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RADIO REGULATORY DIVISION

Specification of Television Standards for 625-Line System I Transmissions in the United Kingdom

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Foreword

Given the explosive demand for new and improved telecommunication services there is a fundamental need to provide technical guidelines which reflect the necessary changes to sustain acceptable system performance standards. Thus, this revised version of the specification applicable to the System I 625-line colour television standard used in the United Kingdom, originally published jointly by the BBC and IBA in 1971, is most welcome.

The revised text incorporates, inter alia, the procedures associated with present practice and has amplified and clarified several key sections as a result of operational experience.

The important task of preparing this document has been undertaken most ably by Sub-Group 11A of UK CCIR Study Group 11, initially chaired by Mr E R Rout (BBC) and more recently by Mr D M Kitson (BBC).

Contents

1 Introduction

The purpose of this document is to specify the PAL colour television system in accordance with the 625-line System I employed within the UK and to indicate some of the tolerances permitted in the generation, processing and transmission of the signal.

The document is not intended to serve either as a specification for the purchase of equipment, or as a statement of performance limits at which maintenance action should be initiated. It is intended to give guidance to users, such as receiver designers, about the performance of the television system which is expected to be achieved for a large proportion of the time.

The specifications and tolerances in Sections 2, 3, 4 and 5 of this document are those which are concerned with the formation of the PAL colour television signal, and the values quoted are generally those which would be expected at the output of the originating studio centre. They do not apply to individual items of equipment. Once the PAL signal has been generated, it will be distorted by transmission impairments (noise, waveform distortion, etc), both within the studio centre and on the routes to the viewers' receivers. These transmission impairments and appropriate methods of measurement are defined in CCIR Recommendation 567, and the magnitudes of some of them, in typical distribution chains, are estimated in Appendix IV of this document.

Sections 2 and 3 are concerned with the basic characteristics of the vision signals, including specification of synchronising and blanking waveforms.

Section 4 specifies the form of the picture information in the vision signal, while Section 5 describes the synthesis of the colour picture information from the red, green and blue signal voltages in a colour camera.

Section 6 gives the radio-frequency characteristics of the sound and vision components of a correctly-adjusted transmitter.

Appendix I presents information on the colour bar test-signals used for the alignment and testing of colour television equipment, and tables showing the amplitudes of the picture components of primary colours and their complements.

Appendix II reiterates the colour signal identities of Section 5 in matrix form and Appendix III gives details of the nature and applications of the insertion signals which are included in the field blanking intervals of the radiated signals.

The estimated performance of the overall system, excluding the original picture source which may be a television camera, a film camera and telecine machine, or an electronic generator, is given in Appendix IV.

2 Basic Video Characteristics

2.1 Picture Signal

The picture signal shall correspond to the scanning of the image at uniform velocities from left to right and from top to bottom.

2.2 General Specification

The colour picture signal shall comprise a luminance (brightness) component and a pair of chrominance (colouring) components transmitted simultaneously as the amplitude modulation sidebands of a pair of suppressed carriers in phase quadrature having a common frequency as defined in Section 2.7. The phase of one of these subcarriers is commutated through 180° after the end of each line, yielding a colour signal conforming to the system generally known as Phase Alternation Line (PAL).

A monochrome picture signal contains the luminance (brightness) component only.

2.3 Number of Lines per Picture

The number of lines per picture shall be 625 (of which 575 are active). During source synchronising operations there may be an addition or deletion of one or two lines per field for a brief period (up to 7 seconds).*

2.4 Interlace

The interlace ratio shall be 2 to 1.

2.5 Aspect Ratio

The ratio of image width to image height within the picture area shall be 4 to 3.

2.6 Gamma

The gamma of the transmitted signal shall be related to a nominal display gamma of 2.8.

*As the use of synchronisers in the broadcasting network increases, disturbances to the synchronising waveform will be correspondingly reduced. There may, however, be very occasional disturbances to the picture relative to the synchronising waveform for brief periods of up to 2 fields. It should be noted that the introduction of a synchroniser may cause a vertical picture shift of up to 1½ lines and a horizontal picture shift of up to 112ns

2.7 Colour Subcarrier Frequency

The frequency of the colour subcarrier shall be:-

$$f_{sc} = 4.43361875\text{MHz} \pm 1\text{Hz}$$

Where the signal originates from a portable or overseas source, the tolerance on this frequency may be relaxed to ±5Hz.

The maximum rate of change of subcarrier frequency shall be 0.1 Hz/s. During source synchronising operations there will be small phase perturbations which may cause the frequency and its rate of change to deviate beyond these limits for up to 5 seconds.*

2.8 Relationship between Colour Subcarrier Frequency and Line Frequency

The line frequency shall be a fraction of the colour subcarrier frequency, the exact relationship being:-

$$f_h = \frac{4f_{sc}}{1135 + \frac{4}{625}}$$

With f_{sc} as in section 2.7:-

$$f_h = 15.625\text{kHz}$$

The converse relationship is:-

$$f_{sc} = (284 - \tfrac{1}{4})\, f_h + 25\text{Hz}$$

Under some conditions, where the signal is derived from an overseas standard or where the reference of synchronism is being changed, this relationship may not apply.* Under these conditions:-

$$f_h = 15.625\text{kHz} \pm 0.02\%$$

and the subcarrier frequency shall conform to section 2.7 above.

*As the use of synchronisers in the broadcasting network increases, disturbances to the synchronising waveform will be correspondingly reduced. There may, however, be very occasional disturbances to the picture relative to the synchronising waveform for brief periods of up to 2 fields. It should be noted that the introduction of a synchroniser may cause a vertical picture shift of up to 1½ lines and a horizontal picture shift of up to 112ns

2.9 Field Frequency

The field scanning frequency shall be:-

$$f_{field} = \frac{2}{625} \times f_h$$

2.10 Video Bandwidth

The nominal video bandwidth shall be 5.5MHz.

3 Synchronising and Blanking Waveforms

3.1 Introduction

The horizontal and vertical synchronising and blanking waveforms shall be as specified in Figs. 1 and 3, and the colour burst waveform shall be as specified in Figs. 2 and 4.

Note that horizontal blanking tolerances may not apply during the vertical blanking interval when data signals are present.

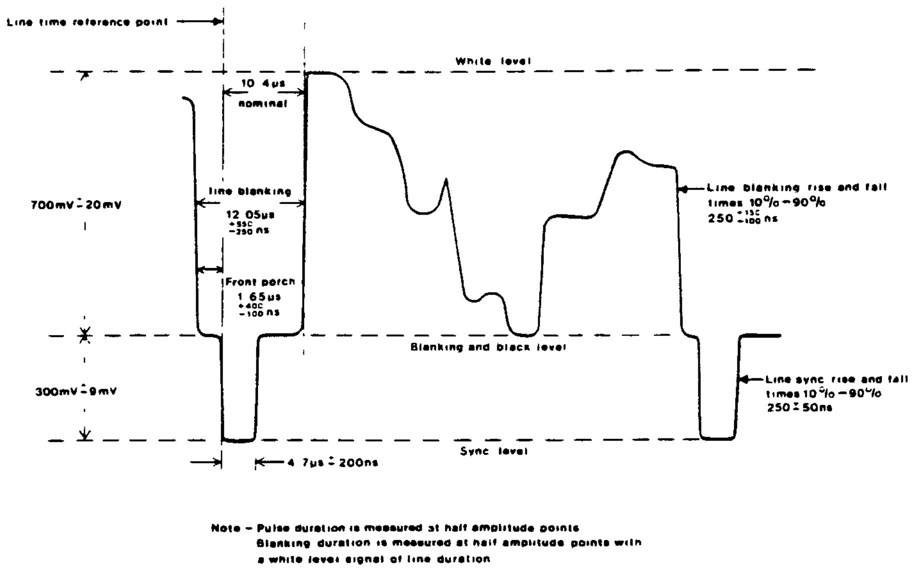


Figure 1 Typical monochrome line showing synchronising signals

3.2 Colour Synchronising Burst

A burst of subcarrier shall be included following the line synchronising pulse to establish the reference subcarrier phase and to syncnronise the switching of the V axis.

3.2.1 *Duration of Burst*

The duration measured between half amplitude points on the envelope of the colour burst is 2.25μs ± 230ns (approximately 10 cycies of subcarrier).

