are used to measure the previously described attributes. The differences between the static results and the dynamic results are those caused by the prediction process. By using this method the processing artifacts of slope overload, edge jitter, quantizing error, prediction error, and signal-to-noise ratio can be measured accurately and with repeatability.

Objective measurements of codec quality are also discussed in Report 1206.

2.3 Testing of signals in digitally encoded form

Some information on the assessment of digital circuits is in Report 1206.

3. Examples of 4:2:2 test signals

[CCIR, 1986-90b and c] describe some test signals and procedures for 4:2:2 digital equipment. Such digital signals are defined below. However, further signals are required to provide a more complete assessment of performance.

Administrations are encouraged to carry out studies to define further test signals.

3.1 Explanatory notes

Each of sub-paragraphs 3.2 to 3.9 describes a 4:2:2 test signal, giving:

- a number and a description for each test signal (in the title of the sub-paragraph);
- the composition of digital active signal lines. Y (i) stands for the value of the luminance signal Y for sample number i of the digital active video line, with samples numbered from 1 to 720 in chronological order. When i is odd C_B (i) and C_R (i) stand for the values taken on by colour difference signals C_R and C_B;
- the use of signal in 4:2:2 digital video equipment tests.

Table I defines six 720-sample digital waveforms, referred to as A1, A2, A3, A4, A5 and A6.

These digital waveforms are made up of pulses in uniform ranges, ramps between two uniform ranges, and transitions between two uniform ranges, shaped by a filter whose impulse response R(t) is defined as a function of time t as follows:

- for $-3T < t < 3T$, $R(t) = 0.42 + 0.50 \cos(\pi t/3T) + 0.08 \cos(2\pi t/3T)$
- otherwise $R(t) = 0$

(R(t) is a Blackman window)

The value of T is 74 ns for digital waveforms A1, A2, A3 and A4 and 148 ns for A5 and A6.

3.2 Test signal No. 1: GREY

The active video lines of this signal are defined by : $Y(i) = A1(i)$, $C_R = C_B = 128$

This signal is critical for transmission via a parallel interface, since each of the 8 interface data binary signals then contains a succession of bits 0, 1, 0, 1, 0, 1 ... and attains maximum power concentration at high frequencies (multiples of 13.5 MHz) which often prove difficult to preserve in practical transmission links.

3.3 Test signal No. 2: ALTERNATING WHITE/BLACK at 0.1 Hz

This signal produces alternately:

- for 5 seconds, pictures containing "white" digital active video lines defined by $Y(i) = A2(i)$, $C_R = C_B = 128$;
- for 5 seconds, pictures containing "black" digital active video lines defined by $Y = 16$, $C_R = C_B = 128$.

This signal produces a variation of the black level in the corresponding analogue video signals, owing to the suppression of continuous components and very low frequencies by the analogue transmission links. It provides a means of checking the compensation for this variation, as well as black stability and accuracy in digital coding.

3.4 Test signal No. 3: END-OF-LINE PULSES

The signal's digital active video lines are defined by:

$Y(i) = A3(i)$, $C_R = C_B = 128$

This four-pulse signal can be used to check the position of the digital active line in relation to the analogue reference, as well as the activity of samples situated at the end of the digital active line.

The outside edges of the two internal pulses coincide with the ends of the line displayed in the 625/50 system.

3.5 Test signal No. 4: BLACK/WHITE RAMP

The digital active video lines of this signal are defined by:

$Y(i) = \text{int}\ (A_4(i));\ C_R = C_B = 128$

This signal may be used to test the existence and position of quantization levels 1 to 254 of the luminance signal.

3.6 Test signal No. 5: YELLOW/GREY RAMP

The digital active lines of this signal are defined by:

$C_B(i) = \text{int}\ (A_5(i))$

$C_R(i) = \text{int}\ (128.5 - (0.114/0.701)\ (A_5(i)-128))$

$Y(i) = \text{int}\ (126 - (169/224)\ (A_5(i)-128))$

This signal can be used to test the existence and position of quantization levels 1 to 128 of the colour difference signal C_B.

TABLE I - Table of values used for defining digital test signals

i	1 ≤ i ≤ 20	21	22	23	24	25	26 ≤ i ≤ 694	695	696	697	698	699	700 ≤ i ≤ 720
A1(i)	16	18	33	72	110	125	127	125	110	72	33	18	16

i	1 ≤ i ≤ 20	21	22	23	24	25	26 ≤ i ≤ 694	695	696	697	698	699	700 ≤ i ≤ 720
A2(i)	16	19	50	126	201	232	235	232	201	126	50	19	16

i	1	2	3	4	5	6	7 ≤ i ≤ 10	11	12	13	14	15	16	17 ≤ i ≤ 706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
A3(i)	16	44	154	235	154	44	16	17	64	185	229	121	31	16	17	64	185	229	121	31	16	16	44	154	235	154	44	16

i	1 ≤ i ≤ 21	22	23	24	25 i 60	61 ≤ i ≤ 88	89 ≤ i ≤ 100	101 ≤ i ≤ 536	537 ≤ i ≤ 550	551 ≤ i ≤ 586	587 ≤ i ≤ 600	601	602	603	604	605	606 ≤ i ≤ 720
A4(i)	16	14	9	3	1	((i-57)/2)	16	((i-67)/2)	235	((i-79)/2)	254	250	217	135	53	20	16

i	1 ≤ i ≤ 20	21	22	23	24	25	26	27	28	29	30 ≤ i ≤ 40	41 ≤ i ≤ 96	97 ≤ i ≤ 120	121 ≤ i ≤ 564	565 ≤ i ≤ 720
A5(i)	128	126	120	108	89	65	40	21	9	3	1	((i-33)/4)	16	((i-53)/4)	128

i	1 ≤ i ≤ 120	121 ≤ i ≤ 564	565 ≤ i ≤ 580	581 ≤ i ≤ 632	633 ≤ i ≤ 660	660	661	662	663	664	665	666	667	668	669	670 ≤ i ≤ 720
A6(i)	128	((i+395)/4)	240	((i+383)/4)	254		252	246	234	215	191	167	148	136	130	128

i is the sample number and takes on values from 1 to 720.

TABLE I - Table of values used for defining digital test signals (continued)

i	1 to 254	255 to 508	509 to 762	763 to 1016	1017 to 1270	1271 to 1440
A7(i)	i	509-i	i-508	1017-i	i-1016	1525-i

i	1 to 47	48	49	50	51	52	53	54	55	56 to 668
A8(i)	235	232	218	187	139	86	46	24	17	16

i	669	670	671	672	673	674	675	676	677 to 720
A8(i)	19	33	64	112	165	205	227	234	235

i	1 to 24	25	26	27	28 to 334	335	336	337	338	339 to 360
A9(i)	240	232	191	143	128	130	152	204	236	240

i	1 to 24	25	26	27	28 to 334	335	336	337	338	339 to 360
A10(i)	16	24	65	113	128	126	104	52	20	16

3.7 Test signal No. 6: GREY/BLUE RAMP

The digital active video lines of this signal are defined by the same formulae as in § 3.6, replacing A_5 by A_6.

This signal can be used to test the existence and position of quantization levels 128 to 254 of the colour difference signal C_B.

3.8 Test signal No. 7: CYAN/GREY RAMP

The digital active video lines of this signal are defined by:

$C_B(i) = \text{int}\ (128.5 - (0.299/0.886)\ (A_5(i) - 128))$

$C_R(i) = \text{int}(A_5(i))$

$Y(i) = \text{int}\ (126 - (88/224)\ (A_5(i) - 128))$

This signal may be used to test the existence and position of quantization levels 1 to 128 of the colour difference signal C_R.

3.9 Test signal No. 8: GREY/RED RAMP

The digital active video lines of this signal are defined by the same formulae as in § 3.8, replacing A_5 by A_6.

This signal may be used to test the existence and position of quantization levels 128 to 254 of the colour difference signal C_R.

3.10 Test signal No. 9: CB, Y, CR, Y ramp

The active video lines of this signal are defined by Table $A_7(i)$ for 1440 samples of the digital active line multiplex.

This signal is useful for testing the conformity of the digital video signal format at the output of the digital processing equipment carrying out demultiplexing and remultiplexing operations on the components of the digital video signal.

Note - This signal produces spurious colours in the R, G, B field.

3.11 Test signal No. 10: white, end-of-line porches

The active video lines of this signal are defined by:

$Y(i) = A_8(i),\ C_B = C_R = 128$

This signal has no shaping of the transitions on Y at the ends of the digital active line and is useful for observing the analogue shaping of the line blankings by the 4-2-2 decoders.

Two integral transitions of the Blackman pulse with a rise time of 300 ns are placed 3 μs from the leading and trailing edges of analogue line blankings for 625-line systems, permitting comparative observation of the transitions and verification of the conformity of the digital-analogue time correspondence on Y.

3.12 Test signal No. 11: blue, end-of-line porches

The active video lines of this signal are defined by:

$Y = 41$, $C_B(i) = A_9(i)$, $C_R = 110$

This signal can be used to make the observations described in section 3.11) for high transitions on C_B.

3.13 Test signal No. 12: red, end-of-line porches

The active video lines of this signal are defined by:

$Y = 81$, $C_B = 90$, $C_R = A_9(i)$

This signal can be used to make the observations described in section 3.11) for high transitions on C_R.

3.14 Test signal No. 13: yellow, end-of-line porches

The active video lines of this signal are defined by:

$Y = 210$, $C_B(i) = A_{10}(i)$, $C_R = 146$

This signal can be used to make the observations described in section 3.11) for low transitions on C_B.

3.15 Test signal No. 14: cyan, end-of-line porches

The active video lines of this signal are defined by:

$Y = 170$, $C_B = 166$, $C_R(i) = A_{10}(i)$

This signal can be used to make the observations described in section 3.11) for low transitions on C_R.

3.16 Test signal No. 15: serial 1010

The active video lines of this signal are defined by:

$Y = 128$, $C_B = C_R = 129$

This signal produces, after parallel-to-serial conversion, the bit sequence ..., 1, 0, 1, 0, ... on the serial multiplex and concentrates the power at the frequency 121.5 MHz.

It is useful for monitoring the 9-bit clock phase recovery performance of the serial-to-parallel converters and assessing the receiver equalization quality.

3.17 Test signal No. 16: serial 11001100

The active video lines of this signal are defined by:

C_B = 192 Y(i uneven) = 218 C_R = 191 Y(i even) = 215

After parallel-to-serial conversion, this signal produces the bit sequence ..., 1, 1, 0, 0, 1, 1, 0, 0, ... on the serial multiplex and concentrates the power at the frequency 60.75 MHz.

