EBU – TECH 3299

High Definition (HD)
Image Formats for Television Production

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Contents

1. Introduction

This document defines the basic image formats and digital sampling systems for the High Definition (HD) television production applications in the European (EBU) 50 Hz environments.

The European Broadcasting Union has published this technical specification to meet the demands of its Members for interoperability, and implementation stability, for high definition television production systems.

The specification comprises 4 HDTV production systems:

- System 1 (S1) with 1280 horizontal samples and 720 active lines in progressive scan with a frame rate of 50Hz, 16 x 9 aspect ratio.
- System 2 (S2) with 1920 horizontal samples and 1080 active lines in interlaced scan with a frame rate of 25Hz, 16 x 9 aspect ratio.
- System 3 (S3) with 1920 horizontal samples and 1080 active lines in progressive scan and a frame rate of 25Hz, 16 x 9 aspect ratio.
- System 4 (S4) with 1920 horizontal samples and 1080 active lines in progressive scan at a frame rate of 50Hz, 16 x 9 aspect ratio.

The application of this specification is intended for, but not limited to, the television production environment.

This specification draws on the specifications in the normative reference section (Section 2) of this document, which define in detail[1]:

– R'G'B' colour encoding;
– R'G'B' analogue and digital representation;
– $Y'P'_BP'_R$ colour encoding, analogue representation and analogue interface; and
– $Y'C'_BC'_R$ colour encoding and digital representation.

Designers should be aware that single link serial digital interfaces such as SMPTE 292M for formats other than $Y'C'_BC'_R$ have not yet been defined, and that the use of System 4 currently requires dual channel usage of SMPTE 292M as specified in SMPTE 372M. Section 10 describes the current conditions for System 4 infrastructures as well as for R'G'B' interfaces for System 2 to 3.

2. Normative references

EBU R112-2004	EBU Statement on HDTV standards
SMPTE 274M-2003	1920 x 1080 Image Sample Structure, Digital Representation and digital Timing Reference Sequences for Multiple Picture Rates.
SMPTE 296M-2001	1280 x 720 Progressive Image Sample Structure – Analogue and Digital Representation and Analogue Interface.
SMPTE RP 177-1993	Derivation of Basic Television Colour Equations
SMPTE 292M-2004	HDTV Signal/Data Serial Interface
SMPTE 372M	Dual Link SMPTE 292M Interface for 1920 x 1080 Picture Raster
SMPTE 297M-2000	Fibre Optic Interfaces for SDTV and HDTV interfaces.
SMPTE 377M-2004	MXF File Format Specification
SMPTE 384M-2004[2]	Mapping of uncompressed pictures to the MXF Generic Container
CIE Publication 15.2 (1986)	Colorimetry, Second Edition.
ITU-R BT.1361	Worldwide unified colorimetry and related characteristics of future television and imaging systems

[1] the apostrophe ' in, for example, R'G'B' means that the signal has been gamma corrected
[2] under final preparation by SMPTE

3. Informative References

EBU Tech 3298 An EBU "route map" to High Definition (HD)

ITU-R BT.1120-5 "Digital interfaces HDTV studio signals"

ITU-R BT.1367 "Serial digital fibre transmission system for signals conforming to Recs ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120

ITU-R BT.1363-1 "Jitter specifications and methods for Jitter measurements of bit-serial signals conforming to Recs BT.656, 799 and 1120

ITU-R BT.1577 SDI-based transport interface for compressed television signals in networked television production based on Rec BT.1120

4. Nomenclatures and Image Sampling Systems

EBU System	Nomenclature and abbreviation [samples horiz. x active lines/ Scanning/ frame rate]	Luma or R'G'B' Samples per active line (S/AL)	Active lines per frame (picture) (AL/F)	Frame rate, Hz	Luma or R'G'B' sampling[3] frequency (fs), MHz	Luma sample periods per total line (S/TL)	Total lines per frame	Net image Bit Rate (4:2:2, 10 bit) [Mbit/s]	Corresponding SMPTE system nomenclature
S1	1280x720/P/50 (abbreviated: 720/P/50)	1280	720	50	74.25	1980	750	921.6	Corresponds to SMPTE 296M System 3
S2	1920 x 1080/I/25 (abbreviated: 1080/I/25)	1920	1080	25 (50Hz field rate)	74.25	2640	1125	1036.8	Corresponds to SMPTE 274 System 6
S3	1920 x 1080/P/25 (abbreviated: 1080/P/25)	1920	1080	25	74.25	2640	1125	1036.8	Corresponds to SMPTE 274 System 9
S4	1920 x 1080/P/50 (abbreviated: 1080/P/50)	1920	1080	50	148.5	2640	1125	2073.6	Corresponds to SMPTE 274 System 3

Table 1: HDTV Systems 1 to 4

The digital representation shall employ eight or ten bits per sample in its uniformly quantized (linear) PCM coded form.

The image aspect ratio for system 1 to 4 shall be 16 x 9, and the sample 'aspect ratio'[4][5] shall be 1x1 ("square pixels").

5. System compliance

The specification of a system in compliance with this specification shall state, inter alia:

- Which of the systems of Table 1 are implemented
- Which signal interface is implemented (R'G'B', $Y'P_BP'_R$, $Y'C'_BC'_R$, R'G'B'A or $Y'\ C'_BC'_RA$)
- Which quantisation (eight, ten bit) is used.