3.2.5 *Field Interval Blanking*

Colour burst shall be omitted during nine lines of each field blanking interval in the manner shown in Fig. 4.

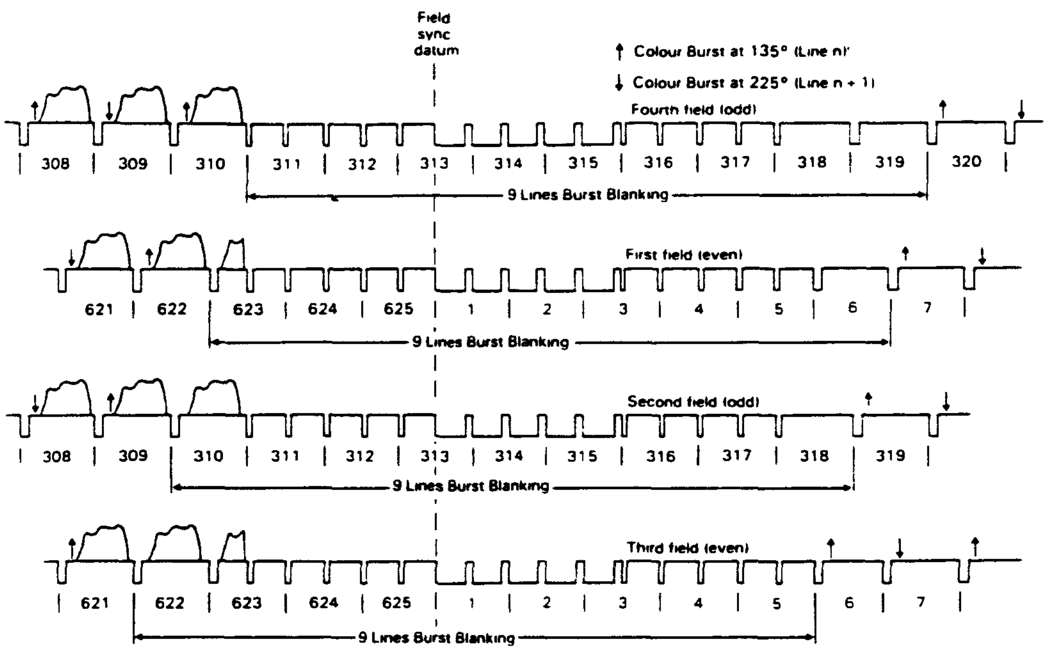
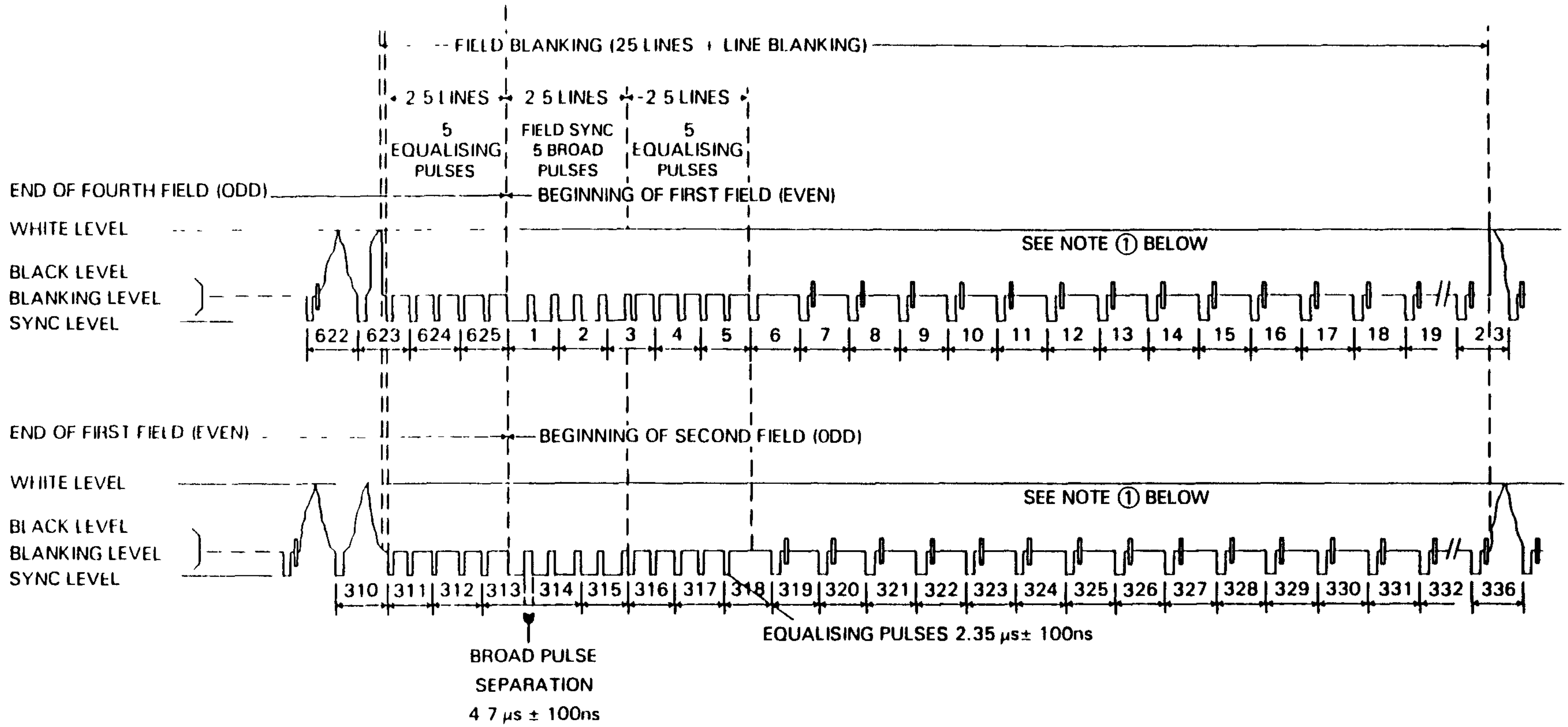


Figure 4 Field interval blanking of the colour burst



NOTE 1
LINES 7 TO 22 INCLUSIVE AND 320 TO 335 INCLUSIVE MAY CONTAIN TELETEXT, IDENTIFICATION, CONTROL OR TEST SIGNALS (SEE APPENDIX III)

NOTE 2:
THE FIRST & SECOND FIELDS ARE IDENTICAL WITH THE THIRD AND FOURTH IN ALL RESPECTS EXCEPT BURST BLANKING (SEE SECTION 3.2.5)

RISE & FALL TIMES 10% – 90% PULSE AMPLITUDE
FIELD BLANKING 300 ± 100ns
FIELD SYNC PULSES 250 ± 50ns
EQUALISING PULSES 250 ± 50ns

Figure 3 Vertical synchronising and blanking waveforms for a typical signal

3.2.2 *Amplitude of Burst*

The peak-to-peak colour burst amplitude (average over two successive lines) shall be three-sevenths of the difference between white and blanking levels. This shall be 300mV ± 9mV on a signal with a 700mV white level.

The amplitude of bursts on successive lines shall be within 5% of one another

3.2.3 *Burst Rise Time*

The rise time of the burst measured between the 10% and 90% burst amplitude points shall be 250 ± 50ns.

3.2.4 *Position of Burst*

The colour burst shall start at 5.6μs ± 100ns from the leading edge of the line synchronising pulse, this time being specified between half amplitude points. This is detailed in Fig. 2.