It is useful for monitoring the bit clock and 9-bit clock phase recovery performance of the serial-to-parallel converters and assessing the receiver equalization quality.

Note - This signal produces spurious colours in the R, G, B field.

3.18 Test signal No. 17: serial 111000111000

The active video lines of this signal are defined by:

Y = 245, C_B = C_R = 248

After parallel-to-serial conversion, this signal produces the bit sequence ..., 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, ... on the serial multiplex and concentrates the power at frequency 40.5 MHz.

It is useful for monitoring the bit clock and 9-bit clock phase recovery performance of the serial-to-parallel converters and for assessing the receiver equalization quality.

Note - This signal produces spurious colours in the R, G, B field.

4. Digital colour bar signals

The frequent use of colour bar signals in analogue television suggests the need to define such encoded signals for digital, in order to monitor levels and phasing between components after 4-2-2 decoding.

Tables IIa and b give a description of 100/0/100/0 and 100/0/75/0 colour bars calculated by means of mathematical equations with the following characteristics:

- shaping of transitions by integral of the Blackman impulse;
- rise time 10% to 90% for Y: 150 ns;
- rise time 10% to 90% for C_B and C_R: 300 ns.

TABLE II - Description of encoded colour-bar signals for digital

a) Designation: 100/0/100/0 colour bars

Definition of Y for digital active line with rise time = 150 ns

i	1 to 14	15	16	17	18	19	20 to 100	101	102	103	104	105	106 to 186	187	188	189	190	191
Y(i)	16	16	39	126	212	235	235	235	232	223	213	210	210	210	206	190	174	170

i	192 to 272	273	274	275	276	277	278 to 358	359	360	361	362	363	364 to 444	445	446	447	448	449
Y(i)	170	169	167	157	147	145	145	144	141	126	110	107	106	106	104	94	84	82

i	450 to 530	531	532	533	534	535	536 to 616	617	618	619	620	621	622 to 720
Y(i)	81	81	77	61	45	41	41	41	38	28	19	16	16

Definition of C_R for digital active line with rise time = 300 ns

i	1 to 6	7	8	9	10	11	12 to 49	50	51	52	53	54	55 to 92	93	94	95	96	97
CR(i)	128	128	128	128	128	128	128	128	130	137	144	146	146	146	133	81	29	16

i	98 to 135	136	137	138	139	140	141 to 178	179	180	181	182	183	184 to 221	222	223	224	225	226
CR(i)	16	16	18	25	32	34	34	35	54	128	202	221	222	222	224	231	238	240

i	227 to 264	265	266	267	268	269	270 to 307	308	309	310	311	312	313 to 360
CR(i)	240	240	227	175	123	110	110	110	112	119	126	128	128

Definition of C_B for digital active line with rise time = 300 ns

i	1 to 6	7	8	9	10	11	12 to 49	50	51	52	53	54	55 to 92	93	94	95	96	97
CB(i)	128	128	128	128	128	128	128	128	116	72	28	16	16	16	31	91	150	166

i	98 to 135	136	137	138	139	140	141 to 178	179	180	181	182	183	184 to 221	222	223	224	225	226
CB(i)	166	166	154	110	65	54	54	54	69	128	187	202	202	202	191	146	102	90

i	227 to 264	265	266	267	268	269	270 to 307	308	309	310	311	312	313 to 360
CB(i)	90	90	106	165	225	240	240	240	228	184	140	128	128

b) **Designation: 100/0/75/0 colour bars**

Definition of Y for digital active line with rise time = 150 ns

i	1 to 14	15	16	17	18	19	20 to 100	101	102	103	104	105	106 to 186	187	188	189	190	191
Y(i)	16	16	39	126	212	235	235	235	227	198	169	162	162	161	158	146	134	131

i	192 to 272	273	274	275	276	277	278 to 358	359	360	361	362	363	364 to 444	445	446	447	448	449
Y(i)	131	131	129	122	114	112	112	112	109	98	87	84	84	84	82	74	67	65

i	450 to 530	531	532	533	534	535	536 to 616	617	618	619	620	621	622 to 720
Y(i)	65	65	62	50	38	35	35	35	33	25	18	16	16

Definition of C_R for digital active line with rise time = 300 ns

i	1 to 6	7	8	9	10	11	12 to 49	50	51	52	53	54	55 to 92	93	94	95	96	97
CR(i):	128	128	128	128	128	128	128	128	129	135	140	142	142	141	132	93	54	44

i	98 to 135	136	137	138	139	140	141 to 178	179	180	181	182	183	184 to 221	222	223	224	225	226
CR(i):	44	44	45	51	56	58	58	58	72	128	184	198	198	198	200	205	211	212

i	227 to 264	265	266	267	268	269	270 to 307	308	309	310	311	312	313 to 360
CR(i):	212	212	202	163	124	115	114	114	116	121	127	128	128

Definition of C_B for digital active line with rise time = 300 ns

i	1 to 6	7	8	9	10	11	12 to 49	50	51	52	53	54	55 to 92	93	94	95	96	97
CB(i):	128	128	128	128	128	128	128	128	119	86	53	44	44	44	56	100	145	156

i	98 to 135	136	137	138	139	140	141 to 178	179	180	181	182	183	184 to 221	222	223	224	225	226
CB(i):	156	156	148	114	81	73	72	73	84	128	172	183	184	183	175	142	108	100

i	227 to 264	265	266	267	268	269	270 to 307	308	309	310	311	312	313 to 360
CB(i):	100	100	111	156	200	212	212	212	203	170	137	128	128

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REPORT 1213

TEST PICTURES AND SEQUENCES FOR SUBJECTIVE ASSESSMENTS OF DIGITAL CODECS

(1990)

1. Introduction

The evaluation of digital transmission equipment for video such as codecs, can best be performed on a subjective basis, due to the complex and adaptive natures of the multi-dimension impairments introduced by bit-rate reduction. CCIR Texts such as Recommendation 500, and Reports 1206 and 1211 provide information on the methods and objectives of this testing. The test pictures (both still and moving) and test sequences for the subjective evaluation of codecs is the subject of this Report, which describes also a recommended set available in digital form.

It is clear that the selection of appropriate test material is a key step in the planning of subjective assessment and that when results are to be correlated between a number of testing sites or groups that the same pictures be used and that they be available at the highest level of quality. The material detailed in this Report meets these criteria and offers the assessor material covering a wide range of criticality.

2. Distribution format

Two possible formats can be identified for this purpose, both based on digital recording techniques.

i) The D1 - digital format specified in Recommendation 657. This format is based precisely on Recommendation 601, thus meeting the first user objective and is becoming widely available. In addition, the cassette format provides convenient handling, adequate playing time and ease of intercharge.

ii) The COST-211bis format on 1/2" computer tape (see ISO Document 1001). This format can be transparent to digital video signals in the Recommendation 601 format, but is limited in transfer speed. This format is useful for down-loading digital video into buffer stores or onto disk for real-time playback, but in this way is limited in uninterrupted play time. It has been found adequate for many laboratory purposes, and is widely used. The increasing use of the D1 format, coupled with the relatively slow transfer speed and bulky storage requirements limit future use of the COST-211 format in this application.

The use of analogue component formats for this purpose is not considered in this application, as only a digital format can deliver reliably and under controlled conditions the component digital video signal of Recommendation 601. At a future date optical or magnetic disks, using digital recording techniques might also be considered but are not today adequate in cost, performance, or flexibility for this purpose. Further studies are required.

From these considerations, the D1 format, defined in Recommendation 657, is the preferred one for the distribution of test pictures and sequences, offering high quality, transparent recording/reproduction and similar performance at both 525-line and 625-line standards.

3. Selection of scenes

In the preparation of subjective assessments, the assessor must have available a variety of scenes than can be considered critical but not unduly so, and which are representative in quality and production values with the best of television broadcasting. The level of difficulty may be checked by objective measurements, such as the determination of the worst-case differential entropy [CCIR 1986-90].

Subjective assessments may also consider a range of possible applications and situations making necessary the inclusion of scenes suitable for the evaluation of basic quality, processibility (chroma key, slow-motion, special effects, etc.), error performance and sound/vision synchronization. Tests for consistency of results as between the 525- and 625-line systems would require also that near-identical scenes for both systems be included.

A library of test scenes must then be based on the essential criteria following:

- images at a number of levels of difficulty and with different rates and modes of motion including stills;
- suitable for contribution and distribution uses;
- scene pairs suitable for colour matte evaluation are required;
- highest quality images with the lowest possible noise levels are needed, but noting the need for some scenes to have known amounts of noise added to evaluate certain facets of codec performance;
- covering a range of programme types;
- suitable for testing codec performance under normal conditions and in the presence of errors, both concealed and unconcealed.

A library of scenes meeting these criteria has been assembled in both the 525-line and the 625-line versions. The scene format is shown in Table I and the list of scenes and their content is shown in Table II. The scenes have been developed by a number of organizations engaged in codec development and evaluation and include the administrations of Canada, France, Federal Rep. of Germany, Italy, Japan and the United Kingdom.

4. Scene arrangements

A number of methods for subjective tests are under consideration, each requiring a somewhat different arrangement of scene material. In addition, the need for a large selection of scenes and for their presentation in a random order for different presentations precludes the preparation of a tape suitable for direct use in sessions for subjective evaluation. A better arrangement is to produce a library tape of the scenes in a format that will allow the assembly of tapes for specific sessions with a minimum of inconvenience by editing between the playback of the library tape and the specific playback medium for that session. The quality loss in this process can be very small, if the interface between machines is in the digital form specified in Rec. 601, Rec. 656.

The scene lengths and their presentations can be arranged for a maximum of commonality with those of the session tape, while avoiding the need to shorten scenes for some presentations, thus reducing the coherence of evaluations using this material in different evaluations. Scenes selected are thought to be suitable for both contribution and distribution level codec evaluations by appropriate selection.

The library tape consists of a leader for technical evaluation, time-code for edit control, an index in video form and a number of scene blocks to be used for evaluations.

Scene identification is carried in a caption title located in the video and audio ahead of the actual scene. Scenes may thus be located visually or by reference to time-code based on addresses from the Index Page at the head of the tape.

5. Ancillary information

Scene identification can be carried in time-code and in the longitudinal or digital audio areas of the D1-DTTR format. In the COST-211 bis format, this data can be included in the digital data of the header.

6. Production

The library tape in both 525-line and 625-line versions has been produced in D1 format (see Recommendation 657). The Rev. 2 level of this tape is listed in Tables I and II.

7. Distribution

Further study is required by IWP 11/7.

