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(also note filter templates p. 13)

Recommendation ITU-R BT.709-6
(06/2015)

Parameter values for the HDTV standards for production and international programme exchange

BT Series

Broadcasting service (television)

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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R BT.709-6

Parameter values for the HDTV[1] standards for production and international programme exchange

(Question ITU-R 27/11)

(1990-1994-1995-1998-2000-2002-2015)

Scope

This Recommendation defines the image format parameters and values for HDTV[2].

Keywords

HDTV (high definition television), Image format, EOTF (electro optical transfer function), OETF (optical electrical transfer function), PsF (progressive segmented frame)

The ITU Radiocommunication Assembly,

considering

a) that for many years HDTV programmes have been produced worldwide;

b) that parameter values for HDTV production standards should have maximum commonality;

c) that the parameters defined for all these systems meet the quality goals set for HDTV;

d) that film productions are an important programme source for HDTV broadcasting and, conversely, the use of HDTV production systems has significant benefits for film programme production;

e) that high-quality conversion between the various HDTV systems, as well as down-conversion to 525/625 television systems, has been successfully implemented;

f) that programmes produced and archived will have a long shelf life,

recommends

that for HDTV programme production and international exchange, one of the systems described in this Recommendation, should be used.

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1 "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". Report ITU-R BT.801.

2 Previous versions of this Recommendation that may contain historic information can be found on the ITU website.

HDTV system with square pixel common image format

Introduction

The common image format (CIF) is defined to have common picture parameter values independent of the picture rate. The following picture rates are specified: 60 Hz, 50 Hz, 30 Hz, 25 Hz and 24 Hz. For the 60, 30 and 24 Hz systems, picture rates having those values divided by 1.001 are also specified.

Pictures are defined for progressive (P) capture and interlace (I) capture. Progressive captured pictures can be transported with progressive (P) transport or progressive segmented frame (PsF) transport. Interlace captured pictures can be transported with interlace (I) transport. Refer to Attachment 2 for a description of segmented frame transport.

This results in the following combinations of picture rates and transports:

System	Capture (Hz)	Transport
60/P	60 or 60/1.001 progressive	Progressive
30/P	30 or 30/1.001 progressive	Progressive
30/PsF	30 or 30/1.001 progressive	Segmented frame
60/I	30 or 30/1.001 interlace	Interlace
50/P	50 progressive	Progressive
25/P	25 progressive	Progressive
25/PsF	25 progressive	Segmented frame
50/I	25 interlace	Interlace
24/P	24 or 24/1.001 progressive	Progressive
24/PsF	24 or 24/1.001 progressive	Segmented frame

1 Opto-electronic conversion

Item	Parameter	System Values	
1.1	Opto-electronic transfer characteristics before non-linear pre-correction	Assumed linear	
1.2	Overall opto-electronic transfer characteristics at source[(1)]	$V = 1.099\ L^{0.45} - 0.099$ for $1 \geq L \geq 0.018$ $V = 4.500\ L$ for $0.018 > L \geq 0$ where: L : luminance of the image $0 \leq L \leq 1$ V : corresponding electrical *signal*	
1.3	Chromaticity coordinates (CIE, 1931)	*x*	*y*
	Primary – Red (*R*) – Green (*G*) – Blue (*B*)	 0.640 0.300 0.150	 0.330 0.600 0.060
1.4	Assumed chromaticity for equal primary signals (Reference white)	D_{65}	
		x	*y*
	$E_R = E_G = E_B$	0.3127	0.3290

(1) In typical production practice the encoding function of image sources is adjusted so that the final picture has the desired look, as viewed on a reference monitor having the reference decoding function of Recommendation ITU-R BT.1886, in the reference viewing environment defined in Recommendation ITU-R BT.2035.

2 Picture characteristics

Item	Parameter	System Values
2.1	Aspect ratio	16:9
2.2	Samples per active line	1 920
2.3	Sampling lattice	Orthogonal
2.4	Active lines per picture	1 080
2.5	Pixel aspect ratio	1:1 (square pixels)