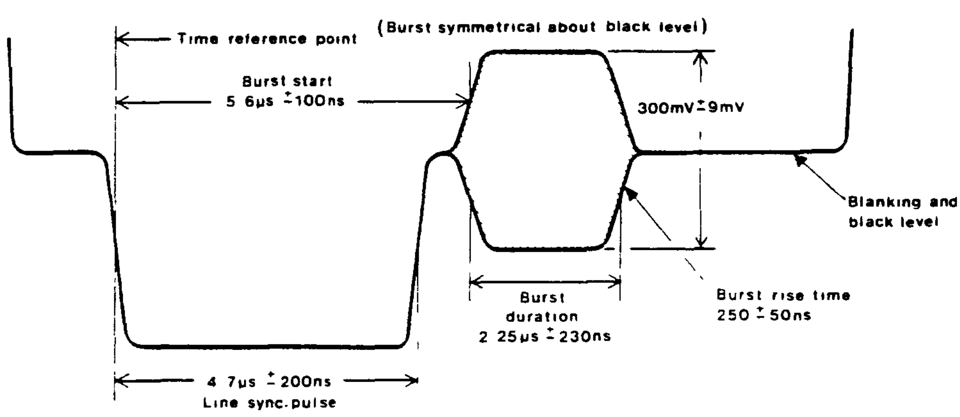


Figure 2 The colour burst on a standard level signal (700mV white level)

3.2.6 *Relationship Between Burst Amplitude and Chrominance Signal Amplitude*

Because the amplitude of the burst is used as a reference for the amplitude of the chrominance signal in receivers, the correct relationship between the two amplitudes shall be maintained at the studio centre output within ± 5%.

3.2.7 *Phase of Colour Burst Relative to the +U Modulation Axis*

Relative to the +U modulation axis, on odd lines of the first and second field and even lines of the third and fourth fields, the phase of the colour burst shall be +135°. On even lines of the first and second fields and odd lines of the third and fourth fields, the phase of the colour burst shall be +225°. The mean burst phase shall be 180° ± 2° from the reference axis. See Fig. 5.

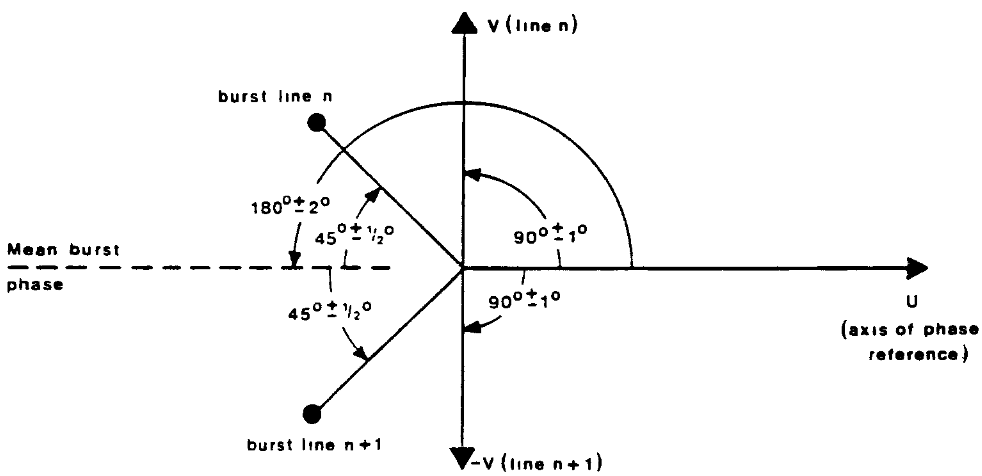


Figure 5 The phases of subcarrier for the two modulation axes

3.2.8 *Eight Field Sequence*

At the leading edge of the field synchronising pulse train (the field sync datum) the phase of the extrapolated colour subcarrier U-axis component (the reference component) advances by 135° per field. Consequently, a particular phase relationship between subcarrier and a given synchronising pulse occurs every eighth field, and thus the composite signal has an eight field sequence.

4 The Picture Signal

4.1 Introduction

This section describes the primary generation of the luminance and chrominance components of the picture signal, giving tolerances where appropriate. Impairments introduced further down the chain are detailed in Appendix IV.

4.2 Luminance Component

An increase in the incident light intensity shall correspond to an increase in the amplitude of the video signal. For a colour signal, the relationship between the spectral composition of the incident light and the luminance amplitude shall be as defined in Section 5.2.

4.2.1 *Amplitude/Frequency Characteristics*

The amplitude/frequency characteristic of the luminance signal path shall be substantially uniform from 0 to 5.5MHz except where it may be modified in the region embracing the subcarrier frequency by the use of a notch or comb filter in the coder.

4.3 Chrominance Component

The chrominance signal shall correspond to the sideband components of two amplitude modulation subcarriers in phase quadrature. The two modulation axes are generally identified by the letters U and V, the polarity of the V axis component being reversed after every line. Colours are thus represented by subcarriers of a particular amplitude and at one of two phases, dependent on the polarity of the V axis. Fig. 6 shows the two representations of the primary colours and their complements, line n corresponding with the odd numbered lines of the first and second fields and the even numbered lines of the third and fourth fields. Line n + 1 corresponds with the even numbered lines of the first and second fields and the odd numbered lines of the third and fourth fields.

Taking the phase relationship between subcarrier and the field sync datum to be X degrees, the subcarrier phase at each field sync datum throughout the eight field sequence is shown in the following table.

Subcarrier U Axis Component Phase During the 8-Field Sequence

Field	Subcarrier Phase at Field Sync Datum (degrees)
1	X
2	X + 135
3	X + 270
4	X + 45
5	X + 180
6	X + 315
7	X + 90
8	X + 225

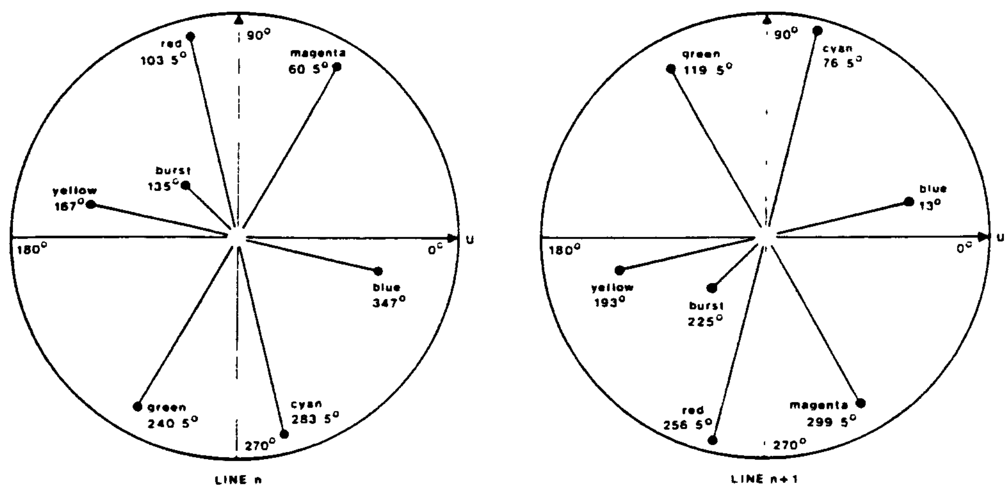


Figure 6 The phases of subcarrier representing primary colours and their complements on alternate lines of the PAL colour system (100% colour bars)

4.3.1 *Delay Inequality Between Chrominance Components*

The delay inequality introduced between the two modulated chrominance components shall be less than 5ns.

4.3.2 *The Chrominance Modulation Bandwidth*

The bandwidth of the modulating signals E'_U and E'_V (see Section 5.4) shall be constrained by the following conditions:-

at 1.3MHz $\leqslant$3dB
attenuation relative to low frequencies

at 4MHz $\geqslant$20dB
attenuation relative to low frequencies

The form of this characteristic shall be approximately Gaussian. The modulating process shall not modify these bandwidths. Nevertheless, the upper chrominance sideband will be subsequently restricted by the nominal video bandwidth of 5.5MHz.

4.3.3 *Colour Display on Zero Chrominance Signal*

It is intended that zero chrominance signal should produce a display chromaticity of CIE Illuminant D_{65}, ie:-

x = 0.313, y = 0.329 (CIE 1931)

u = 0.198, v = 0.312 (CIE 1964)

u′ = 0.198, v′ = 0.468 (CIE LUV 1976)

These are three methods of defining the same colorimetric specification according to different formulations recommended by the Commission International d'Eclairage.

4.3.4 *Residual Subcarrier*

The peak-to-peak subcarrier amplitude when the chrominance signal is intended to be zero shall not exceed 4mV in a 700mV picture signal.

4.4 Signal Excursions at Decoder Output

The composite picture signal shall be such that the red, green and blue decoded signals should not lie outside the levels corresponding to black level and white level apart from transient overshoots.