8. Copyright

All segments of the library tape are in the public domain and may be used freely for evaluations and demonstrations.

REFERENCES

[1986-90]: IWP 11/7-261 (UKIBA).

TABLE I

Scene arrangement

Block Number	Duration (secs)	Time Code (start)	Video	Audio
1	60	00:54:15:00	Colour Bars - Full Level	Tone - 440 Hz (All Channels)
2	30	00:55:15:00	Flat Field 1	Tone (All Channels) 400 Hz
3	30	00:55:45:00	Flat Field 2	"
4	30	00:56:15:00	Ramp	"
5	20	00:56:45:00	Zone Plate - Y only - Still $C_B = C_R = 128$	"
6	20	00:57:05:00	Zone Plate - C_B only - Still Y=16, C_R = 128	"
7	20	00:57:25:00	Zone Plate - C_R only - Still Y=16, C_B = 128	"
8	20	00:57:45:00	Zone Plate - Y only - Moving $C_B = C_R = 128$	"
9	20	00:58:25:00	Zone Plate - C_B only - Moving Y=16, C_R = 128	"
10	20	00:58:05:00	Zone Plate - C_R only - Moving Y=16, C_B = 128	"
11	10	00:58:45:00	Title/Caption - CCIR Test tape Rev(x), YY/MM/DD	Voice announcement
12	10	00:58:55:00	Credits	Voice Over
13	40	00:59:05:00	Rolling Index	Silence
14(a)	10	00:59:45:00	Title - "Formal Pond"	"Formal Pond" (Ch.1)
14(b)	05	00:59:55:00	Grey (Y=64, $C_B = C_R$ 128)	Silence
14(c)	30	01:00:00:00	Test Scene 1 - Formal Pond	Tone Seq.(Ch.1)
14(d)	15	01:00:30:00	Grey	Silence
15(a)	10	01:00:45:00	Title-"Boats"	"Boats" (Ch.1)
			ETC.	ETC.
NN	60		Color Bars - End of Video	Tone (All Channels) 400 Hz

TABLE II

CONTENT OF LIBRARY TAPE

SCENE NO	TITLE	CHARACTERISTIC	MOTION	SOURCE	525	625
1	Formal Pond	Luminance resolution	Still	Slide	o	o
2	Boats	Luminance & color resolution	Still	Slide	o	o
3	Clown	Horizontal resolution	Still	Slide	o	o
4	Boy with Toys	Skin & color edges	Still	Slide	o	o
5	Girl with Toys	Skin & color edges	Still	Slide	o	o
6	Young couple	Luminance & fine detail	Still	Slide	o	o
7	Blackboard	Color, vertical resolution	Still	Slide	o	o
8	Tree	Luminance patterns	Still	Slide	o	o
9	Old Master	Chroma key FG	Still	Video	-	o
10	Old Master	Chroma key BG	Still	Video	-	o
11	Still life	Chroma key FG	Still	Video	o	o
12	Still life	Chroma key BG	Still	Video	o	o
13	Kiel Harbour-1	High resolution	Still	8x10 slide	o	o
14	Sailboat	Luminance resolution	Slow	Video	o	o
15	Flower Garden	Color details	Slow pan	Video	o	o
16	Susie	Skin tones	Slow	Video	o	o
17	Diva with noise	Rapid entropy changes	Prod. wipe	Video	o	o
18	Dinner Party	Chroma key BG		Video	o	o
19	Boy with toys	Skin & color edges	Pan [H, V]	Slide	-	o
20	Old Master	Chroma key FG	Slow pan	Video	-	o
21	Old Master	Chroma key BG	Slow pan	Video	-	o
22	Clown	Lum.& color horiz. resolution	Pan [H, V]	Slide	-	o
23	BBC disc	Random movement	Circular	Video	-	o
24	Kiel Harbour-2	Cycle motion [narrow filter]	Rapid rocking	Component	o	o
25	Kiel Harbour-3	Cycle motion [wide filter]	Rapid rocking	Component	o	o
26	Kiel Harbour-4	High res. in H,V,T dimensions	Slow pan/zoom	Component	o	o
27	Balls of wool	Moving colors	Medium	Video	o	o
28	Popple	Moving colors	Pan/rotate	Video	o	o
29	Table tennis	Multiple rapid motions	Pan/zoom/cut	Video	o	o
30	Mobile & calendar	Random motion of objects	Slow	Video	o	o
31	Autumn leaves	Color details	Slow pan/zoom	Camera	o	-
32	Summer flowers	Saturated colors, texture	Slow pan	Camera	o	-
33	Birches	Luminance details, sky	Slow tilt up	Camera	o	-
34	Horse riding	Landscape	Zoom	Camera	o	-
35	Bicycles	Bicycle wheels	Complex, fast	Camera	o	-
36	Ferris wheel	Luminance & color details	Fast, complex	Camera	o	-
37	Shinjuku	Horizontal & vertical detail	Slow pan	Camera	o	-
38	Football	Sports	Rapid motion	Camera	o	-
39	Cheerleaders	Fast, complex	Zoom	Camera	o	-

TABLE II (Continued)

CONTENT OF LIBRARY TAPE

SCENE NO	TITLE	CHARACTERISTIC	MOTION	SOURCE	525	625
40	Ciao!	CK FG, Lum, color details	Slow pan/zm	Camera	•	•
41	Ciao!	CK BG, Lum, color details	Slow pan/zm	Camera	•	•
42	Portrait de famille	Progressive tilisation	Wipe	Camera/SE	•	-
43	Diva	Cuts on titles/busy scene	Cuts	Camera/SE	•	-
44	Tempête	H,V Lum, color details	Rand. motion	Camera	•	•
45	Tempête with noise	H,V Lum, color details	Rand. motion	Camera	•	•
46	TV trip	3D graph. HV lum/col detail	zoom/rotate	Graphics	•	-
47	Cruising	Animated freeze frames	2-10 freezes	Camera	•	•
48	Decoded NTSC	Cross luminance color	Slow pan/zm	Camera	- •	-
49	Decoded PAL	Cross luminance color	Slow pan/zm	Camera	-	•
50	Un générique	Rolling & crawling titles	Crawl/roll	Cam/CG	•	•
51	Error Recovery	Frame & calibration	Slow	Cam/Key	•	•
52	Text for 625 Diva	Cuts on titles	Cuts	SE		•

DECISIONS

DECISION 18-6*

DIGITAL SYSTEMS FOR THE TRANSMISSION OF SOUND-PROGRAMME AND TELEVISION SIGNALS

(1974-1976-1978-1981-1983-1989)

The CMTT,

CONSIDERING

(a) that CCITT Study Group XVIII is studying the problems associated with the establishment of an integrated services digital network (ISDN) for the transmission of all kinds of signals, including those for sound-programme and television;

(b) that CCITT Study Group XV is studying digital multiplex and line systems, including equipment for the digital transmission of sound-programme and television signals, and coding for interactive audio-visual services;

(c) that CCITT Study Group I is studying the end-to-end service quality of all interactive audio-visual services supported on the ISDN:

(d) that there is an urgent need to ensure that the standards adopted for the integrated services digital network shall be compatible with the requirements necessary for the transmission of sound-programme and television signals;

(e) that CCIR Study Groups 10 and 11 are studying the use of digital techniques in programme production and emission;

(f) that CCIR Study Groups 10 and 11 have the primary responsibility for specifying the overall performance, apportioning and methods of assessment of systems in the broadcasting service;

(g) that the CMTT is studying the performance requirements applicable to ———— digital transmission circuits for sound-programmes and television, either for contribution or distribution circuits;

(h) that the CMTT has to consider the transition period during which technological changes will take place;

(j) that there is a need to co-ordinate the studies undertaken by Study Groups 10 and 11 and the CMTT, together with those in progress in CCITT Study Groups XV and XVIII,

DECIDES

1. that a Joint Interim Working Party CMTT-10-11/2 be established with the following terms of reference:

1.1 to examine the results of studies on digital techniques effected in Study Groups 10 and 11 and the CMTT and to make any proposals necessary to ensure maximum compatibility between the recommendations of the Study Groups;

1.2 to co-operate with CCITT Study Group XV and XVIII to ensure maximum compatibility between the Recommendations of the CCIR and the CCITT related to the digital transmission of sound-programme and television signals;

* This Decision should be brought to the attention of CCITT Study Groups I, IV, XV and XVIII.

1.3 to cooperate with CCITT Study Group I to ensure appropriate compatibility between interactive audio-visual services and the broadcasting services;

2. that the Chairman of JIWP CMTT-10-11/2 shall be a representative of the Administration of the United Kingdom;

3. that JIWP CMTT-10-11/2 shall be composed of the Chairmen and Vice-Chairmen of the CCIR Study Groups 10, 11 and the CMTT and representatives of the CCITT Study Groups concerned, as well as of representatives nominated by the following Administrations: Germany (Federal Republic of) Australia, Canada, Denmark, United States of America, Finland, France, India, Italy, Japan, Norway, the Netherlands, United Kingdom, Sweden, Switzerland, the USSR and Yugoslavia;

4. that, as far as possible, the work of JIWP CMTT-10-11/2 shall be carried out by correspondence;

5. that coordination of digital studies in the CCIR shall be carried out in accordance with Annex I;

6. that the specification of performance for digital transmission circuits in general shall be in accordance with the principle that the first objective for systems employing digital or digital and analogue methods should be that the overall performance is not worse than the equivalent analogue system. Later in the development of digital systems it may be possible to improve standards of performance.

ANNEX I

COORDINATION OF DIGITAL STUDIES IN STUDY GROUPS 10, 11 AND CMTT

1. Organization of work

To provide effective coordination of studies of Study Groups 10, 11 and the CMTT on digital techniques, the results of the work of these Study Groups will be examined by the Joint Interim Working Party before transmission to the CCITT Study Groups I, XV and XVIII.
———————————————— If necessary, it will make proposals to ensure compatibility between the results of the Study Groups. Between Study Group meetings this work will continue by correspondence. The results of the study by correspondence will be transmitted to the Study Groups prior to their meeting. The timing of the work of the Joint Interim Working Party must take account of meetings of the CCIR Study Groups concerned.

The JIWP CMTT-10-11/2 considers that the work of coordination would be expedited if the meetings of Study Groups 10, 11 and the CMTT could be held simultaneously and separate from meetings of the other CCIR Study Groups.

2. Coordination of studies

The JIWP CMTT-10-11/2 proposes that particular parts of studies concerning digital techniques should receive emphasis by Study Groups in the manner given in Table I.