3 Signal format

Item	Parameter	System Values
3.1	Conceptual non-linear pre-correction of primary signals	$\gamma = 0.45$ (see item 1.2)
3.2	Derivation of luminance signal E'_Y	$E'_Y = 0.2126\,E'_R + 0.7152\,E'_G + 0.0722\,E'_B$
3.3	Derivation of colour-difference signal (analogue coding)	$E'_{CB} = \frac{E'_B - E'_Y}{1.8556}$ $= \frac{-0.2126\,E'_R - 0.7152\,E'_G + 0.9278\,E'_B}{1.8556}$ $E'_{CR} = \frac{E'_R - E'_Y}{1.5748}$ $= \frac{0.7874\,E'_R - 0.7152\,E'_G - 0.0722\,E'_B}{1.5748}$
3.4	Quantization of *RGB*, luminance and colour-difference signals(1), (2)	$D'_R = \mathrm{INT}\left[(219\,E'_R + 16)\cdot 2^{n-8}\right]$ $D'_G = \mathrm{INT}\left[(219\,E'_G + 16)\cdot 2^{n-8}\right]$ $D'_B = \mathrm{INT}\left[(219\,E'_B + 16)\cdot 2^{n-8}\right]$ $D'_Y = \mathrm{INT}\left[(219\,E'_Y + 16)\cdot 2^{n-8}\right]$ $D'_{CB} = \mathrm{INT}\left[(224\,E'_{CB} + 128)\cdot 2^{n-8}\right]$ $D'_{CR} = \mathrm{INT}\left[(224\,E'_{CR} + 128)\cdot 2^{n-8}\right]$
3.5	Derivation of luminance and colour-difference signals via quantized *RGB* signals	$D'_Y = \mathrm{INT}\left[0.2126\,D'_R + 0.7152\,D'_G + 0.0722\,D'_B\right]$ $D'_{CB} = \mathrm{INT}\left[\left(-\frac{0.2126}{1.8556}D'_R - \frac{0.7152}{1.8556}D'_G + \frac{0.9278}{1.8556}D'_B\right)\cdot\frac{224}{219} + 2^{n-1}\right]$ $D'_{CR} = \mathrm{INT}\left[\left(\frac{0.7874}{1.5748}D'_R - \frac{0.7152}{1.5748}D'_G - \frac{0.0722}{1.5748}D'_B\right)\cdot\frac{224}{219} + 2^{n-1}\right]$

(1) "*n*" denotes the number of the bit length of the quantized signal.

(2) The operator INT returns the value of 0 for fractional parts in the range of 0 to 0.4999... and +1 for fractional parts in the range of 0.5 to 0.9999..., i.e. it rounds up fractions above 0.5.

4 Digital representation

Item	Parameter	System Values	
4.1	Coded signal	*R*, *G*, *B* or *Y*, C_B, C_R	
4.2	Sampling lattice – *R*, *G*, *B*, *Y*	Orthogonal, line and picture repetitive	
4.3	Sampling lattice – C_B, C_R	Orthogonal, line and picture repetitive co-sited with each other and with alternate(1) *Y* samples	
4.4	Number of active samples per line – *R*, *G*, *B*, *Y* – C_B, C_R	 1 920 960	
4.5	Coding format	Linear 8 or 10 bits/component	
4.6	Quantization levels	8-bit coding	10-bit coding
	– Black level *R*, *G*, *B*, *Y* – Achromatic C_B, C_R – Nominal peak – *R*, *G*, *B*, *Y* – C_B, C_R	 16 128 235 16 and 240	 64 512 940 64 and 960
4.7	Quantization level assignment	8-bit coding	10-bit coding
	– Video data – Timing reference	1 through 254 0 and 255	4 through 1 019 0-3 and 1 020-1 023
4.8	Filter characteristics(2) – *R*, *G*, *B*, *Y* – C_B, C_R	See Attachment 1	

(1) The first active colour-difference samples being co-sited with the first active luminance sample.

(2) These filter templates are defined as guidelines.

5 Picture scanning characteristics

Item	Parameter	System Values									
		60/P	30/P	30/PsF	60/I	50/P	25/P	25/PsF	50/I	24/P	24/PsF
5.1	Order of sample presentation in a scanned system	Left to right, top to bottom For interlace and segmented frame systems, 1st active line of field 1 at top of picture									
5.2	Total number of lines	1 125									
5.3	Field/frame/segment frequency (Hz)	60, 60/1.001	30, 30/1.001	60, 60/1.001		50	25	50		24, 24/1.001	48, 48/1.001
5.4	Interlace ratio	1:1			2:1	1:1			2:1	1:1	
5.5	Picture rate (Hz)	60, 60/1.001	30, 30/1.001			50	25			24, 24/1.001	
5.6	Samples per full line – R, G, B, Y – C_B, C_R	 2 200 1 100				 2 640 1 320				 2 750 1 375	
5.7	Nominal analogue signal bandwidths(1) (MHz)	60	30			60	30				
5.8	Sampling frequency – R, G, B, Y (MHz)	148.5, 148.5/1.001	74.25, 74.25/1.001			148.5	74.25			74.25, 74.25/1.001	
5.9	Sampling frequency(2) – C_B, C_R (MHz)	74.25, 74.25/1.001	37.125, 37.125/1.001			74.25	37.125			37.125, 37.125/1.001	

(1) Bandwidth is for all components.