5 Colour Signal Equations

5.1 Primary Colour Chromaticities

The chromaticity co-ordinates of the colour display tube phosphors chosen as standard (CCIR Report 476-1, EBU Tech. 3213) are, according to the CIE system of specification:—

	x	y	u	v	u′	v′
Red	0.64	0.33	0.45	0.35	0.45	0.52
Green	0.29	0.60	0.12	0.37	0.12	0.56
Blue	0.15	0.06	0.18	0.11	0.18	0.16

These co-ordinates and the gamma assumed for the display tube dictate the nature of the colour analysis characteristics of the colour camera. The gamma-corrected voltages corresponding to the red, green and blue signals from the camera are designated E'_R, E'_G and E'_B.

5.2 Luminance Signal Voltage

The luminance signal voltage E'_Y shall be related to the colour separation signal voltages E'_R, E'_G and E'_B by the following equation:-

$$E'_Y = 0.299\,E'_R + 0.587\,E'_G + 0.114\,E'_B$$

(Note that the coefficients in this equation are derived from the NTSC primaries and Illuminant C and not from the figures in Section 5.1. This only affects the compatibility of the black and white picture and the error is small).

5.3 Colour-difference Signal Voltages

The colour-difference signal voltages shall be defined by the equations:-

$$E'_R - E'_Y = 0.701\,E'_R - 0.587\,E'_G - 0.114\,E'_B$$

$$E'_B - E'_Y = -0.299\,E'_R - 0.587\,E'_G + 0.886\,E'_B$$

These equations are derived from Section 5.2

5.4 Chrominance Modulating Signal Voltages

In order to restrict the excursions of the transmitted composite picture signal to within the range +133% and −33% of black level to white level, the chrominance signal voltages E'_U and E'_V shall be derived from the equations:

$$E'_U = 0.493\,(E'_B - E'_Y)$$

$$E'_V = 0.877\,(E'_R - E'_Y)$$

These equations apply only for frequencies within the chrominance bandwidth. See Section 4.3.2.

5.5 Equation for the Modulated Chrominance Signal

The modulated chrominance signal shall be defined by the equations:-

$$u = E'_U \sin \omega t$$

$$v_n = E'_V \cos \omega t \quad \text{(line n)}$$

$$v_{n+1} = -E'_V \cos \omega t \quad \text{(line n+1)}$$

Where: $\omega = 2\pi f_{sc}$

E'_U is the peak chrominance voltage along the reference axis.

E'_V is the peak chrominance voltage in quadrature with the reference axis.

Line n refers to the odd lines of the first and second fields and the even lines of the third and fourth fields.

Line n+1 refers to the even lines of the first and second fields and the odd lines of the third and fourtn fields.

(See Sections 3.2.7, 3.2.8 and Figure 5).

The peak-to-peak chrominance amplitude (2S) is given by the equation:-

$$2S = 2\sqrt{E'^2_U + E'^2_V}$$

The phase angle α of the chrominance vector relative to the reference phase along the positive U axis is given by:-

$$\alpha_n = \tan^{-1} \frac{E'_V}{E'_U}$$

and

$$\alpha_{n+1} = -\tan^{-1} \frac{E'_V}{E'_U}$$

5.6 Equation for the Complete Colour Signal

The instantaneous voltage E_m of the complete colour signal during the picture period shall be defined by:-

$$E_{m_n} = E'_Y + E'_U \sin \omega t + E'_V \cos \omega t$$

$$E_{m_{n+1}} = E'_Y + E'_U \sin \omega t - E'_V \cos \omega t$$

6 Radio Frequency Characteristics

6.1 Introduction

The following characteristics relate to the signal at the output of a correctly adjusted transmitter. Since the transmitter network is largely unattended, the tolerances will be exceeded from time to time. See Appendix IV for further details.

6.2 Channel Bandwidth

The vision signal and the sound signal shall be transmitted in an 8MHz channel The limiting envelope of the spectrum radiated by a practical transmitter is as shown in Fig. 7.

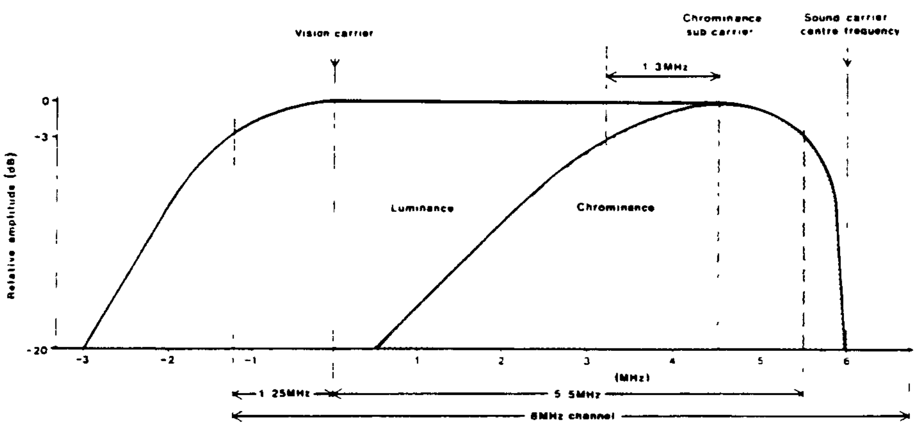


Figure 7 The frequency spectrum occupied by the colour picture components and sound signal

6.3 Polarisation

The common polarisation of the sound and vision transmissions shall be either vertical or horizontal, as dictated by the need to minimise interference by co-channel or adjacent channel interference.

6.4 Asymmetric-sideband Vision Transmission Characteristics

The nominal transmission characteristics shall be as follows:-

The bandwidth of the upper sideband shall be 5.5MHz.

The bandwidth of the lower sideband shall be 1.25MHz.

Ideally, the delay characteristics of the transmitted waveform should be uniform, there being no pre-correction for receiver delay characteristics. In practice there will be some group delay distortion at the top end of the band and slightly less at the vertigial cut-off.

6.5 Vision Carrier Modulation

The vision carrier shall be amplitude modulated with negative polarity, sync level corresponding to peak carrier power.

6.6 Vision Carrier Envelope

The idealised carrier amplitude as a function of time before asymmetric side-band limitation shall be as shown in Fig. 8 with reference to a particular colour bar test signal. The 1.3% and 94.7% carrier levels embrace the entire range of chrominance signals encountered with the PAL system. The transmitter carrier amplitude at black level and white level may vary by up to ±2%.

Fig. 11 represents the output from a balanced synchronous demodulator in an ideal receiver when receiving the transmitted signal shown in Fig. 8. The ideal receiver has an r.f. response curve as shown in Fig. 9 and constant group delay at all frequencies.

6.7 Vision Carrier to Sound Carrier Spacing

The difference in frequency between the unmodulated sound signal carrier and the vision signal carrier shall be:-

5.9996MHz ± 500Hz

6.8 Vision Carrier to Sound Carrier Power Ratio

The ratio between peak vision carrier power and the sound carrier power shall be approximately 5 : 1.* The peak vision carrier power is that which occurs during the transmission of the synchronising pulses.

* Note: Consideration is being given to increasing this ratio.

6.9 Sound Carrier Modulation

The sound programme modulating signal frequency shall not exceed 15kHz. The sound carrier shall be frequency modulated. The peak carrier deviation shall be ±50kHz and there shall be pre-emphasis with a time constant of 50μs.

The voltage pre-emphasis characteristic is given by

$$|g(f)| = [1+(2\pi T f)^2]^{1/2}$$

where:

time constant $T = 50 \times 10^{-6}$ seconds

and f is in Hz

Pilot tones may be added to the sound signal for monitoring and signalling purposes. The peak deviations corresponding to the various signals are as follows:-

BBC Transmission

400Hz Sound at +8dBm0	±	42.7kHz deviation
19kHz pilot tone	±	1.9kHz
23kHz pilot tone	±	2.3kHz
27.1kHz pilot tone	±	2.7kHz

IBA Transmission

400Hz Sound at +8dBm0	±	42.7kHz deviation
22.5kHz pilot tone	±	5kHz

Excessive deviation that might arise from the pre-emphasis of high frequency components is avoided by the use of programme limiters.