TABLE I

Distribution of the emphasis on studies concerning digital techniques among certain Study Groups of the CCITT and the CCIR, the CMTT, and the Joint Interim Working Party CMTT-10-11/2

1. Specification of all ISDN network aspects (CCITT Study Group XVIII); specification of transmission equipment and systems (CCITT Study Group XV); and specifications relating to telecommunication services (CCITT Study Group I).

2.* Coding methods, including redundancy reduction and standards to be adopted for foreseen application of:

2.1 Sound-broadcasting and television (see Note 1)

2.1.1 studio installations including recording — sound (SG 10) / television (SG 11);

2.1.2 terrestrial radio-relay links
2.1.3 cable transmission links
2.1.4 satellite transmission links
— (CMTT);

2.1.5 broadcasting from terrestrial transmitters and from satellites — sound (SG 10) / television (SG 11).

2.1.6 B-ISDN (distribution) (CMTT)

2.2 Interactive audio-visual services (Study Group XV)

3.* Compatibility of the relevant coding methods (see § 2) for:

3.1 studio installations, including recording;**
3.2 terrestrial radio-relay links;
3.3 cable transmission links;
3.4 satellite transmission links;
3.5 broadcasting from terrestrial transmitters and from satellites between themselves and with the other services envisaged under § 1
— JIWP CMTT-10-11/2

3.6 Interactive audio-visual services

4.* Study of ways of protecting against digital transmission impairments (e.g. errors, jitter, slip) for:

		Studio	*Transmission link*
4.1	sound programmes	(SG 10)	(CMTT).
4.2	television	(SG 11)	

4.3 Interactive audio-visual services (Study Group XV)

* Close cooperation between the Joint Interim Working Party CMTT-10-11/2 and Study Groups XV and XVIII is essential for these studies.

** Aspects of compatibility relating to the exchange of recordings are matters for Study Groups 10 and 11.

5. Study of transmission methods over various transmission media ——————— for:

5.1 studio installation, including recording | sound (SG 10) television (SG 11);

5.2 terrestrial radio-relay links (SG 9);

5.3 optical and metallic cable transmission links (SG XV);

5.4 satellite transmission links (SG 4);

5.5 broadcasting from terrestrial transmitters and from satellites | sound (SG 10) television (SG 11).

5.6 multiplex equipment and digital line systems on optical fibre cables in local networks, including ISDN access (Study Group XV).

6. Equipment for digital coding and multiplexing for sound and television programmes, including insertion of programme signals into telephony digital links (Study Group XV).

7. Methods of code conversion of programme signals in digital form, for example, conversion of signals encoded in a form suitable for studio application into a form suitable for long-distance transmission (see Note 1):

7.1 sound programmes | (CMTT).

7.2 television

8. Definitions of hypothetical reference circuits and chains for sound programme and television circuits (CMTT).

9. Transmission requirements to be satisfied by the hypothetical reference circuits and chains defined in § 8 (CMTT).

10. Definitions of hypothetical reference circuits and reference connections for the integrated services digital network (Study Group XVIII).

11. Measuring methods for performance and test signals for sound programmes and television:

11.1 within each part of the system for:

11.1.1 studio installations, including recording | sound (SG 10) television (SG 11);

11.1.2 terrestrial radio-relay links (SG 9);

11.1.3 cable transmission links (Study Groups IV and XV);

11.1.4 satellite transmission links (SG 4);

11.1.5 broadcasting from terrestrial transmitters and from satellites | sound (SG 10) television (SG 11);

11.2 between the input ports and output ports of the transmission chain of § 11.1.2, 11.1.3 and 11.1.4 (CMTT).

12. Study of subjective quality of signals encoded and transmitted in digital form, or which have been processed (e.g. chroma-key/colour-matte or other special effects) using signals transmitted in digital form for (see Note 1):

12.1 sound programmes (SG 10);

12.2 television (SG 11).

13. Interfaces

13.1 within studios and within broadcasting transmitters (Study Groups 10 and 11).

13.2 within transmission links other than in the B-ISDN (CMTT).

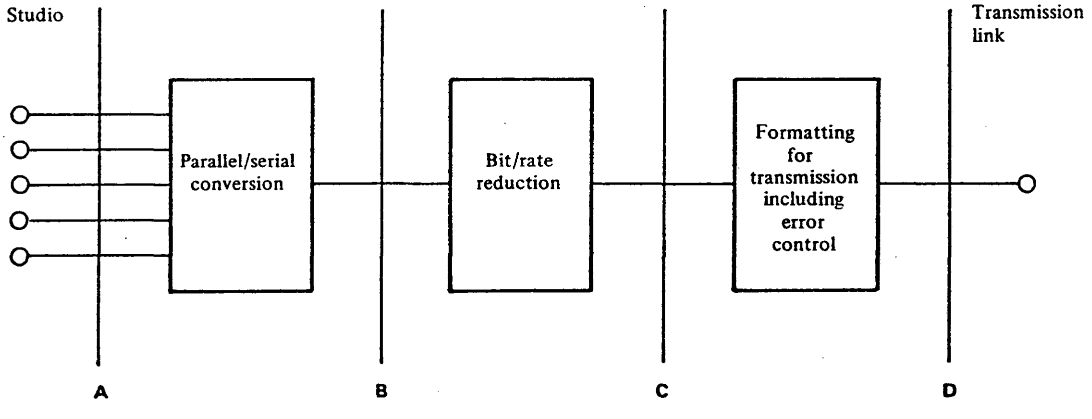
13.3 between studios and transmission links and between transmission links and broadcasting transmitters (CMTT), see Note 2.

13.4 within the B-ISDN including the B-ISDN user-network interface (Study Group XVIII).

Note 1. – The basic representations of sound and vision signals by digital codes and the associated quality requirements are studied and recommended by Study Groups 10 and 11. Irreversible transformations of these basic representations into other representations required for transmission should be subject to subjective and objective evaluation criterias defined by Study Groups 10 and 11 before their recommendation by the CMTT.

Note 2. – Digital interfaces for sound-programme and television signals.

Digital interfaces between studios and transmission circuits may involve either serial or parallel transmission of information and, in general, may involve processing for bit-rate reduction and formatting to suit the transmission circuit. These stages are illustrated in the following diagrams.



The interface at the output of the studio may be either A, B or C. Depending on the requirements of the transmission links, the block between interfaces C and D may, or may not, be required.

The process of bit-rate reduction shown between interfaces B and C may be carried out in the studio prior to parallel/serial conversion. This block may also include some processes for error protection.

Taking account of the above, Study Groups 10 and 11 (for sound and television respectively) should have the prime responsibility for interfaces A and B but the CMTT should have the opportunity to comment on them before final agreements are reached. Similarly, for interface C, the CMTT should have the prime responsibility but Study Groups 10 and 11 should have the opportunity to comment before final agreements are reached. In the case of interface D this should be studied with close coordination between the CMTT and CCITT Study Group XVIII but Study Groups 10 and 11 should have the opportunity to comment before final agreements are reached. This interface will also be of interest for access to the ISDN. Prime responsibility for interface D is in CCITT Study Group XVIII.

DECISION 42-4

RADIO-FREQUENCY PROTECTION RATIO AND RF RECEIVER CHARACTERISTICS FOR TELEVISION SYSTEMS

Terrestrial and cable services

(1980-1982-1985-1987-1989)

CCIR Study Group 11,

CONSIDERING

(a) that Recommendation 655 contains information on protection ratios relating to established television systems;

(b) that additional information is still required;

(c) that the compatibility between new and conventional television systems is under study,

DECIDES

1. that within the general terms of reference of Study Group 11, Interim Working Party 11/5 be maintained:

1.1 to collect additional information and establish protection ratios applicable to:

- improved receiver characteristics; image channel; adjacent channel, channel spacing, etc.,
- out-of-channel response,
- the effect of non-linearity in receivers,
- steady interference (100% of time),
- data signals within the vision or sound channels,
- sound signals including additional analogue or digital sound channels,
- enhanced conventional 525/625-line television systems, e.g. wide aspect ratio receivers,

- new 525/625-line television systems, compatible and non-compatible,

- analogue and digital HDTV systems,

in order to complete Recommendation 655;

1.2 to relate protection ratios to the principal RF characteristics of terrestrial and cable services:

- RF receiver characteristics,

- RF transmitter characteristics and offset requirements,

- RF requirements for community antenna and cable systems;

1.3 to collect data regarding the compatibility of new, enhanced television systems and HDTV systems:

- with the existing terrestrial service,

- with cable distribution and community antenna system,

- introduction strategy for enhanced television and HDTV systems;

1.4 to collect data on other matters including:

- assessment methods for interference to television sound,

- RF requirements of multi-media receivers for the simultaneous display of multiple programme channels, e.g. as sub-pictures on a wide aspect ratio display,

- ghost cancellation;

2. to invite administration to undertake the necessary studies;

3. that the IWP 11/5 should maintain liaison with IWP 11/6 and JIWP 10-11/3, and with the IEC for television receiver aspects;

4. to prepare regular updated reports on the progress of its studies;

5. that, as far as possible, the work of IWP 11/5 be conducted by correspondence; however, it may meet upon the proposal of its Chairman, following with the Director of the CCIR;

6. that the Chairman and composition of IWP 11/5 will be as shown in Annex I.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated their participation in the work of Interim Working Party 11/5:

Administrations:

Germany (Federal Republic of)
Australia
Austria
Benin
Cameroon
Canada
Egypt
Spain
United States of America
Finland
France
Gabon
Israel
Italy
Japan
Kenya
Poland (People's Republic of)
Portugal
United Kingdom
Swaziland
Tanzania
USSR
Venezuela
Yugoslavia (Socialist Federal Republic of)
Zimbabwe

International Organizations and Recognized Private Operating Agencies:

EBU
Norddeutscher Rundfunk (NDR)

Chairman of Interim Working Party 11/5:

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assisted by two Vice-Chairmen:

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and

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DECISION 58-4*

HIGH-DEFINITION TELEVISION STANDARD

(1983-1986-1987-1989)

CCIR Study Group 11,

CONSIDERING

(a) that high-definition television (HDTV) is a subject of intense current interest and activity in the world;

(b) that this work is the subject of Question 27/11 and the Study Programmes which derive from it, and is detailed in the texts on HDTV published in the Recommendations and Reports of the CCIR, 1990 (Volume XI.1);

(c) that it would be beneficial to HDTV broadcasters and to the public alike if the CCIR could recommend the adoption of a single, worldwide studio standard for high-definition television;

(d) that a step to attain this goal is to define the characteristics of a single high-definition television standard to be adopted worldwide for the high-definition television studio, and for the international exchange of programmes;

(e) that prompt action in this respect is required, to avoid the establishment of one or several *de facto* studio standards before all aspects of the problem have been adequately considered;

(f) that two proposals for a Recommendation defining full sets of basic parameter values for an HDTV standard were presented to the Extraordinary Meeting of Study Group 11;

(g) that ——— Recommendation 709 ——— defines a number of basic parameter values for the HDTV standard for the studio and for international programme exchange;

(h) the number and importance of interfaces in the future HDTV multi-media environment and the need for their harmonization, which are addressed in Study Programme 18U-1/11 and in Report 1232,

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* This Decision should be brought to the attention of the IEC and ISO.