(2) C_B, C_R sampling frequency is half of luminance sampling frequency.

6 Analogue tri level sync signal

The tri level sync signal may be used as a reference signal for synchronization of devices operating on this Recommendation.

Item	Parameter	System Values									
		60/P	**30/P**	**30/PsF**	**60/I**	**50/P**	**25/P**	**25/PsF**	**50/I**	**24/P**	**24/PsF**
6.1	Nominal level (mV) E'_R, E'_G, E'_B, E'_Y	Reference black: 0 Reference white: 700 (see Fig. 2B)									
6.2	Nominal level (mV) E'_{C_B}, E'_{C_R}	±350 (see Fig. 2B)									
6.3	Form of synchronizing signal	Tri-level bipolar (see Fig. 2A)									
6.4	Line sync timing reference	O_H (see Fig. 2A)									
6.5	Sync level (mV)	±300 ± 2%									
6.6	Sync signal timing	Sync on all components (see Table 1, Figs 1 and 2)									
6.7	Blanking interval	(see Table 1, Figs 1 and 2)									

TABLE 1

Level and line timing specification
(See Figs 1 and 2)

Symbol	Parameter	System Values									
		60/P	**30/P**	**30/PsF**	**60/I**	**50/P**	**25/P**	**25/PsF**	**50/I**	**24/P**	**24/PsF**
T	Reference clock interval (µs)	1/148.5, 1.001/148.5	1/74.25, 1.001/74.25			1/148.5	1/74.25			1/74.25, 1.001/74.25	
a	Negative line sync width[(1)] (T)	44 ± 3									
b	End of active video[(2)] (T)	88 + 6 – 0				528 + 6 – 0				638 + 6 – 0	
c	Positive line sync width (T)	44 ± 3									
d	Clamp period (T)	132 ± 3									
e	Start of active video (T)	192 + 6 – 0									
f	Rise/fall time (T)	4 ± 1.5									
–	Active line interval (T)	1 920 + 0 – 12									
S_m	Amplitude of negative pulse (mV)	300 ± 6									
S_p	Amplitude of positive pulse (mV)	300 ± 6									
V	Amplitude of video signal (mV)	700									
H	Total line interval (T)	2 200				2 640				2 750	
g	Half line interval (T)	1 100				1 320				1 375	
h	Vertical sync width (T)	1 980 ± 3		880 ± 3		1 980 ± 3		880 ± 3		1 980 ± 3	880 ± 3
k	End of vertical sync pulse (T)	88 ± 3				528 ± 3		308 ± 3		638 ± 3	363 ± 3

(1) "T" denotes the duration of a reference clock or the reciprocal of the clock frequency.

(2) A "line" starts at line sync timing reference O_H (inclusive), and ends just before the subsequent O_H (exclusive).