Common Versions of Luminance Step Colour Bars

Three versions of luminance step colour bars are in general use, and are illustrated in Figures 10–13.

100% Colour Bars:	100% amplitude 100% Saturation with White and Black
95% Colour Bars:	100% amplitude 98% Saturation with White and Black
EBU Colour Bars:	75% amplitude 100% Saturation with White and Black

Specification of colour bar variants may also be effected by reference to the colour separation components produced by demodulation. This system uniquely specifies each colour bar signal by four numbers, eg:-

(a) Maximum value of E'_R, E'_G or E'_B for an uncoloured bar

(b) Minimum value of E'_R, E'_G or E'_B for an uncoloured bar

(c) Maximum value of E'_R, E'_G or E'_B for a coloured bar (E_{max})

(d) Minimum value of E'_R, E'_G or E'_B for a coloured bar (E_{min}).

The three common colour bar signals are thus defined:-

(a)	(b)	(c)	(d)	
100	0	100	0	(100% bars)
100	0	100	25	(95% bars)
100	0	75	0	(EBU bars)

This is the preferred system of colour bar specification.

100.0.100.25 Colour Bars (95%)

Colour	Luminance E'_Y	Peak-to-peak Chrominance			Chrominance Angle (α) in degrees	
		U axis $2E'_U$	V axis $2E'_V$	Total 2S	Line n	Line n+1
White	0.700	0	0	0	–	–
Yellow	0.640	0.459	0.105	0.470	167	193
Cyan	0.543	0.155	0.646	0.664	283.5	76.5
Green	0.483	0.304	0.541	0.620	240.5	119.5
Magenta	0.392	0.304	0.541	0.620	60.5	299.5
Red	0.332	0.155	0.646	0.664	103.5	256.5
Blue	0.235	0.459	0.105	0.470	347	13.0
Burst	0	0.212	0.212	0.300	135	225

100.0.75.0 Colour Bars (EBU)

Colour	Luminance E'_Y	Peak-to-peak Chrominance			Chrominance Angle (α) in degrees	
		U axis $2E'_U$	V axis $2E'_V$	Total 2S	Line n	Line n+1
White	0.700	0	0	0	–	–
Yellow	0.465	0.459	0.105	0.471	167	193
Cyan	0.368	0.155	0.646	0.664	283.5	76.5
Green	0.308	0.304	0.541	0.620	240.5	119.5
Magenta	0.217	0.304	0.541	0.620	60.5	299.5
Red	0.157	0.155	0.646	0.664	103.5	256.5
Blue	0.060	0.459	0.105	0.471	347	13.0
Burst	0	0.212	0.212	0.300	135	225

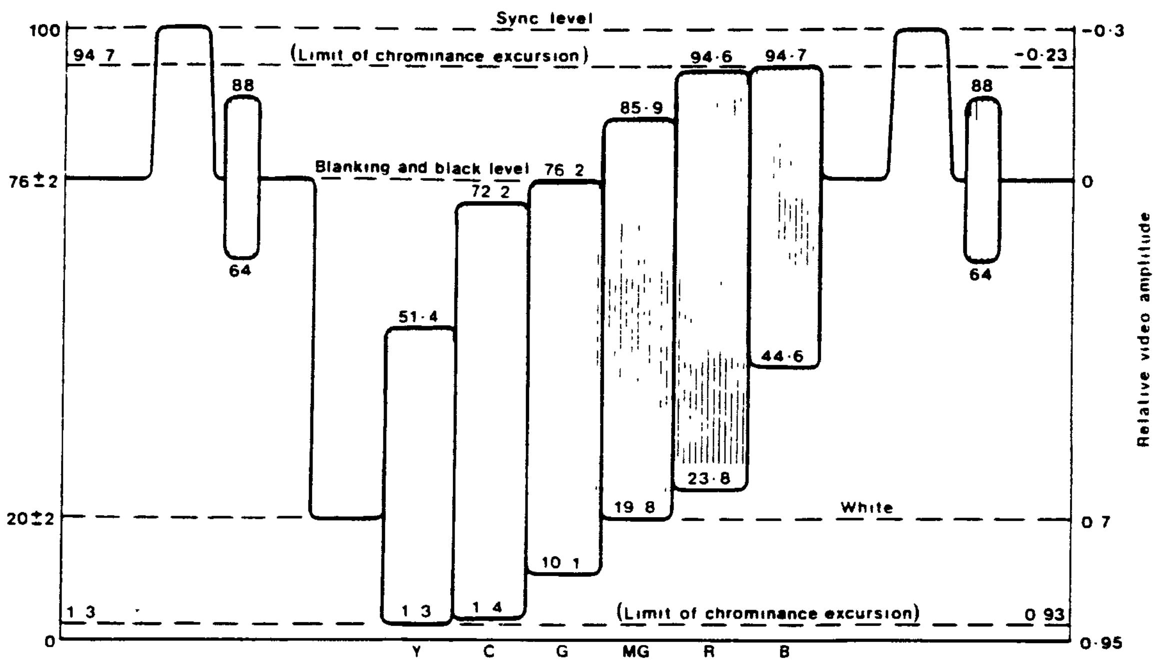


Figure 8 Waveform showing variation of carrier amplitude with time for a line of 100.0.100.0 colour bars (100%) Ideal double sideband example