DECIDES

1. that Interim Working Party 11/6 should continue its work within the general terms of reference of CCIR Study Group 11, taking note of Question 27/11 and the Study Programmes which derive from it and with the following specific terms of reference:

1.1 to encourage administrations to participate in a coordinated way in the study of a high-definition television standard for the studio and for international programme exchange;

1.2 to continue the work necessary to define a full set of relevant digital parameters (in collaboration with IWP 11/7) and analogue parameters for a single worldwide high-definition television standard for programme production and for the international exchange of programmes, for which agreement can be reached. The studies should take into account the texts published in the Recommendations and Reports of the CCIR, 1990 (Volume XI.1), including technical, economical and operational aspects;

1.3 to study the subject of the emission of HDTV from the point of view of terrestrial broadcasting. This study should be undertaken with the technical assistance of the other competent IWPs and JIWPs of Study Group 11;

1.4 to provide technical assistance, as required, to JIWP 10-11/3 in its study of the emission of HDTV by satellite broadcasting;

1.5 in accordance with the above studies, to produce the specification of the baseband signal format, unique if possible, to be used for emission applicable to both satellite and terrestrial broadcasting;

1.6 similarly, in cooperation with the CMTT, to prepare a specification for the baseband signal format to be used for the international exchange of HDTV programmes via transmission links;

1.7 to seek advice from JIWP 10-11/6 on quality assessment concerning § 1.2, 1.5 and 1.6;

1.8 to study the requirements and implications of interfaces in the future environment of HDTV production and delivery;

1.9 to prepare regularly updated draft Reports on the progress of its studies;

1.10 to complete the studies as rapidly as possible and to prepare a report to the Interim Meeting of Study Group 11 in 1991;

2. that IWP 11/6 should, as far as possible, work by correspondence; however, it may meet upon proposal of its Chairman, following consultation with the Chairman of Study Group 11 and with the Director of the CCIR;

3. that the Chairman and the composition of IWP 11/6 shall be as shown in Annex I.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated that they wished to participate in the work of Interim Working Party 11/6 (effective in October 1989):

Administrations:

Germany (Federal Republic of)
Australia
Belgium
Brazil
Canada
China (People's Republic of)
Denmark
Egypt
Spain
United States of America
Finland
France
India
Italy
Japan
New Zealand
Netherlands
Portugal
United Kingdom
Sweden
USSR
Yugoslavia (Socialist Federal Republic of)

International Organizations and Recognized Private Operating Agencies:

ABU
CBC
EBU
IEC
NBC
NHK
Philips
Thomson-CSF
BBC
CBS
ESCO
NANBA
NDR/ZDF
OIRT
RTVE
UKIBA

Chairman of Interim Working Party 11/6:

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ANNEX II

1. To further the development of ——— Recommendation 709 ————— by completing the work on the HDTV studio standard by specifying the parameters under study. In particular, attention should be focussed on the provisional values for the chromaticity coordinates and derivation of luminance and colour-difference signals, the number of active lines, the picture rate, and the blanking periods.

2. To carry out objective and subjective tests to confirm the basis for the work of HDTV development. Areas which require contributions include:

- the relationship between the HDTV studio standard and specific emission systems in such matters as line and picture rate conversions;

- the possible advantages of improved coding at various levels in the HDTV system;

- the relationships between source and display picture rates, exposure apertures and motion rendition in a variety of situations.

3. Further compatible enhancements of the HDTV studio standard by the wider colour gamut, improved luminance coding, and greater contrast ratio as technology progresses.

4. In accordance with Study Programme 18U-1/11, to cooperate with IWP 11/9 in the development of a coherent set of documents to define the interfaces and the application of HDTV in broadcasting, in non-broadcast and consumer media, and in other non-broadcast uses (e.g. medical, printing, aviation, computers).

DECISION 60-3*

DIGITAL TELEVISION STANDARDS

(1983-1985-1987-1989)

CCIR Study Group 11,

CONSIDERING

(a) that Recommendation 601 has established the basis for digital coding standards for television studios both in countries using the 525-line system and in those using the 625-line system;

(b) that the practical implementation of Recommendation 601 requires definition of the details of various studio interfaces and the data streams traversing them;

(c) that such interfaces should, as far as possible, have common characteristics between 525-line and 625-line versions;

(d) that electrical interfaces in both parallel and serial form have been defined in Recommendation 656 for digital signals at the 4:2:2 encoding level;

(e) that it is desirable for similar interfaces to be defined for the 4:4:4 level and for the higher and lower levels of the family of encoding standards, including high-definition and enhanced definition television, and since transmission by optical fibre has advantages, particularly at higher bit rates and over longer distances, it is desirable for compatible optical interfaces to be defined;

(f) that it is desirable for standard synchronizing signals for digital television studios to be further specified, especially for the 4:2:2 level and for high definition television;

(g) that it is similarly desirable for standard digital test signals to be specified;

(h) that the ancillary signals provided for in Recommendation 656 need to be studied further and international standards proposed as necessary;

(j) that digital television signals may be a potential source of interference to other services;

(k) that further studies are required to complete the specifications in Recommendation 601 for the various members of the encoding family, and for specifications for high-definition and enhanced quality television;

---

* This Decision should be brought to the attention of the IEC.

(l) that consideration should be given to any special provisions necessary in relation to the associated sound channels;

(m) that further studies are urgently required on bit rate reduction especially for high-definition television so that standard methods may be chosen in the near future;

(n) that during a transition period the television studio centre will include both analogue and digital elements,

(o) that the proposed extension of Question 25/11 (see Question 25-3/11) introduces the question of digital coding for broadcasting by cable or optical fibre networks.

DECIDES

1. that Interim Working Party 11/7 should be maintained, its terms of reference being to establish and submit to Study Group 11, before the end of the current study period, the following:

1.1 the information necessary to extend Recommendation 601 to fully specify the 4:4:4 level, and also to include other levels if necessary, and to specify encoding parameters for high-definition and enhanced quality television, with the complete specification of filter characteristics;

1.2 a draft Recommendation for optical interfaces, for the 4:2:2 and 4:4:4 levels and for high definition television;

1.3 further information for the draft Report, preferably with a further draft Recommendation, defining standard synchronizing signals for the digital studio;

1.4 similarly, a draft Report, preferably with a draft Recommendation, for standard digital test signals;

1.5 a draft Recommendation for international standards, as studies may show to be desirable, for the utilization of the provision for ancillary signals in interface specifications;

1.6 a draft Report, preferably with a draft Recommendation, defining any special provisions that studies show to be desirable in relation to the sound channels associated with the video signals carried by interfaces, with due regard to Recommendation 647 of Study Group 10;

1.7 draft Recommendations for bit-parallel and bit-serial interfaces for high-definition television, for the 4:4:4 level and for other levels for which the need may be established;

1.8 draft Recommendations for bit-rate reduction methods giving satisfactory picture quality and processing capability for each of the applications identified, it being necessary:

- to define each application;
- to establish objectives in respect of picture quality and processing capability for each application;

- to establish what bit-rate reduction methods will meet the objectives;

- to establish agreed test materials and test methods;

taking account of:

- available bit rates (e.g. CCITT levels);
- ease of conversion between coding schemes;
- the performance of systems, including differing systems, in cascade;
- special needs of the associated sound channels;

1.9 a draft Report on methods for deriving digital component signals, conforming to the digital studio interface standard, Recommendation 656, from a composite analogue signal (NTSC, PAL or SECAM) and vice versa.

1.10 draft additions to ——— Report 1209 defining the further practical methods required to ensure acceptably low levels of radiated interference from the digital signals conforming to any new encoding levels;

1.11 the information necessary to add to the draft Reports or Recommendations indicated in items 1.1 to 1.9 above, as far as possible, the requirements for broadcasting by cable or optical fibre networks;

2. that liaison should be maintained with Joint Interim Working Parties 10-11/4 and 10-11/6, Interim Working Parties 11/6 and 11/9, Study Group 10 and with due regard to Decision 18, close liaison with the CMTT and its IWP CMTT/2;

3. that IWP 11/7 should, as far as possible, work by correspondence. However, it may meet upon the proposal of its Chairman, following consultation with the Chairman of Study Group 11 and the Director of the CCIR. It would be advantageous for IWP 11/7 and the CMTT IWP CMTT/2 to meet at the same place and time;

4. that the results of the work of the IWP should be reported to Study Group 11 at the Interim Meetings of the Study Period 1990-1994.

5. that the Chairman, the Vice-Chairmen and composition of IWP 1/7 will be as shown in Annex I.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated their participation in the work of Interim Working Party 11/7 on digital television standards:

Administrations:

Germany(Federal Republic of)
Australia
Belgium
Canada
China (People's Republic of)
Egypt
Spain
United States of America
Finland

France
India
Italy
Japan
German Democratic Republic
United Kingdom
Sweden
USSR
Yugoslavia (Socialist Federal Republic of)

International Organizations and Recognized Private Operating Agencies:

EBU	CBS
NANBA	NDR
OIRT	ZDF

Chairman of Interim Working Party 11/7:

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Telefax: +81 3 4175536
Telex: 22377 radio nhk

DECISION 72-1*

DATA BROADCASTING SERVICES

(1986-1989)

CCIR Study Groups 10 and 11,

CONSIDERING

(a) that data broadcasting services on terrestrial and satellite channels either associated with sound or vision signals or exclusively, are under development in many countries;

(b) that data broadcasting services, such as teletext, programme identification in television and radio data services in sound broadcasting are already implemented in many countries;

(c) that new high-quality sound and vision services should be accompanied by data services with appropriate improved quality;

(d) that the CCITT is studying similar services in telecommunication networks,

DECIDE

1. that Joint Interim Working Party 10-11/5 should continue its work within the general terms of reference of CCIR Study Groups 10 and 11 and with the following specific terms of reference:

1.1 to carry out studies on the presentation layer requirements of some non-Latin based alphabets and non-alphabetic writing systems as indicated in Recommendation 653;

1.2 to carry out studies on the presentation layer requirements for data services associated with HDTV signals (see Report 1225);

1.3 to propose definitions of data broadcasting services in television and sound broadcasting channels, whether terrestrial or satellite**;

1.4 to study the data coding for these services, keeping coordination with JIWP 10-11/3, which is responsible for the accommodation of data signals in terrestrial and satellite broadcasting channels**;

---

* This Decision should be brought to the attention of the CCITT, the IEC and the ISO. This topic should be studied jointly with Study Group 10.

