

High Definition (HD) Image Formats for Television Production

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High Definition (HD) Image Formats for Television Production

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1. Introduction

This document specifies the basic image formats and digital sampling systems for High Definition Television (HDTV) production in the European 50 Hz environment. It is intended to meet the demands of EBU Members for interoperability and implementation stability in their HDTV production systems. The application of this specification is intended for, but not limited to, the television production environment.

Four HDTV production systems are recognised for use in Europe:

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

In order to transport these signals around a production site, variants of the HD-SDI (High Definition Serial Digital Interface) are typically used. Designers of HD-SDI infrastructures should carefully study whether to apply the 1.485 Gbit/s single link HD-SDI (specified in SMPTE 292M) for Systems S1, S2 and S3 only, or an advanced 2.97 Gbit/s single link HD-SDI (specified in SMPTE 424M) for Systems S1 to S4 inclusive, but with some additional constraints. Section 10 of this document discusses these interfaces and their practical constraints in more detail.

2. Normative references

This specification depends upon the following external specifications, which define in detail:

- 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.

Note that the apostrophe, ' , in the above means that the signal has been gamma corrected.

| Normative Reference | Title |
|-----------------------------|---|
| SMPTE 274M-2008 | 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-2008 | HDTV Signal/Data Serial Interface |
| SMPTE 372M-2009 | Dual Link SMPTE 292M Interface for 1920 x 1080 Picture Raster |
| SMPTE 424M-2006 | 3 Gbit/s Signal/Data Serial Interface ("3G SDI") |
| SMPTE 425-2008 | 3 Gbit/s Signal/Data Serial Interface - Source Image Format Mapping |
| SMPTE 297M-2006 | Fibre Optic Interfaces for SDTV and HDTV interfaces. |
| SMPTE 377M-1 2009 | MXF File Format Specification |
| SMPTE 384M-2005 | Mapping of uncompressed pictures to the MXF Generic Container |
| CIE Publication 15.2 (1986) | Colorimetry, Second Edition. |
| ITU-R BT.1361-1 | Worldwide unified colorimetry and related characteristics of future television and imaging systems |
| ITU-R BT.709-5 | Parameter values for the HDTV standards for production and international programme exchange |

3. Other References

| Reference | Title |
|-----------------|---|
| EBU Tech 3298 | An EBU "route map" to High Definition (HD) |
| EBU R112-2004 | EBU Statement on HDTV standards |
| EBU R124-2009 | Choice of HDTV Compression Algorithm and Bitrate for Acquisition, Production, Contribution & Distribution |
| ITU-R BT.1120-5 | Digital interfaces HDTV studio signals |
| ITU-R BT.136-1 | Serial digital fibre transmission system for signals conforming to Rec 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. ITU-R BT.656, 799 and 1120 |
| ITU-R BT.1577 | SDI-based transport interface for compressed television signals in networked television production based on Rec. ITU-R BT.1120 |
| ITU-R BT.1847 | 1280 x 720, 16:9 progressively-captured image format for production and international programme exchange in the 50 Hz environment |

4. Nomenclatures and Image Sampling Systems

Table 1: HDTV Systems 1 to 4

| EBU System | Nomenclature ¹ of abbreviations [activeLinesScanning /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 ² frequency (fs), MHz | Luma sample periods per total line (S/TL) | Total lines per frame | Net image Bit Rate (4:2:2, 10 bit) [Gbit/s] | Corresponding SMPTE system nomenclature |
|------------|--|---|---|--------------------------|--|---|-----------------------|---|---|
| S1 | 720p/50 | 1280 | 720 | 50 | 74.25 | 1980 | 750 | 0.92 | SMPTE 296M System 3 |
| S2 | 1080i/25 | 1920 | 1080 | 25 (50 Hz field rate) | 74.25 | 2640 | 1125 | 1.04 | SMPTE 274 System 6 |
| S3 | 1080p/25 | 1920 | 1080 | 25 | 74.25 | 2640 | 1125 | 1.04 | SMPTE 274 System 9 |
| S4 | 1080p/50 | 1920 | 1080 | 50 | 148.5 | 2640 | 1125 | 2.08 | SMPTE 274 System 3 |

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

The image aspect ratio for Systems S1 to S4 shall be 16:9, and the sample 'aspect ratio'³⁴ shall be 1x1 ("square pixels").

5. System compliance

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

- Which of the systems of Table 1 is implemented
- Which signal interface is implemented (R'G'B', Y'PBP'R, Y'C'BC'R, R'G'B'A or Y' C'BC'RA)
- Which quantisation (eight bit, ten bit) is used.
- In the case of 3G-SDI interfaces, which Level is implemented (see § 10.2) and what is the tested cable length (including cable type, BNC, crimping technology, etc.).

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

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

¹ The EBU uses the nomenclature in Table 1 whilst the ITU-R uses a different nomenclature, such as 'interlaced as "2:1"' or alternatively '1920 x 1080/50/I' where "50" corresponds to the field-rate (see ITU-R BT.1846)

² Usually the sampling frequency on the interface; some equipment may use a different sampling frequency internally.