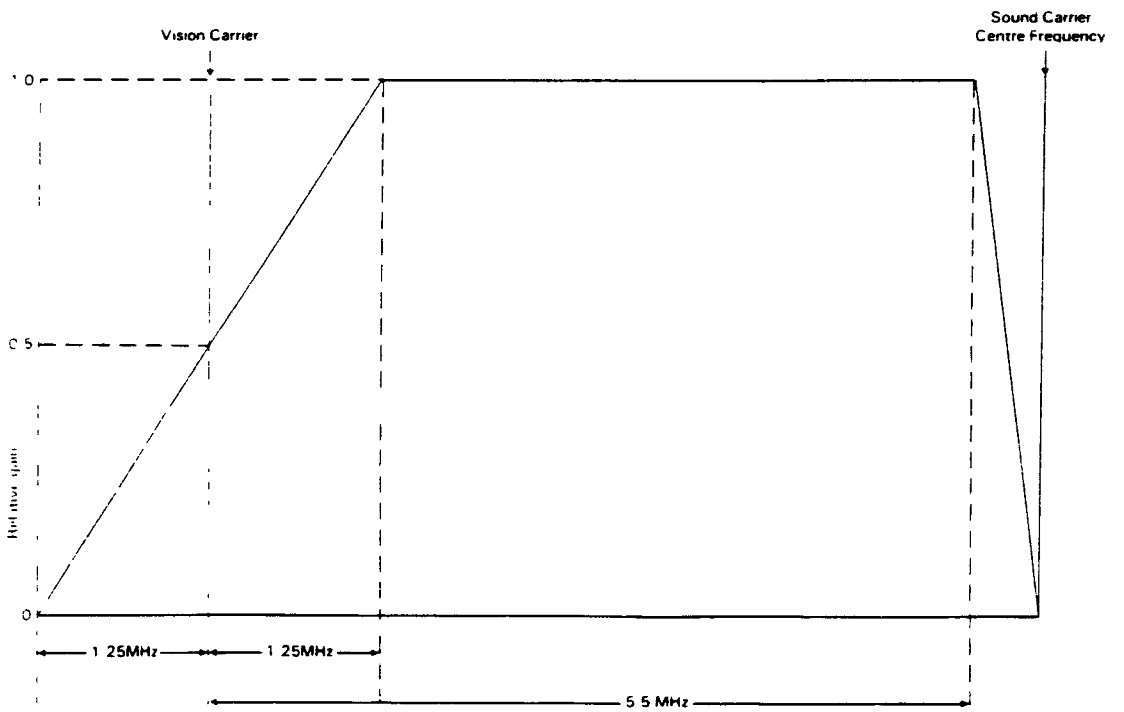


Figure 9 R.F. response of an ideal monitoring receiver

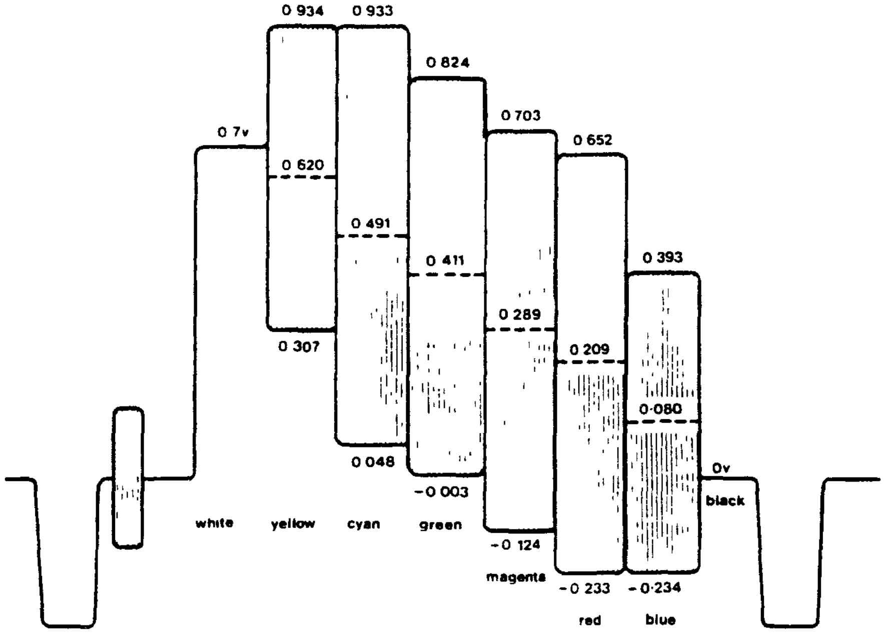


Figure 11 The line waveform of 100.0.100.0 colour bars (100%)

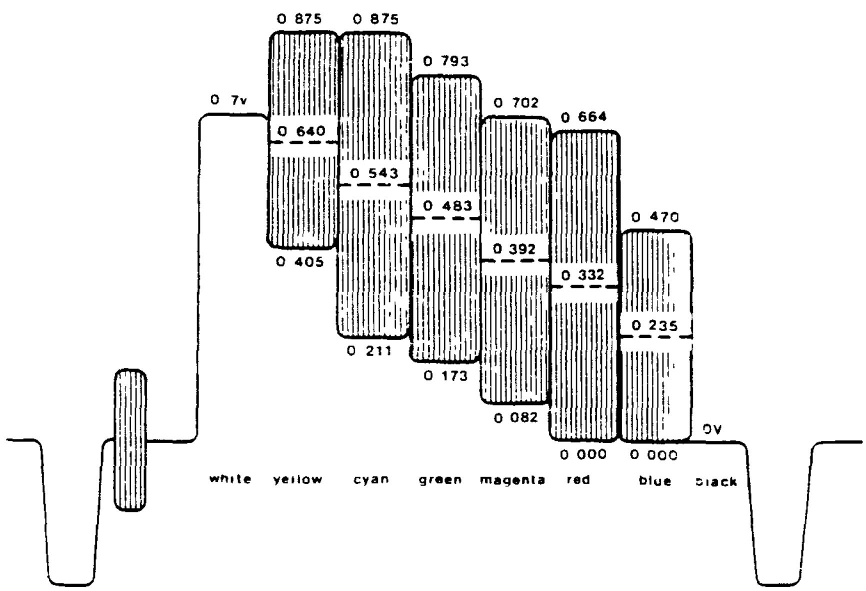


Figure 12 The line waveform of 100.0.100.25 colour bars (95%)

Colour Bar Waveforms

General

Coloured patterns involving only the primary hues and their complements at a particular luminance and saturation may be generated electronically and used to confirm the correct operation of colour coding, decoding and processing equipment. The most common form of these patterns comprises several vertical bars of colour in descending order of luminance and it is this display which is described in the following sections.

Amplitude

Each of the colour separation signals (E'_R, E'_G and E'_B) which produce the colour pattern shall, for each coloured bar, take up one of two voltage levels (designated E_{max} and E_{min} with respect to black level).

The amplitude of a particular set of colour bars is derived from the expression:

$$\text{Amplitude \%} = \frac{E'_{max}\ \text{(during colours bars)} \times 100}{\text{Max. value of } E'_R,\ E'_G,\ \text{or } E'_B \text{ for white bar}}$$

Saturation

The saturation of a colour bar signal shall be less than 100% if E_{min} (as defined above) is not zero (coincident with black level).

The saturation of a particular set of colour bars is derived from the expression:

$$\text{Saturation \%} = \left[1 - \left(\frac{E_{min}}{E_{max}}\right)^{\Upsilon}\right] \times 100$$

where: E_{max} is the maximum value of E'_R, E'_G or E'_B during coloured bars.

E_{min} is the minimum value of E'_R, E'_G or E'_B during coloured bars.

Υ is the gamma exponent – see Section 2.6

Signal Parameters for Primary Colours and their Complements
(See Section 5.5)

Peak-to-peak amplitudes of chrominance components and peak luminance components are tabulated for colour bar signals with 0.7-volt peak luminance. These amplitudes and phases are quoted for ideal signals, not subjected to any distortions.

Line n refers to the odd lines of the first and second fields and the even lines of the third and fourth fields and line n+1 to the even lines of the first and second fields and the odd lines of the third and fourth fields.

The specified chrominance angle is measured from the positive U axis as defined in Section 4.3.

100.0.100.0 Colour Bars (100%)

Colour	Luminance E'_Y	Peak-to-peak Chrominance			Chrominance Angle (α) in degrees	
		U axis $2E'_U$	V axis $2E'_V$	Total 2S	Line n	Line n+1
White	0.700	0	0	0	–	–
Yellow	0.620	0.612	0.140	0.628	167	193
Cyan	0.491	0.206	0.861	0.885	283.5	76.5
Green	0.411	0.405	0.721	0.827	240.5	119.5
Magenta	0.289	0.405	0.721	0.827	60.5	299.5
Red	0.209	0.206	0.861	0.885	103.5	256.5
Blue	0.080	0.612	0.140	0.628	347	13.0
Burst	0	0.212	0.212	0.300	135	225

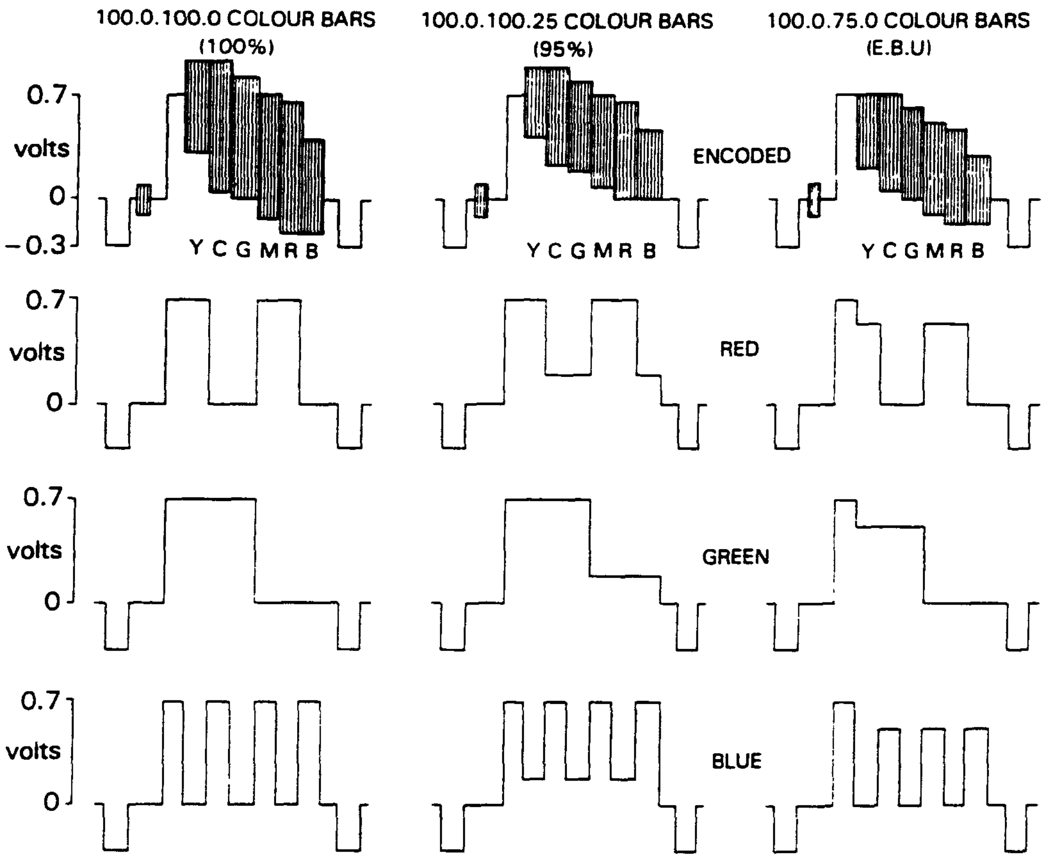


Figure 10 The complete colour waveform and colour separation voltages for a scanning line of three common versions of luminance step colour bars