FIGURE 1A

Field/frame/segment synchronizing signal waveform

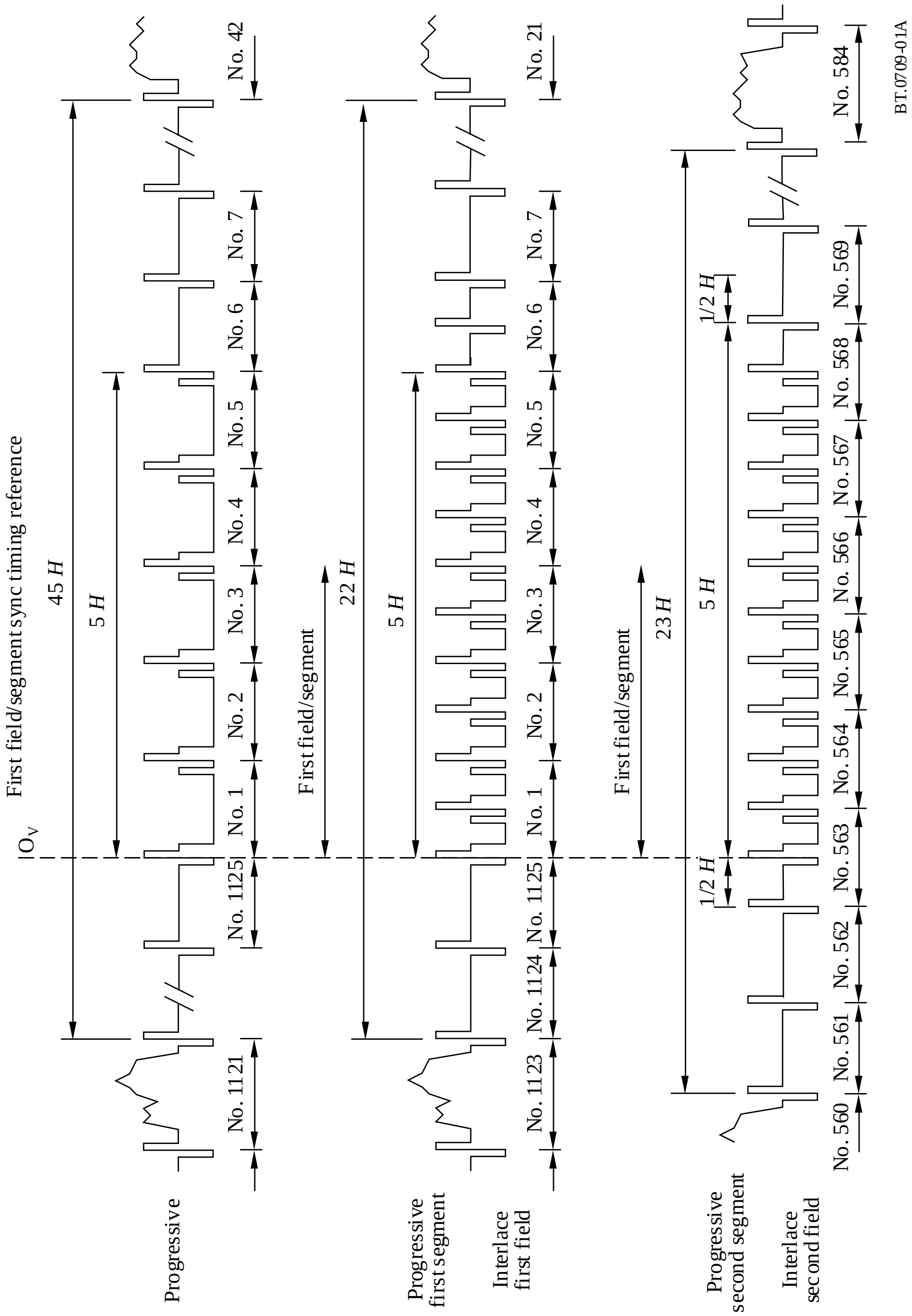


FIGURE 1B

Detail of field/frame/segment synchronizing signal waveform