³ The ratio of the densities of vertical 'samples' and horizontal 'samples'.

⁴ For interlace scanning several factors reduce vertical resolution, please see EBU Tech 3298.

Table 2: Opto-electronic conversion characteristics

| 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 |

7. Signal Formats for Systems S1 to S4

Table 3: Signal formats

| Item | Parameter | Value |
|------|---|---|
| 1 | Conceptual non-linear pre correction of primary signals | $\Gamma=0.45$ |
| 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 S1 an example filter template is given in <i>SMPTE 296M Figure B.2</i> . For Systems S2 to S4 an example filter template is given in <i>SMPTE 274-2004 Figure D.2</i> . | $P'_B = \frac{0.5}{1 - 0.0722} (B' - Y')$ $P'_R = \frac{0.5}{1 - 0.0722} (B' - Y')$ |

8. Raster structure, digital picture representation and timing reference

The raster structure, digital picture representation and timing reference for System S1 shall be according to *SMPTE 296M* and for Systems S2, S3 and S4 in accordance with *SMPTE 274M*.

9. Digital Signal Formats for System S1 to S4

- The digital signal format for Systems S1 to 4 shall employ R'G'B' or Y'C'R C'B components.
- The digital signals should be pre-filtered prior to sampling to prevent aliasing.
- The nominal bandwidth for Systems S1 to S3 shall be 30 MHz and shall be 60 MHz for System S4 according to Table 4.

Table 4: Bandwidth for each System

| Bandwidth and sampling frequency | Signal component | Systems S1, S2 and S3 (4:2:2) | System S4 ⁵ (4:2:2) |
|----------------------------------|-----------------------------------|-------------------------------|--------------------------------|
| Bandwidth | R', G', B' | 30 MHz | 60 MHz |
| | Y' | 30 MHz | 60 MHz |
| | C' _B , C' _R | 15 MHz | 30 MHz |
| Interface sampling frequency | R', G', B' | 74.25 MHz | 148.5 MHz |
| | Y' | 74.25 MHz | 148.5 MHz |
| | C' _B , C' _R | 37.125 MHz | 74.25 MHz |

Further details and example filter templates are given in *SMPTE 296M* for System S1 and *SMPTE 274* for Systems S2 to S4.

10. Digital Interfaces and their constraints

10.1 1.5 Gbit/s HD-SDI

Systems S1 to S3 can be transferred over the single link HD-SDI described in *SMPTE 292M*, which operates at a nominal bit-rate of 1.485 Gbit/s at 8-bit and 10-bit resolution. *SMPTE 292M* defines the coaxial interface and *SMPTE 297M* defines the optical interface.

10.2 3 Gbit/s HD-SDI

Systems S1 to S4 can also be transferred over the single link HD-SDI described in *SMPTE 424M-2006*, which operates at a nominal bit-rate of 2.97 Gbit/s at 10-bit resolution. As well as a coaxial interface there is also an optical transmission specification (*SMPTE 297M-2006*) available. Further considerations when employing this “3G-SDI” interface are:

10.3 Coaxial cable length

In 3G-SDI particular attention should be given to the type, quality and length of the coaxial cable. It should be noted that depending on the implementation in products and the type and quality of the coax cable used, the workable cable length can typically vary between 70 - 140 m.

Passive components such as patch panels and in particular the type and quality of the BNC connectors used and how they are crimped to the coax cables will significantly impact the maximum cable length.

10.4 3G-SDI mapping Levels

The 3G-SDI interface allows for two different mappings of the image format, described in *SMPTE 425-2008*. This choice of Level also impacts the number of embedded audio channels that can be carried in the interface. Users of the interface should pay particular attention that their production equipment supports the Levels required in operation.

Note An EBU project (P/HIPS) is addressing the issue of interoperability between the two Levels (January 2010).

⁵ Users are advised to verify the bandwidth values with practical implementations of S4.

11. General remarks concerning 3G SDI

- It is suggested that users should investigate the possible implementation of the 3G-SDI interface in their HDTV installations. For existing HDTV installations, users should investigate whether they can upgrade their interfaces to 3G-SDI.
- Conversion from 8-bit to 10-bit shall be performed by adding two padding bits.
- R'G'B' encoding for Systems S2 and S3, and Y'C'_B, C'_R for System S4, require using either the dual link bit serial interface version of *SMPTE 292M* as specified in *SMPTE 372M*, or preferably, the single link 3G-SDI (*SMPTE 424M*) interface described above.
- For file format transport of Systems S1 to S4, the Material Exchange Format (MXF), described in *SMPTE 377M*, should be used. The mapping of uncompressed pictures in MXF, including Systems S1 to S4, is defined in *SMPTE 384M*.

12. System S4 infrastructure (informative note)

Users should be aware that whereas an increasing number of dedicated production systems are available today to support 1080p/50, complex IT-based studio production systems are not yet available for System S4.