6. System colorimetry and opto-electrical conversion for system S1 to S4

1.1. Equipment shall be designed in accordance with the colorimetric analysis and opto-electronic transfer function defined in ITU-R BT.1361.

1.2. Picture information shall be linearly represented by red, green and blue tri-stimulus values (RGB), lying in the range 0 (reference black) to 1 (reference white), whose colorimetric attributes are based upon reference primaries with the following chromaticity coordinates, in conformance with ITU-R BT.1361, and whose white reference conforms to CIE D65 as defined by CIE 15.2 and table 2:

[3] Usually the sampling frequency on the interface; some equipment may use a different sampling frequency internally
[4] The ratio of the densities of vertical 'samples' and horizontal 'samples'
[5] For interlace scanning several factors reduce vertical resolution , please see EBU Tech 3298

Item	Parameter	Value	
1	Opto-electronic transfer characteristics before non-linear pre-correction	Assumed linear	
2	Overall opto-electronic transfer characteristics at source	$V = 1.099\ L^{0.45} - 0.099$ 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	
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
4	Assumed chromaticity for equal primary signals (reference white):	D_{65}	
		X	y
	– $E_R = E_G = E_B$	0.3127	0.3290

Table 2: Opto-electronic conversion characteristics

7. Signal Formats for System 1 to 4

Item	Parameter	Value
1	Conceptual non-linear pre-correction of primary signals	Γ=0.45
2	Derivation of luminance signal Y’	Y’ = 0.2126 R + 0.7152 G’ + 0.0722 B’
3	Derivation of colour-difference component signals. P'_B, P'_R are filtered and may be coded as C'_B, C'_R components for digital transmissions. For system 1 an example filter template is given in SMPTE 296M Figure B.2. For system 2 to 4 an example filter template is given in SMPTE 274-2004 Figure D.2.	$P'_B = \frac{0.5}{1-0.0722}(B'-Y')$ $P'_R = \frac{0.5}{1-0.2126}(R'-Y')$

Table 3: Signal formats

8. Raster structure, digital picture representation and timing reference

The raster structure, digital picture representation and timing reference for System 1 shall be according to SMPTE 296M and for System 2, 3 and 4 in accordance with SMPTE 274M.

9. Digital Signal Formats for System 1 to 4

1.3. The digital signal format for system 1 to 4 shall employ R'G'B' or Y'C'$_R$C'$_B$ components.

1.4. The digital signals should be pre-filtered prior to sampling to prevent aliasing

1.5. The nominal bandwidth for system 1 to 3 shall be 30MHz and shall be 60MHz for system 4 according to table 4.

Bandwidth and sampling frequency	Signal component	Systems 1,2,3 (4:2:2)	System 4[6] (4:2:2)
Bandwidth	R', G', B'	30 MHz	60MHz
	Y'	30 MHz	60MHz
	C'$_B$, C'$_R$	15 MHz	30MHz
Interface sampling frequency	R', G', B'	74.25MHz	148.5MHz
	Y'	74.25MHz	148.5MHz
	C'$_B$, C'$_R$	37.125MHz	74.25MHz

Table 4 Bandwidth for each system

Further details and example filter templates are given in SMPTE 296M for system 1 and SMPTE 274 for system 2 to 4.

10. Digital Interfaces

1.6. Systems 1 to 3 should employ the single link Bit Serial Interface according to SMPTE 292M, which operates at a nominal bit-rate of 1.485Gbit/s at 8 and 10 bit resolution. SMPTE 292M defines the coaxial interface and SMPTE 297M defines the optical interface.

1.7. Conversion from 8 bit to 10 bit shall be performed by adding two padding bits

1.8. Users are advised that the SMPTE 292M interface represents a "standard-interface for real-time HDTV signals" in traditional studio infrastructures which is similar to the SDTV serial digital interface (SDI).

Informative Note: The SMPTE is currently revising SMPTE 292 with respect to the interface. Check also for a revised SMPTE 297M standard for the optical interface part.

1.9. R'G'B' encoding of System 2 and 3, and Y'C'$_B$, C'$_R$ for System 4 currently require the dual link bit serial interface version of SMPTE 292M as specified in SMPTE 372M.

Informative Note: Users should be aware that only a limited number of systems are available today to support System 4 and that setting up a large television production studio infrastructure with a dual-link interface may be a complex task. Studies are planned on light compression systems for studio use with System 4, including the use of 4:2:0 compression. System 4 technologies are in development by several manufacturers.

1.10. For file format transport of Systems 1 to 4, the Material Exchange Format (MXF), according to SMPTE 377M, should be used. The mapping of uncompressed pictures in MXF covering systems 1 to 4 of this specification is defined in SMPTE 384M.

1.11. Informative section on data exchange using compressed versions of systems 1 to 4

There are possibilities of mapping data corresponding to compressed versions of systems 1 to 4 into bit-serial digital interfaces such as SMPTE 305M (SDTI) and SMPTE 348M (H-SDTI). Further studies are required before any of these interfaces and compression algorithms can be recommended, however. This is also true for a file format mapping of compressed versions of systems 1 to 4.

[6] Users are advised to verify the bandwidth values with practical implementations