** The Study Programmes derived from Question 29-2/11, Study Programmes 44J/10, 46H/10, 47A/10 and 51D/10 as well as Study Programme 2N/10 and 11 are relevant.

1.5 to define appropriate service quality criteria and assessment methods;

1.6 to study the requirements for international exchange and system transcoding;

1.7 to study the requirements for equipment interface standardization;

1.8 to maintain contact with the CMTT, the appropriate CCITT Study Groups, the IEC and the ISO;

2. that JIWP 10-11/5 should, as far as possible, work by correspondence; however, it may meet upon proposal of its Chairman, following consultation with the Chairmen of Study Groups 10 and 11 and the Director of the CCIR;

3. that the Chairman and the composition of JIWP 10-11/5 shall be as shown in Annex I.

ANNEX I

The following Administrations and International Organizations have indicated that they wished to participate in the work of Joint Interim Working Party 10-11/5:

Administrations:

Germany (Federal Republic of)
Australia
Brazil (Federative Republic of)
Canada
China (People's Republic of)
Spain
United States of America
France
Iran (Islamic Republic of)
Italy
Japan
Netherlands
United Kingdom
Sweden
USSR
Yugoslavia (Socialist Federal Republic of)

International Organizations:

EBU
OIRT

Chairman of Joint Interim Working Party 10-11/5:

Professor F. CAPPUCCINI
Consiglio Superiore Tecnico
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DECISION 76-1

SATELLITE NEWS GATHERING (SNG)

(Question 13/CMTT, Study Programmes 13H/CMTT and 22D/CMTT)

(1987-1989)

CCIR Study Groups 4, 10, 11 and CMTT,

CONSIDERING

(a) that satellite transmissions using transportable or portable earth stations is an invaluable and at times the only viable solution to the timely transmission of television news from remote locations;

(b) that throughout the world, where news events take place, standardized and uniform technical and operating procedures should be established to ensure prompt activation of SNG service;

(c) that there was a unanimous Recommendation of the Fifth World Conference of Broadcasting Unions in Prague, 1986, on the use of international auxiliary broadcast frequencies and transportable earth stations;

(d) that the special characteristics needed for transportable or portable transmitting earth stations may necessitate acceptance of performance objectives differing from those specified in Recommendation 567 for general purpose satellite television connections;

(e) that there will be a requirement to provide, on the same uplink service, auxiliary circuits for programme and technical coordination, and for the management of the transportable earth station interface;

(f) that SNG services from any specific location will be classified as occasional and/or temporary;

(g) that the very nature of SNG requires that earth stations be activated in an expedient manner, the philosophy of which is not compatible with the long advance notice periods normally established for fixed permanent services;

(h) that it is expected in the future that HDTV transmissions could originate from portable uplink facilities;

(j) that the ITU Constitution states in its Preamble: "...fully recognizing the sovereign right of each State to regulate its telecommunication... ."

DECIDE

1. that Joint Interim Working Party JIWP CMTT-4-10-11/1 be continued, to prepare, within the Terms of Reference of Study Groups CMTT, 4, 10 and 11, an overall strategy for SNG transmissions, proposals intended to solve the technical, operating and organizational aspects associated with the use of transportable or portable transmitting earth stations for SNG;

2. that the Terms of Reference of the JIWP should be as follows:

2.1 to define the technical quality specifications for the programme video signal acceptable for SNG;

2.2 to define the number and the technical quality specifications for the programme audio signals acceptable for SNG;

2.3 to define the number and the technical quality specifications of auxiliary circuits required for SNG operations;

2.4 to study uniform technical parameters for SNG that may be applicable on a geographically wide scale;

2.5 to study uniform operating procedures for SNG that may also be applicable on a geographically wide scale;

2.6 to study the overall transmission and performance objectives for HDTV transmission by portable satellite earth stations for SNG;

2.7 to determine the technical characteristics of the specific equipment required to meet the objectives in 2.6;

2.8 to identify the operational requirements related to HDTV transmission by portable satellite earth stations for SNG;

2.9 to prepare draft Recommendations on the study items above;

2.10 to investigate and prepare a Report on means to simplify the procedures required to obtain, as expeditiously as possible, temporary authorization to operate SNG facilities;

3. that, in accordance with §2.3.3 of CCIR Resolution 24, Study Groups CMTT, 4, 10 and 11 are jointly entrusted with the responsibility of the work of the JIWP, and in accordance with §2.3.9 of Resolution 24, CMTT is designated to coordinate the work of the JIWP. The JIWP shall submit its reports and results of its work to joint meetings of these Study Groups, when possible;

4. that the work of the JIWP should be completed in the course of the current Study Period; a report and the results of its work shall be submitted to the Final Study Group Meetings in 1993;

5. that the JIWP should, as far as possible, work by correspondence; however it may meet when this is considered necessary by its Chairman, by the Chairmen of Study Groups CMTT, 4, 10 and 11, and by the Director, CCIR;

6. that the JIWP will be chaired by:

Mr. Joseph A. COLSON (NANBA)
Chairman, NANBA Technical Committee
CTV Television Network Limited
42 Charles Street East
Toronto, CANADA M4Y 1T5

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Telex : 06-22080
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DECISION 80-1

REARRANGEMENT OF QUESTIONS AND STUDY PROGRAMMES OF STUDY GROUP 11

(1987-1989)

CCIR Study Group 11,

CONSIDERING

(a) that the structure of the existing Questions and Study Programmes of this Study Group has evolved historically and is now not as logical and as systematic as it should be due to the textual amendments and deletions that have been made at various times in the past decades;

(b) that further expansion of the field of study is expected in accordance with the trends in the development of both the television broadcasting service and technology;

(c) that a rearrangement of the Questions and Study Programmes is advisable with the purpose of facilitating the future work and assisting the reader;

(d) that such a task has a bearing on the harmonization of the totality of the tasks to be performed by this Study Group and needs therefore careful consideration;

(e) that the draft rearrangement scheme of Questions and Study Programmes of Study Group 11 (revised), which is attached as Annex II to the present Decision, can serve as a basis for the next stage of work;

(f) that the participation in this task of the experienced Chairmen of the Working Groups, Joint Working Groups, and the Editorial Group of Study Group 11 that served at the Final Meeting (Geneva, 1989), is of high importance,

DECIDES

1. that IWP 11/8 set up according to Decision 80 (1987) should continue its work in the study period 1990-1994 within the general terms of reference of Study Group 11 and with the following specific terms of reference:

1.1 to develop further the draft rearrangement scheme of Questions and Study Programmes of Study Group 11 (revised), including addition of new Questions and Study Programmes, and present it to the Interim Meeting of Study Group 11 in 1991 for approval;

In pursuing this, IWP 11/8 should aim at the following objectives:

- reflecting the key issues confronting the broadcasters throughout the world and in the decade to come;

- highlighting trends in the development of television broadcasting technology;

- grouping together Questions and Study Programmes relating to the same major topics, allowing for the possibility of Study Group 11 adding new Questions to these groupings in the future;

- harmonizing, where possible, the grouping of Questions and the traditional assignment of tasks to Working Groups in order to facilitate the work of the Study Group at its Interim and Final Meetings;

1.2 to propose amendments to the extent possible, to the existing texts of Questions and Study Programmes, based on the draft finalized rearrangement scheme. However, these amendments should not change the technical content of the texts for which they are proposed;

2. that liaison should be maintained as necessary with Study Group 10 and the CMTT;

3. that IWP 11/8 should, as far as possible, work by correspondence. However, it may meet upon the proposal of the Chairman, following consultation with the Chairman of Study Group 11 and the Director of the CCIR;

4. that IWP 11/8 should present its report on the results of the work to the Chairman of Study Group 11 prior to the Interim Meeting of Study Group 11 in 1991, so as to allow the Chairman to implement the necessary steps for dissemination of the report to the participants in the Interim Meeting for evaluation and comment;

5. that the Chairman, the Vice-Chairman and the composition of IWP 11/8 should be as shown in Annex I. It should be pointed out that Chairmen of the Working Groups, Joint Working Groups and Editorial Group pertaining to Study Group 11 that served at the Final Meeting (Geneva, 1989) should be invited to take part in the work of IWP 11/8.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated their participation in the work of IWP 11/8.

Administrations:

Germany (Federal Republic of)
Australia
China (People's Republic of)
Spain
France
Italy
Japan
United Kingdom
USSR
Yugoslavia (Socialist Federal Republic of)

International Organizations:

OIRT
EBU

Chairman of Interim Working Party 11/8:

WU XIANLUN
Vice-Chairman, Study Group 11, CCIR
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ANNEX II

DRAFT REARRANGEMENT SCHEME OF QUESTIONS AND STUDY PROGRAMMES OF STUDY GROUP 11 (REVISED) (Note 1)

<u>GROUP A</u> - <u>ANALOGUE TELEVISION SYSTEMS</u>

(Numbers 50 to 59 reserved)

<u>Question 50/11</u> - Conventional television systems
(Question 1-2/11, Document 11/631) (Note 2)

Study Programme 50A/11	Ratio of picture-signal to synchronizing-signal (Study Programme 1D/11)
Study Programme 50B/11	Simplification of synchronizing signals in television (Study Programme 1E/11)
Study Programme 50C/11	Reduction of channel bandwidth in television broadcasting by incorporating the sound information in the video signal (Study Programme 1H/11)

<u>Question 51/11</u> - Enhanced quality television systems
(Question 42-1/11, Document 11/717)

Study Programme 51A/11	Analogue component signals for studio application (Study Programme 42A-1/11, Document 11/599)
Study Programme 51B/11	Terrestrial emission of enhanced television (Study Programme 42B/11, Document 11/689) (Note 2)

<u>Question 52/11</u> - High definition television systems
(Question 27-1/11) (Note 2)

Study Programme 52A/11	The compatibility of the HDTV standard with existing and future standards (Study Programme 27A-1/11, Documents 11/410 and 11/718) (Note 2)
Study Programme 52B/11	Effect of display technology on the HDTV standard (Study Programme 27B/11)
Study Programme 52C/11	Objective measurement in an HDTV environment (Study Programme 27C/11, Documents 11/410 and 11/728)