Colour Signal Identities: Matrix Equations

Within the chrominance bandwidth:-

$$\begin{bmatrix} E'_Y \\ E'_U \\ E'_V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.437 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} E'_R \\ E'_G \\ E'_B \end{bmatrix}$$

$$\begin{bmatrix} E'_R \\ E'_G \\ E'_B \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.14 \\ 1 & -0.394 & -0.581 \\ 1 & 2.03 & 0 \end{bmatrix} \begin{bmatrix} E'_Y \\ E'_U \\ E'_V \end{bmatrix}$$

where: E'_R E'_G and E'_B are gamma corrected colour separation voltages.

E'_Y is the luminance voltage.

E'_U is the chrominance modulating voltage used to produce a modulated subcarrier component lying along the reference axis.

E'_V is the chrominance modulating voltage used to produce a modulated subcarrier component at +90° to the reference axis (U) on odd lines of the first and second fields and even lines of the third and fourth fields. It produces a modulated subcarrier component at −90° to the reference on the remaining lines.

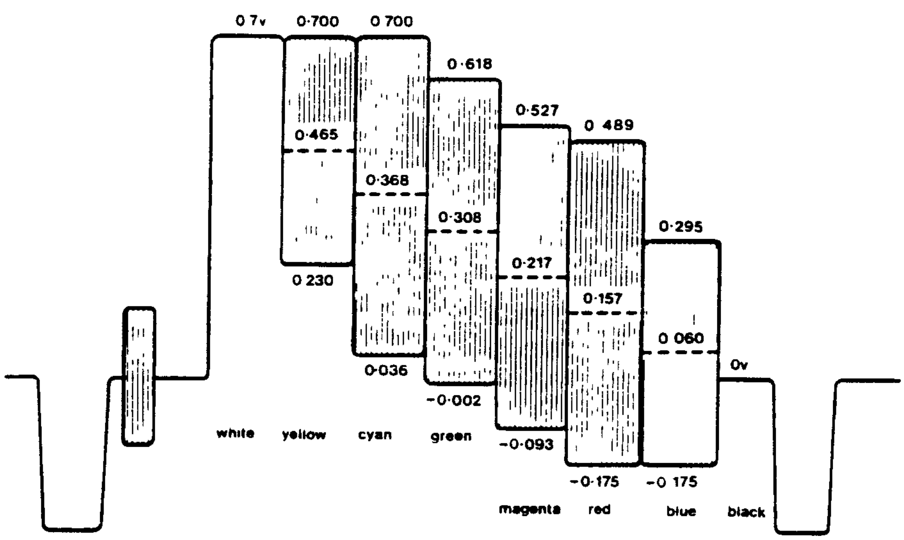


Figure 13 The line waveform of 100.0.75.0 colour bars (EBU)

Insertion Signals

General

During the field blanking interval, certain lines may contain control, teletext and test signals. These lines are numbered 7 to 22 inclusive on first and third (even) fields and 320 to 335 inclusive on second and fourth (odd) fields.

Lines 7 to 22 and 320 to 335 may contain teletext signals.

Lines 10, 12, 22 and 323, 325, 335 may be blank for the purpose of noise measurements or may contain teletext signals.

Lines 19, 20, 332 and 333 normally contain national test signals.

Lines 21 and 334 may contain identification and control signals.

Lines 22 and 335 may occasionally carry signals for local testing at transmitters.

National Test Signals

The national test signals normally transmitted on lines 19, 20, 332 and 333 are detailed in Figures 14, 15 and 16. Both the IBA and the BBC distribute Insertion Test Signal 1 on lines 19 and 332 as shown in Figure 14. The IBA distributes Insertion Test Signal 2 on lines 20 and 333 as shown in Figure 15. The BBC distributes Insertion Test Signal 3 on lines 20 and 333 as shown in Figure 16. These lines contain the necessary test waveforms to facilitate the measurement of transmission performance.

Insertion Test Signal 1, on lines 19 and 332, comprises a 10μs white bar, a full amplitude 2T positive pulse, a composite pulse (10T) consisting of a half amplitude luminance pulse with a full amplitude chrominance pulse and a five-riser staircase with an added 4.43MHz subcarrier at constant phase and amplitude. The peak to peak magnitude of this subcarrier is 140mV in a standard 700mV peak to peak picture signal.

The 2T pulse and 10μs bar on test signal 1 enable the K rating to be obtained, while measurement of line-time non-linearity may be made by passing the staircase waveform through a differentiating and shaping filter. The 10T composite pulse permits assessment of chrominance-to-luminance gain and delay inequalities. Details of the use of these test signals are given in CCIR Recommendation 567.

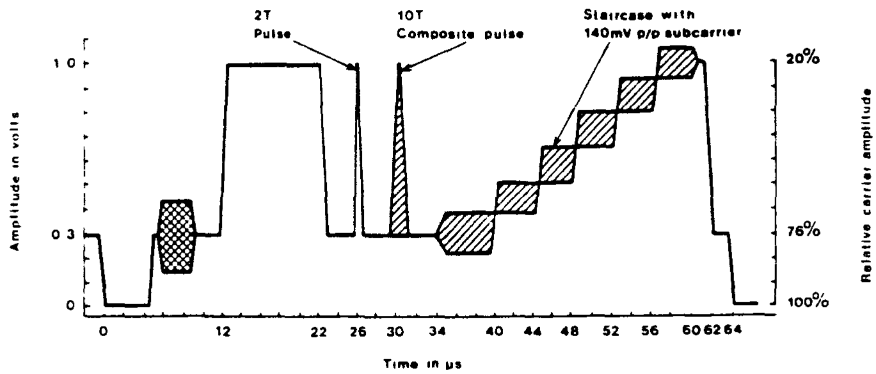


Figure 14 Insertion test signal 1 (lines 19 and 332)

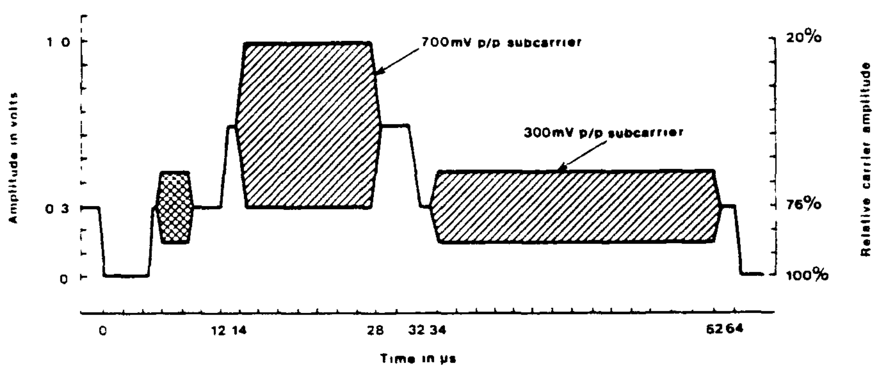


Figure 15 Insertion test signal 2 (lines 20 and 333)

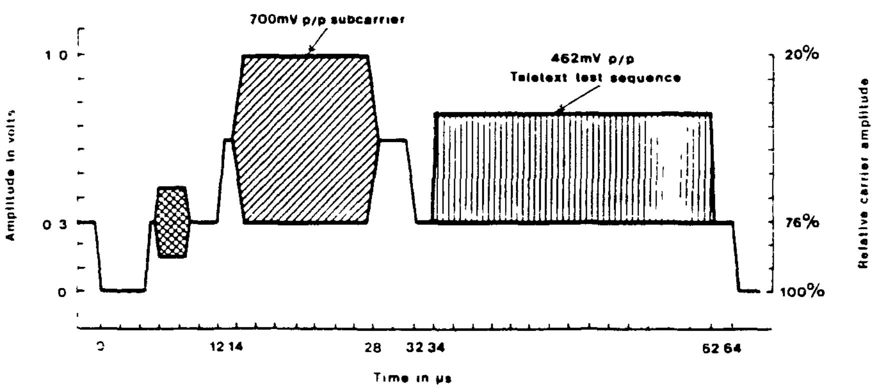


Figure 16 Insertion test signal 3 (lines 20 and 333)

Insertion Test Signal 2, distributed by the IBA on lines 20 and 333, contains a half-amplitude luminance bar, part of which has 700mV 4.43MHz subcarrier superimposed and 28μs of subcarrier having an amplitude of 280mV during the second half of the line.