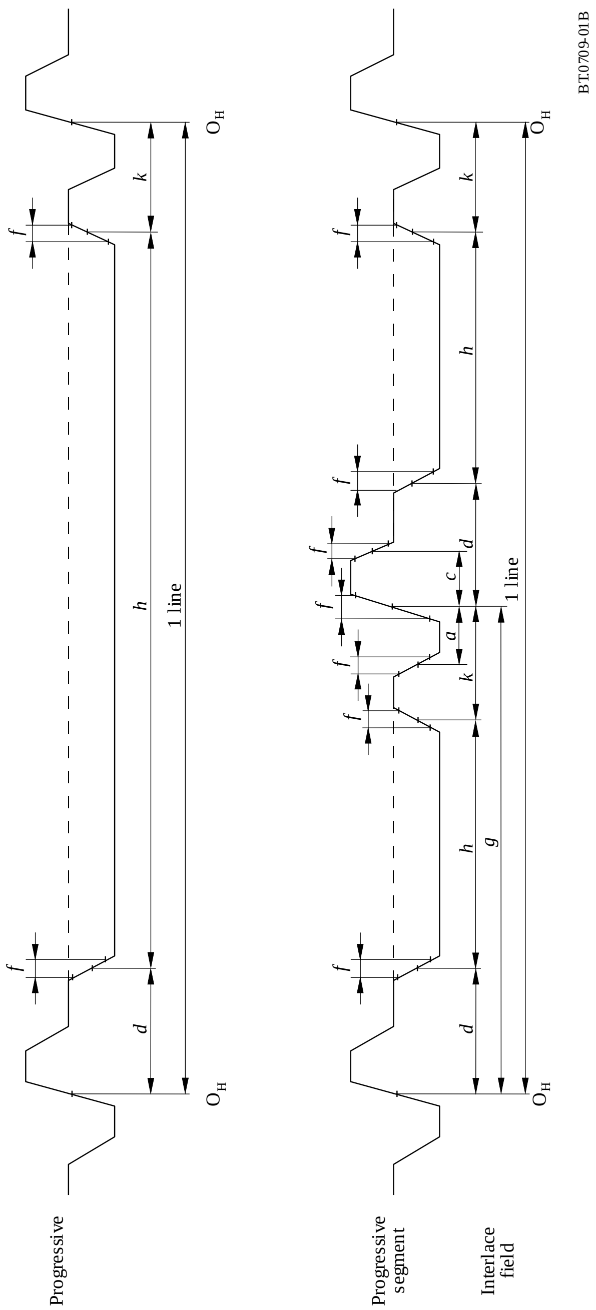


FIGURE 2A

Line synchronizing signal waveform

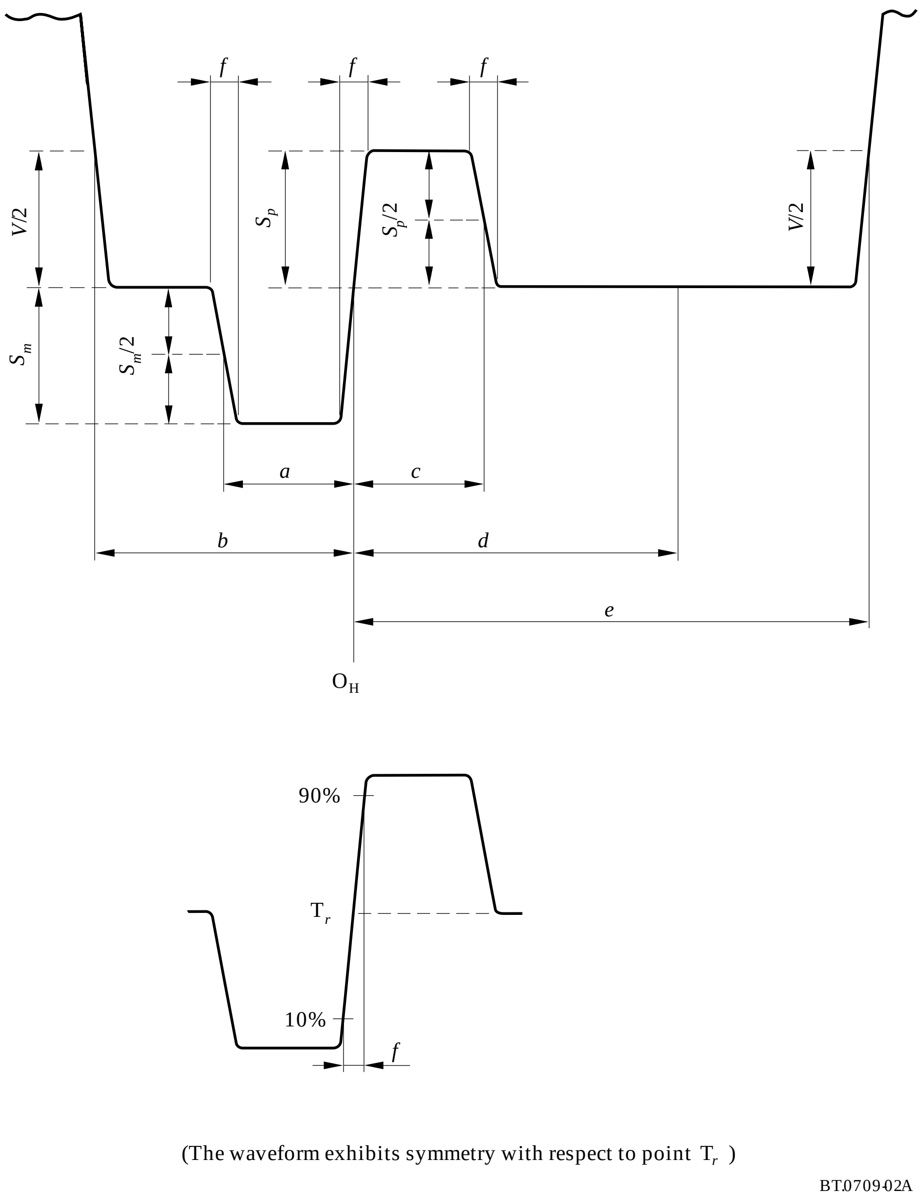
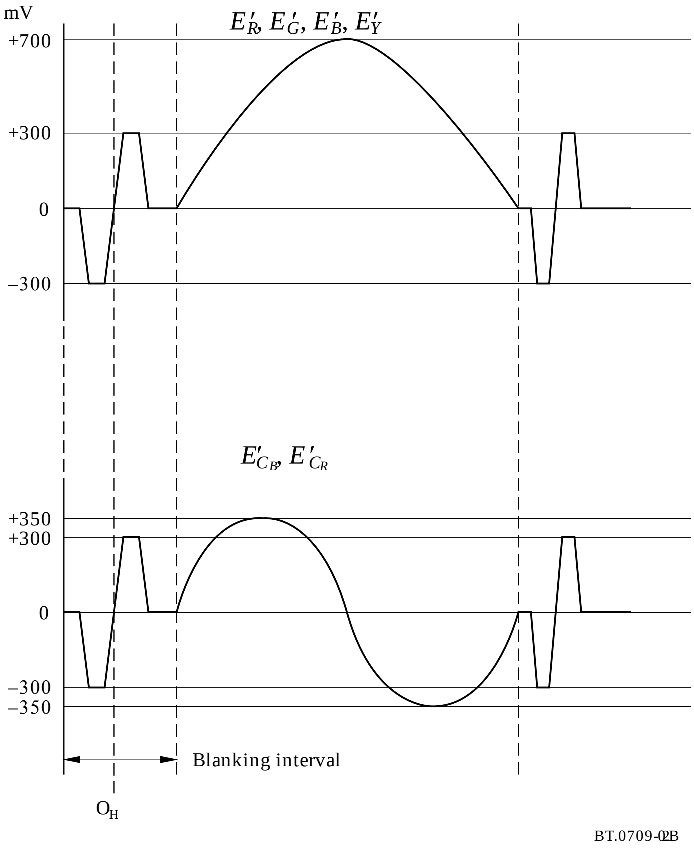