<u>Question 53/11</u> - Stereoscopic television systems
(Study Programme 1C-2/11, Document 11/690)

Question 54/11 - Transcoding and standards conversion between television systems (Question 2-4/11, Documents 11/277 and 11/728)

Study Programme 54A/11	Transcoding of colour television signals from one system to another (Study Programme 2A-1/11)
Study Programme 54B/11	Conversion between different television scanning standards (Study Programme 2B/11)
Study Programme 54C/11	Insertion of special signals in the field blanking interval of a television signal (Study Programme 12A-2/11)

Question 55/11 - Processability margins required for contribution programme material in television production (Question 45/11, Document 11/277))

Question 56/11 - Synchronization between sound and picture signals (Question 35-1/11)

Question 57/11 - Interconnection specifications for audiovisual equipment related to broadcasting (Question AA/10-11, Document 11/601)

GROUP B - DIGITAL STANDARDS FOR TELEVISION SYSTEMS

(Numbers 60 to 69 reserved)

Question 60/11 - Standards for television systems using digital modulation (Question 25-3/11, Documents 11/277 and 11/725)

Study Programme 60A/11	Digital encoding of colour television signals (Study Programme 25G-1/11)
Study Programme 60B/11	Filtering and sampling for digital encoding of colour television signals (Study Programme 25H-1/11)
Study Programme 60C/11	Protection against errors, jitter and slip for digital television signals (Study Programme 25K/11)
Study Programme 60D/11	Deriving digital component signals from analogue composite signals (and vice versa) (Study Programme 25L-1/11)
Study Programme 60E/11	Quality parameters and measurement and monitoring methods to be used in the studio complex and in terrestrial broadcasting using digital or analogue and digital modulation (Study Programme 25M-1/11)
Study Programme 60F/11	Interfaces for digital video signals (Study Programme 25N/11)

<u>Question 61/11</u> - Standards for digital high definition television (Question ../11, Document 11/625)

<u>Question 62/11</u> - Bit rate reduction and associated quality parameters for digital television signals (Question 44/11, Documents 11/277 and 11/725)

Study Programme 62A/11	Reduction in the bit rate in the digital coding of colour television signals (Study Programme AL/11, Documents 11/277 and 11/725)
Study Programme 62B/11	Objective quality parameters for the bit rate reduction of digital television signals (Study Programme AM/11, Documents 11/277 and 11/725) (Note 2)

<u>Question 63/11</u> - Application of a layered model to digital television-chains (Question 46/11, Documents 11/277 and 11/725)

<u>GROUP C</u> - <u>COMPLEMENTARY OR ADDITIONAL TELEVISION SERVICES</u> (Document 11/663)

(Numbers 70 to 74 reserved)

<u>Question 70/11</u> - Broadcasting of still pictures and other information intended for the public using a television or narrow-band channel (Question 29-3/11)

Study Programme 70A/11	Broadcasting of analogue television signals for still pictures (Study Programme 29A-2/11)
Study Programme 70B/11	Specification for multiplex broadcasting of information in the television channel or in an integrated digital channel (Study Programme 29C-2/11, Document 11/663)
Study Programme 70C/11	Exchange of captioning material for television programmes (Study Programme 29G-1/11, Document 11/663)
Study Programme 70D/11	Additional services provided by data broadcasting in a television or narrow-band channel (Study Programme 29H/11)

<u>Question 71/11</u> - Systems for television with conditional access (Question 37/11)

Study Programme 71A/11	Conditional access broadcasting systems (Study Programme 37A/11)

GROUP D - SUBJECTIVE ASSESSMENT OF PICTURE QUALITY

(Numbers 75 to 79 reserved)

Question 75/11 - Assessment of the quality of television pictures including alphanumeric and graphic pictures for teletext and similar services (Question 3-3/11, Document 11/636)

Study Programme 75A/11	Subjective assessment of the quality of television pictures (Study Programme 3A-5/11, Document 11/694)
Study Programme 75B/11	Subjective assessment and objective measurement of impairments to television pictures (Study Programme 3B-1/11, Document 11/691)
Study Programme 75C/11	Subjective assessment of the quality of alphanumeric and graphic pictures for teletext and similar services (Study Programme 3C-1/11, Document 11/639)
Study Programme 75D/11	Processing of the results of subjective assessments of the quality of television pictures (Study Programme 3D-1/11)
Study Programme 75E/11	Subjective assessment procedures for pictures originating in high definition television (Study Programme 3E-1/11, Document 11/640)
Study Programme 75F/11	Systems which allow a direct displayed indication of picture quality (Study Programme 3F/11, Document 11/692)
Study Programme 75G/11	Subjective quality parameters for the bit rate reduction of digital television signals (Study Programme AM/11) (Note 2)

GROUP E - TERRESTRIAL BROADCASTING SERVICE (TELEVISION) - PLANNING AND FACILITIES

(Numbers 80 to 94 reserved)

Question 80/11 - Quality targets of overall television systems (Question 14-2/11, Document 11/707)

Study Programme 80A/11	Quality targets of overall television systems and allocation of tolerances (Study Programme 14A-2/11, Document 11/707)
Study Programme 80B/11	Quality targets of overall television systems (Reference receiving installations) (Study Programme 14B-1/11, Document 11/707)

Question 81/11 - Technical bases required for planning the broadcasting service (television) in bands 8, 9 and 10 (Question 43-1/11, Document 11/708)

Study Programme 81A/11	Characteristics of television signals radiated in band 10 (SHF) from terrestrial broadcasting transmitters (Study Programme 1G-2/11, Document 11/627) (Note 2)
Study Programme 81B/11	Transmitting antenna characteristics for planning in VHF and UHF broadcasting (Study Programme 43A/11, Document 11/711)

Question 82/11 - Protection ratios in television (Question 4-4/11, Document 11/709)

Study Programme 82A/11	Protection ratios for television (Use of frequency offset) (Study Programme 4A-2/11, Document 11/710)

Question 83/11 - Compatibility of the broadcasting service (television) with other services (Question 39-1/11, Document 11/668)

Study Programme 83A/11	Methods of reducing interference to the broadcasting service (television) from other services operating in the same or adjacent bands (Study Programme 30A/11, Document 11/670 and 11/726)
Study Programme 83B/11	Frequency sharing between the broadcasting service (television) and the fixed and mobile services (Study Programme 39A/11, Document 11/669)

Question 84/11 - Polarization of emissions in the terrestrial broadcasting service (television) (Question 36-2/11, Document 11/707)

Question 85/11 - Distortions and imperfections of radiated television signals (Question 6-1/11, Document 11/703)

Study Programme 85A/11	Conditions for a satisfactory television service in the presence of reflected signals (Study Programme 6A-2/11, Document 11/704)
Study Programme 85B/11	Distortion of television and data broadcasting signals in emission and reception, caused by the use of vestigial sideband techniques (Study Programme 9A-2/11)

Question 86/11 - Characteristics of television receivers and receiving antennas essential for frequency planning (Question 26-2/11, Document 11/707)

Study Programme 86A/11	Principal characteristics of television receiving installations (Study Programme 26A-2/11, Document 11/707)
Study Programme 86B/11	Recommended characteristics for individual, collective and cable distribution antenna systems for domestic reception of television and data broadcasting signals from terrestrial transmitters (Study Programme 26C/11, Document 11/698 and 11/726)
Study Programme 86C/11	Minimum performance specifications for low-cost television receivers (Study Programme 26B/11, Document 11/699 and 11/726)

Question 87/11 - Performance and testing of cable distribution systems for television signals (Question 31-1/11, Document 11/701)

Study Programme 87A/11	Radiation from cable distribution networks (Study Programme 31A/11)

Question 88/11 - Protection of television broadcasting stations against lightning (Question 38/11)

Question 89/11 - Automatic monitoring of television stations (Question 15/11)

GROUP F - RECORDING OF TELEVISION PROGRAMMES

(Numbers 95 to 105 reserved)

Question 95/11 - Recording of television programmes (Question 18-3/11, Documents 11/276 and 11/682)

Study Programme 95A/11	Analogue recording of television programmes on magnetic tape (Study Programme 18K-1/11)
Study Programme 95B/11	Digital recording of television programmes on magnetic tape (Study Programme 18L-1/11, Documents 11/276 and 11/682)
Study Programme 95C/11	Recording of television programmes by new methods (Study Programme 18M/11)
Study Programme 95D/11	International exchange of television recordings for programme evaluation (Study Programme 18N/11)
Study Programme 95E/11	Television recordings on magnetic tape for electronic news gathering (Study Programme 18Q-2/11, Document 11/682)

Study Programme 95F/11 — Recording of colour television programmes on cinematographic film (Study Programme 18R-1/11)

Study Programme 95G/11 — Recording of high definition television programmes (Study Programme 18S-1/11, Document 11/682)

Study Programme 95H/11 — Recording of high definition television programmes on cinematographic film (Study Programme 18T-1/11, Document 11/655)

Study Programme 95J/11 — Transfer of high definition television programmes to non-broadcast media for domestic use (Study Programme 18U-2/11, Document 11/626)

Question 96/11 - International exchange programmes on film for television use (Question 41-1/11, Document 11/659)

Study Programme 96A/11 — Picture standards for the international exchange of programmes on film for television use (Study Programme 41A-1/11, Document 11/659)

Study Programme 96B/11 — Optical sound standards for the international exchange of programmes on film for television use (Study Programme 41B-1/11, Documents 11/659 and 11/679)

Question 97/11 - International exchange of recorded television programmes. Control of automatic equipment (Question 28/11)

Study Programme 97A/11 — Addition to television programmes (recorded on magnetic tape, film or other material) of data for controlling automatic equipment (Study Programme 28A/11)

Question 98/11 - Methods of synchronizing various recording and reproducing systems (Question 40-1/11)

Study Programme 98A/11 — Recording of time and control code information on magnetic tapes for television (Study Programme 40A-1/11)

GROUP G - MISCELLANEOUS

(Numbers 105 to 114 reserved)

Note 1 - The amendments to the existing Questions and Study Programmes and the new Questions and Study Programmes adopted by the Final Meeting of Study Group 11 (Geneva, 1989) have been incorporated in this draft rearrangement scheme on the basis of the indicated source documents. The existing Question and Study Programme numbers are shown in parentheses after the corresponding Question and Study Programme titles.

Note 2 - Unanimous consensus for this item has not been achieved among relevant Working Groups at the Final Meeting of Study Group 11 (Geneva, 1989).