Chrominance-to-luminance crosstalk can be measured from the bar waveform on test signal 2. The subcarrier on the remainder of the line is of constant phase and amplitude and is intended for demodulating the subcarrier on the previous line in order to measure the differential phase.

Test signal 3, distributed by the BBC on lines 20 and 333, is the same as test signal 2 except that the period of subcarrier on the latter half of the line is replaced by a sequence of teletext pulses which are intended to allow measurement of significant teletext waveform parameters. After 16 bits of clock run-in, the data sequence on line 333 is the complement of the data sequence on line 20 in order to allow a stationary superimposed display on an oscilloscope. The complete data sequences are listed in the Table.

Teletext

With the reservations made above, teletext signals may be carried on lines 7 to 22 and 320 to 335. The Broadcast Teletext Specification was published in 1976 in a document with that title jointly by the British Broadcasting Corporation, the Independent Broadcasting Authority and the British Radio Equipment Manufacturers Association.

The waveform of the television lines which carry teletext signals is illustrated in Figure 17. The teletext data is carried in the form of non-return to zero pulses at a bit rate of 6.9375Mbits/s ± 25 parts per million (444 x nominal line frequency).

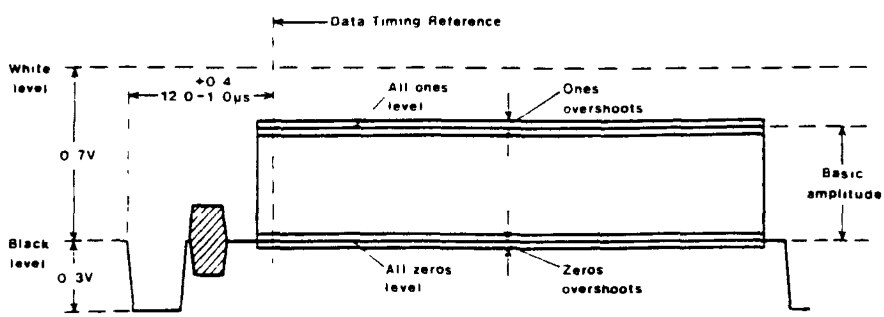


Figure 17   Typical line snowing teletext signals

Teletext Data Sequence in Test Signal 3

Digital Word No.	Line 20 Bits	Line 333 Bits
1	10101011	01010100
2	00101010	11010101
3	10000000	01111111
4	00001000	11110111
5	00000001	11111110
6	00100000	11011111
7	11000010	00111101
8	10001111	01110000
9	01000101	10111010
10	10011101	01100010
11	01001111	10110000
12	10100001	01011110
13	11000100	00111011
14	10011011	01100100
15	01011011	10100100
16	11101100	00010011
17	00011010	11100101
18	10010111	01101000
19	01110011	10001100
20	00101010	11010101
21	11111110	00000001
22	00000100	11111011

The all-zeros level is the level resulting from a continuous stream of 'zero' pulses and is equal to black level in the video waveform with a tolerance of ±2% of white level. The all-ones level is the level resulting from a continuous stream of 'one' pulses. The difference between the all-zeros and all-ones levels is the basic amplitude and is equal to 66 ± 3% of white level.

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 sampling positions. It is expressed as a proportion of the basic amplitude.

In a received signal, in the presence of noise and other waveform disturbances, 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 percentage of a specified basic amplitude.

Estimated Performance of System I/PAL from Coder Input to Final Transmitter Output

Between the programme originating source and the final transmitter output there is a considerable amount of equipment which will introduce distortion. The deviations shown in the following table are neither tolerances laid down in formal specifications of equipment, nor necessarily limits assigned for maintenance purposes. They are estimates, based on operational experience, of deviations considered to have a high probability (say 90%) of not being exceeded when the equipment is installed and operated in accordance with current specifications and maintenance practices.

The waveforms and the tolerances specified so far in Sections 2 to 5 of this document are those which exist at the output of a studio centre. No mention has been made of the distortions to the picture component of the signal which can be caused by the equipment inside the studio centre. These are liable to vary considerably depending on the number and types of equipment in use. The figures used in Column A of the Table relate to a studio chain comprising one coder, studio equipment such as mixers, switching matrices, etc., and three video tape recorders (three recording and three replay processes). The waveform and tolerances of the synchronising components of the waveform are nearly always determined by the mixer at the output of the studio centre and the blanking waveforms and tolerances by the video tape recording processes.

To give a guide to the distortions which occur after the signal leaves the studio centre further columns have been added to the table. The performance of the transmission chain is fairly well established by measurement of the parameters available in the test signals carried in the field blanking interval. However, high power television transmitters employ extensive signal processing which can cause significant distortions of the synchronising components of the waveforms (e.g. overshoots on the line synchronising pulses).

The performance of the British Telecom network feeding the main transmitters has been listed separately in Column B. In the BBC the insertion test signals are added to the waveforms at the output of Television Centre (except during regional opt-outs when they are added to the signal at the output of the regional studio centre). In the IBA the practice is to add the test signals to the waveform at the output of each of the Television Contractors' main studio centres. Consequently the radiated test signal is not a measure of the inter-city distribution network. The figures listed in Column B are typical of the performance of a long national chain such as between the BBC's Television Centre and a main transmitter in Scotland or Wales.

The figures listed in Column C apply to the output of a main transmitter assuming that the test signals are undistorted at the input. Column D refers to the output of a rebroadcast transmitter fed from a main transmitter and Column E to the output of a transposer fed from a rebroadcast transmitter. In each case the additional effects of distortion occurring inside the Studio Centre and on the British Telecom network can be estimated by adding the limits in Columns A and B on a power law basis according to CCIR Recommendation 567.

Estimated deviations from ideal performance, having a high probability of not being exceeded

Parameter No.	Parameter	Studio Centre Output A	British Telecom Network B	Main Transmitter Output C	Rebroadcast Transmitter Output D	Transposer Output E	A + B + E F
1	Signal/Random Noise, Unweighted (dB)	39	48	46	45	42	37
2	Signal/Noise, Luminance Weighted (dB)	48	56	52	51	48	45
3	Signal/Noise, Chrominance Weighted (dB)	42	52	52	51	48	41
4	Chrominance-Luminance Gain Inequality (%)	±7	±12	±7	±18	±25	±29
5	Chrominance-Luminance Delay Inequality (ns)	±53	±65	±30	±75	±110	±138
6	K Bar (%)	5	3	1	3	4	7
7	K 2T Pulse (%)	5	2	2	3	4	8
8	K 2T Pulse/Bar (%)	5	2	1.5	3	4	8
9	K 50Hz Square Wave (%)	5	4	1	1	1	1
10	Luminance Non-Linearity (%)	15	14	7	14	20	34
11	Differential Gain (%)	15	10	7	10	15	28
12	Differential Phase (degrees)	15	10	4	10	15	28
13	Chrominance/Luminance Crosstalk (%)		±8	±3	±8	±10	
14	Carrier at Peak White Error (%)			±4	±8	±10	
15	Carrier at Blanking Level Error (%)			±4	±4	±5	
16	Sound/Vision Power Ratio Error (dB)			±1	±1	±2	
17	Incidental Phase Modulation (degrees)			10	10	14	
18	Teletext Decoding Margin (%)			65	57	54	