FIGURE 2B

Sync level on component signals



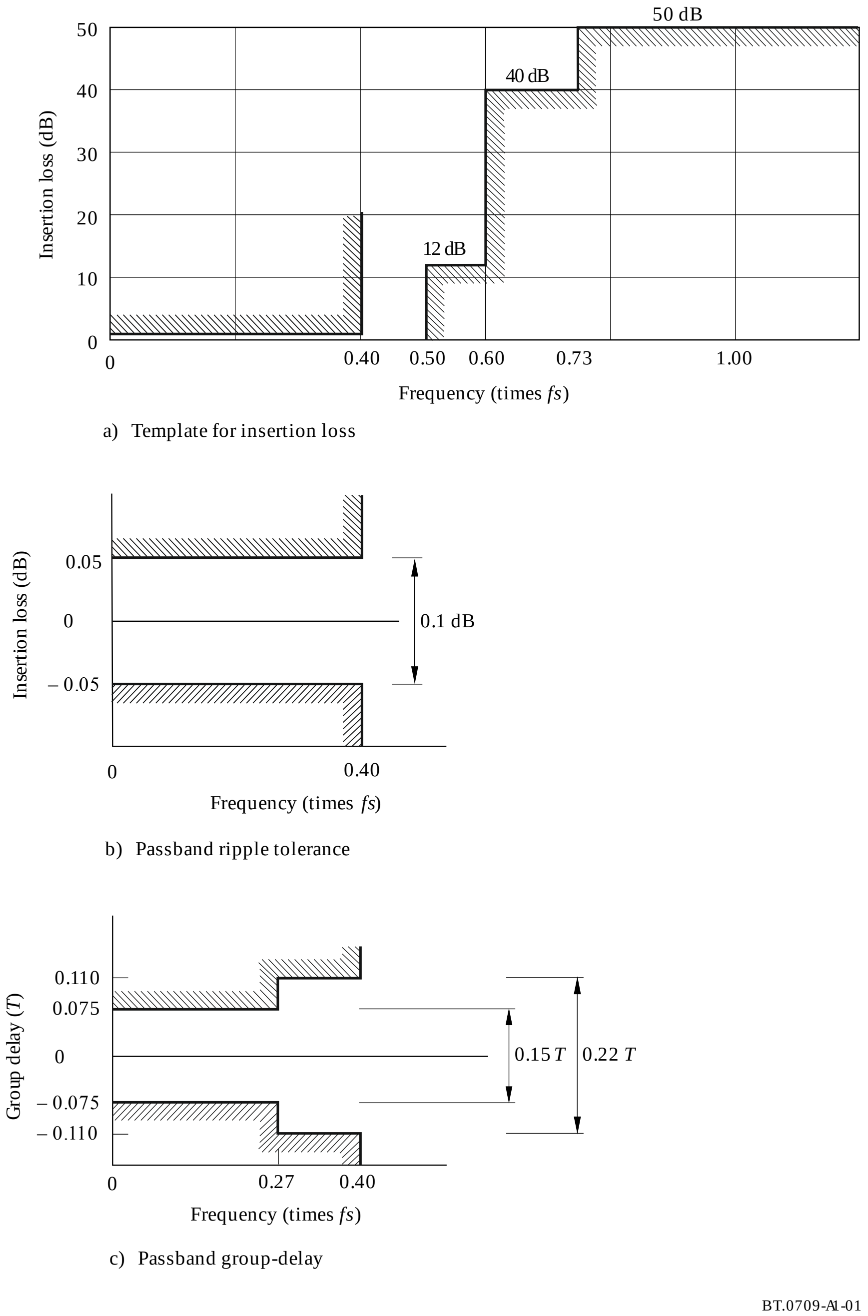
Attachment 1
(Informative)