DECISION 87 *

DETERMINATION OF THE COORDINATION AREA

(Appendix 28 of the Radio Regulations)

(1989)

This text may be found in the Annex to Part 2 of Volumes IV and IX.

*) According to the decision of Chairmen and Vice-Chairmen's Meeting (Geneva, 4-6 July, 1990) the tasks of JIWP 2-4-5-8-9-10-11/1 on the determination of the coordination area are transferred to Study Group 12 for study by Task Group 12/3.

DECISION 90

SPECIAL MEETING CONCERNING THE DRAFT RECOMMENDATION FOR THE HDTV STUDIO STANDARD

(1989)

CCIR Study Group 11,

CONSIDERING

(a) that, pursuant to Resolution 96 of the XVIth Plenary Assembly and in accordance with Decision 74, an Extraordinary Meeting of Study Group 11 on HDTV was held, resulting in rapid progress towards the desired Recommendation for the HDTV studio standard;

(b) that further progress towards completion of this Recommendation was made at the Final Meeting of Study Group 11;

(c) that important progress is anticipated prior to the XVIIth Plenary Assembly in May 1990;

(d) that IWP 11/6 is working within the terms of reference given in Decision 58-4;

(e) that the digital representation of HDTV is being studied in IWP 11/7 (Decision 60-3),

NOTING

(a) the need for timely action to complete the draft Recommendation;

(b) the urgent need for contributions from Administrations to provide the basis for completion of the draft Recommendation;

(c) that a draft Recommendation submitted for the approval of the CCIR Plenary Assembly must not contain square brackets in its final form,

DECIDES

1. to convene a special meeting of IWP 11/6, with representation from IWP 11/7, in March 1990 in the United States of America for not more than one week;

2. that the Agenda for this meeting shall be:

2.1 to consider the contributions made concerning the outstanding parameter values of ——— Recommendation 709;

2.2 to prepare appropriate documentation concerning the outstanding parameter values to supplement Recommendation 709 in the following areas:

- chromaticity coordinates and derivation of luminance and colour-difference signals;
- picture characteristics;
- bit-rates for the digital representation.

2.3 to present, in the supplementary documentation, its recommendations concerning:

- the treatment of the square brackets and, as necessary, of the information in square brackets in Sections 1.3, 4.2, 4.3 and 5.5, of associated notes in the main body of the draft Recommendation, and of related material in its Annex;
- supplementary information on picture characteristics in Section 2 of the Annex and, if agreement is reached, reflection of this agreement in Section 2.4 of the main body of the draft Recommendation;
- supplementary information on digital representation in Section 6 of the Annex and, if agreement is reached, reflection of this agreement in Sections 6.6 and 6.7 of the main body of the draft Recommendation;

3. that the Chairman of Study Group 11 shall consider this supplementary documentation as an Addendum to his Report to the XVIIth CCIR Plenary Assembly in May 1990,

FURTHER NOTES

that the actions proposed in this Decision are in accordance with the rules of procedure of the CCIR.

DECISION 91

HARMONIZATION OF HDTV STANDARDS BETWEEN BROADCAST AND NON-BROADCAST APPLICATIONS

(1989)

CCIR Study Group 11,

CONSIDERING

(a) that the need for improved picture quality is developing rapidly in non-broadcast areas, including medical imaging, printing industry, teleconferencing, etc...;

(b) that HDTV technology being initially developed for broadcast usage, is being applied to these non-broadcast applications;

(c) that a number of Questions and Study Programmes on HDTV have been adopted by the CCIR;

(d) that several possible television applications for the wide-screen format are identified in Report 1220 that could use HDTV displays in their implementation;

(e) that JIWP 10-11/4 has already done some work on harmonization in the field of HDTV recording;

(f) that IEC envisages dealing with HDTV equipment and standards;

(g) that ISO studies include HDTV imagery;

(h) that CCITT is developing broadband ISDN Recommendations, facilitating HDTV transmission;

(j) that the CMTT is cooperating with the CCITT on HDTV transmission;

(k) that it would be advantageous to all potential users that the standards developed by these international bodies feature as much commonality as possible;

(l) that the HDTV studio production standard — Recommendation 709 — as well as a number of other HDTV Recommendations, are already being prepared by the CCIR,

DECIDES

1. that an IWP 11/9 should be set-up, with representatives from the IEC, ISO, CCITT and CMTT, with the objective of harmonizing the HDTV standards prepared by the CCIR, taking into account the requirements of the IEC, ISO, CCITT and CMTT;

2. that IWP 11/9 should provide information related to HDTV to Study Group 11 to ensure harmonization of HDTV Recommendations;

3. that IWP 11/9 should provide the IEC, ISO, CCITT and CMTT with the relevant
information on HDTV studies in the CCIR;

4. that the first task of IWP 11/9 will be to bring information to Study Group 11 concerning those parameters of the HDTV studio production standard, which are still under study;

5. that IWP 11/9 should report on the progress of its work, to the Interim and Final Meetings of Study Group 11;

6. that IWP 11/9 should liaise with IWP 11/6. 11/7 and JIWPs 10-11/3, 10-11/4 and 10-11/5;

7. that IWP 11/9 should, as far as possible, work by correspondence, however, it could meet, on request by its Chairman, after consultation with the Chairman of Study Group 11 and the Director of the CCIR;

8. that the Chairman, Vice-Chairmen and membership of IWP 11/9 are those given in Annex I.

FURTHER DECIDES

to convene a meeting of IWP 11/9 in September 1990 in Japan for not more than one week.

Note. - The Director of the CCIR is requested to notify this Decision to the CMTT, IEC, ISO and CCITT and invite them to nominate their participants in the work of the IWP.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated that they wished to participate in the work of Interim Working Party 11/9 (effective in October 1989):

Administrations:

Australia
Canada
Denmark
United States of America
Finland

International Organizations and Recognized Private Operating Agencies:

Chairman of Interim Working Party 11/9:

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United States of America

Telephone: (201) 758 4646
Telefax: (201) 758-0190
Telex: None

DECISION 95**

SUBJECTIVE ASSESSMENT OF SOUND AND TELEVISION PICTURE QUALITY

(1989)

CCIR Study Groups 10 and 11

CONSIDERING

(a) that Recommendation 500 has established some methods of test for assessing the subjective quality of television systems;

(b) that Report 1082 describes new methods and approaches to picture quality assessment, Report 1205 describes advanced methods for the presentation and analysis of test results, Report 405 presents further information about subjective tests, Report 1206 presents information about subjective picture quality in digital television, and Report 1216 presents information about picture quality assessment in high-definition television;

(c) that Recommendation 654 establishes reference relationships between subjective quality and objective impairments for the more common forms of impairment in current NTSC, PAL and SECAM systems while Report 959 tabulates measured values for particular systems;

(d) that Report 313 contains a lengthy bibliography of published work and CCIR contributions on subjective assessments;

(e) that the introduction of new kinds of television signal processing such as digital coding and bit-rate reduction, new kinds of television signals using time-multiplexed components and new services such as enhanced television and HDTV, may require changes in the methods of making subjective assessments;

(f) that significant progress has been made in the measurement of human perception;

(g) that Recommendation 562 of Study Group 10 has established some methods for assessing the subjective quality of sound;

(h) that the introduction of new sound broadcasting systems may require advanced development of the existing methods of subjective assessments;

(j) that there is a common core of assessment methodology for sound and vision;

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* This Decision supersedes Decision 66 which is hereby deleted.

(k) that some assessments may involve both sound and vision as components of a single service;

(l) that both sound and vision methodology will benefit from a cross flow of ideas,

DECIDE

1. that a Joint Interim Working Party 10-11/6 should be formed within the general terms of reference of Study Groups 10 and 11, and with the following specific terms of reference:

1.1 to review Questions 3-2/11 and 14-1/11, and their associated Study Programmes, in order to:

- identify those tasks which have been completed, and
- define new areas where studies are required;

1.2 to review the texts in Volume XI, Part 1 of the Recommendations and Reports of the CCIR which are concerned with the subjective evaluation of picture quality with a view to:

- consolidate and eliminate repetitive material,
- improve clarity and brevity,
- make them more comprehensible to non-specialists,
- provide a framework for the introduction of new material without reducing the clarity of the complete text;

1.3 to examine current trends in television systems described in CONSIDERING *(e)* and determine what changes, if any, will be required in the methodology of subjective testing to accommodate these trends and prepare any draft revision of Study Programmes which may be appropriate;

1.4 to collect, collate and harmonize contributions to studies on the methodology of subjective testing of new systems such as those described in CONSIDERING *(e)*;

1.5 to prepare regularly updated draft Reports on the progress of such studies;

1.6 to review Study Programme 50C-1/10 in order to identify those tasks which have been completed, and define new areas where studies are required;

1.7 to review Recommendation 562-2 with a view to its consolidation and development in the light of recent developments and knowledge;

1.8 to examine current trends in sound broadcasting systems and determine what additions or changes, if any, will be required in the methodology of subjective assessments to accommodate these trends, and prepare draft new texts as appropriate;

1.9 to maintain liaison with IWP 10/12 in order to advise on subjective assessments of multi-channel sound systems, including those suited to high-definition television and enhanced definition television;

1.10 to prepare regularly updated Reports and Recommendations to Study Groups 10 and 11.

ANNEX I

The following Administrations, International Organizations and Recognized Private Operating Agencies have indicated that they wish to participate in the work of Joint Interim Working Party 10-11/6. These include those administrations who were members of IWP 11/4 and those who have expressed an interest in participating in the new JIWP studies concerning sound quality.

Administrations:

Germany (Federal Republic of)
Australia
Canada
China (People's Republic of)
United States of America
France
Italy
Japan
Netherlands
German Democratic Republic
United Kingdom
Sweden
Switzerland
USSR
Yugoslavia (Socialist Federal Republic of)

International Organizations and Recognized Private Operating Agencies:

Broadcasting Corporation of New Zealand (BCNZ)
EBU
Nippon Hoso Kyokai (NHK)
Norddeutscher Rundfunk (NDR)
OIRT
Zweites Deutsches Fernsehen (ZDF)

Chairman of Joint Interim Working Party 10-11/6:

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assisted by a Vice-Chairman:

Miss B. JONES
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United States of America

DECISION 106*

COORDINATION OF THE WORK OF STUDY GROUPS 1, 8 AND 11 IN THE ESTABLISHMENT OF SHARING CRITERIA BETWEEN THE TELEVISION AND LAND MOBILE SERVICES IN SHARED BANDS

(1989)

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* The CCIR XVIIth Plenary Assembly decided to transfer joint studies related to sharing between the television broadcasting and mobile services in shared bands to Study Group 12.

92-61-04291-0