Filter templates

Figures in this Attachment are suggested filter templates intended to remove alias components.

FIGURE A1-1

Guideline filter characteristics for *R*, *G*, *B* and *Y* signals (informative)

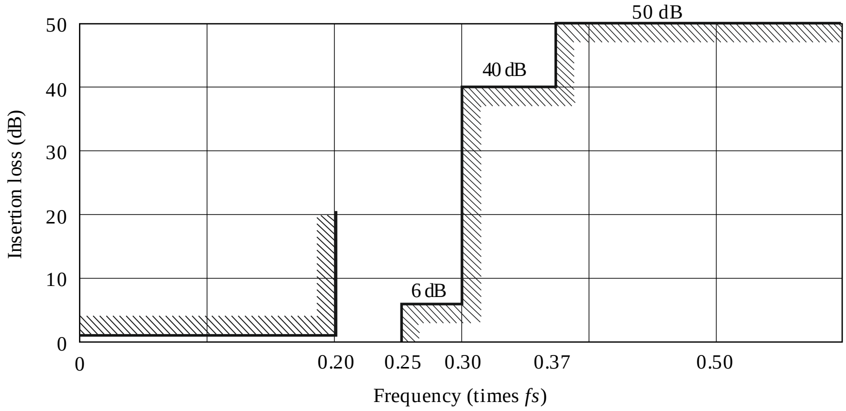


Note 1 – *fs* denotes luminance sampling frequency, the value of which is given in item 5.7.

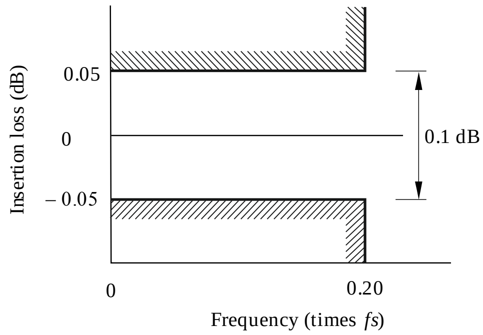
Note 2 – Ripple and group delay are specified relative to the value at 100 kHz.

FIGURE A1-2

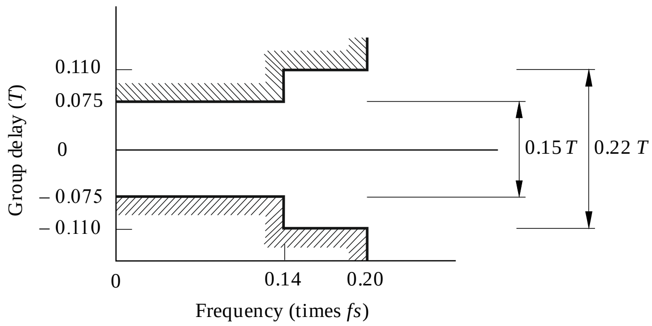
Guideline filter characteristics for C_B and C_R signals (informative)



a) Template for insertion loss



b) Passband ripple tolerance



c) Passband group-delay

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Note 1 – *fs* denotes luminance sampling frequency, the value of which is given in item 5.8.

Note 2 – Ripple and group delay are specified relative to the value at 100 kHz.

Attachment 2
(Informative)

Segmented frame (See Note 1)

NOTE 1 – The term segmented frame in the context of this Recommendation is intended to indicate that a picture has been captured in a progressive mode, and transported as two segments. One segment containing the odd lines of the progressive image, the second segment containing the even lines of the progressive image.

1 Background

The television systems in current use have typically used interlace capture (acquisition) and transmission. The frame/field rates of these systems have been 50/60 Hz, a rate that when presented on cathode ray tube (CRT) display devices did not require any associated picture flicker correction. Current Television systems support both interlace and progressive capture and display technology with wide deployment of flat panel displays capable of displaying images from 24 Hz to 60 Hz without any flicker.

Specifically, the PsF technology is intended to be implemented only when frames rates of 30 Hz and lower are being used and displayed on CRTs. PsF is an interface technology not an image capture or processing technology.

2 24-frame/s production

Using the CIF of $1\,920 \times 1\,080$, film material may be transferred using progressive capture. This transfer will provide the highest resolution capture, with no 3:2 pull-down artefacts, moreover both 30 Hz frame rate and 25 Hz frame rate versions may be created from a single master with no quality loss.

The 30 Hz frame rate copy may be created by playing the 24-frame/s original and inserting the 3:2 pull-down during the replay process. This process also has the advantage of maintaining the 3:2 pull-down sequence during the replay process such that any downstream picture processing, such as an MPEG encoder, will not be affected by any 3:2 discontinuities.

The 25 Hz frame rate copy may be created by simply playing back the 24 Hz film rate original at the slightly faster 25 Hz rate; there is no picture quality loss.

In addition to simply transferring film originated material it is expected that electronic capture of images will occur at a 24-frame/s rate; this will provide the production community with yet another tool for seamless integration of images from various sources.

3 Progressive/interlace compatibility

The post production world has a need to cater for both progressive and interlace television signal formats for the foreseeable future. Therefore any new signal format such as 24 P, the original film frame rate, will need to coexist with interlace formats of 25 Hz and 30 Hz systems. One of the constraints in monitoring the 24-frame/s systems is the picture flicker that is present when displaying a 24-frame/s signal on a CRT display. Interlace systems minimize this flicker by refreshing the CRT phosphors every 60 th/50 th of a second. There are at least two solutions to the flicker created by the 24-frame/s systems, install a frame store in every monitor, or provide to the monitor a signal that emulates the interlace refresh rate.

24PsF/25PsF/30PsF are interface formats that will provide monitoring devices with signal refresh rates that will permit direct monitoring of the original frame rate of the material.

It should be noted that in some cases users may want to monitor 24-frame/30-frame material at other than the original frame rates.

The use of 24PsF/25PsF/30PsF does not in any way limit the monitoring of the signal by the newer flat panel displays.

A second potential use of the 24PsF/25PsF/30PsF transmission format is in the area of digital post production switchers. A common switcher design handling both interlace and progressive signals is economically possible, and addresses the requirements of end users who have a requirement to work in interlace and progressive formats with common equipment. The digital interface of an interlace signal and a PsF signal are common, only the signal content is different.

4 Signal mapping

The 24PsF/25PsF/30PsF transmission format maps a progressive image onto the interlace digital serial interface as defined in this Recommendation (see Fig. A2-1).

Line numbering convention for the image capture and image transmission is contained in the introduction (see also Fig. A2-1).

The same line numbers of an interlace picture are used by the PsF to carry the segmented frame format.

The sF format is not related to any interlace format characteristics. It is a way to convey a progressive image that has been captured at a 24/25/30 Hz rate. Capture at these low frequencies may require special monitoring considerations. The sF transmission format is intended to provide an economical solution while still retaining the compatibility with interlace systems.

In cases where a progressive captured image is transported as a segmented frame, or a segmented frame signal is processed in a progressive format, the following rules shall be observed (see Fig. A2-1):

– line numbering from the top of the captured frame to the bottom of the captured frame shall be sequential;
– active line 1 and active line 1 080 of the progressive captured image shall be mapped onto total line 42 and total line 1 121, respectively, of the 1 125 total lines;
– odd active lines of the progressive captured image (1, 3, ..., 1 079) shall be mapped onto total lines 21 through 560 of the segmented frame interface;
– even active lines of the progressive captured image (2, 4, ..., 1 080) shall be mapped onto total lines 584 through 1 123 of the segmented frame interface.

With these rules, segmented frame transport has the same line numbering as that of interlace transport.

FIGURE A2-1

Mapping of progressive images into progressive and segmented frame transport interfaces