HDR Signaling and Propagation Within IP Workflows

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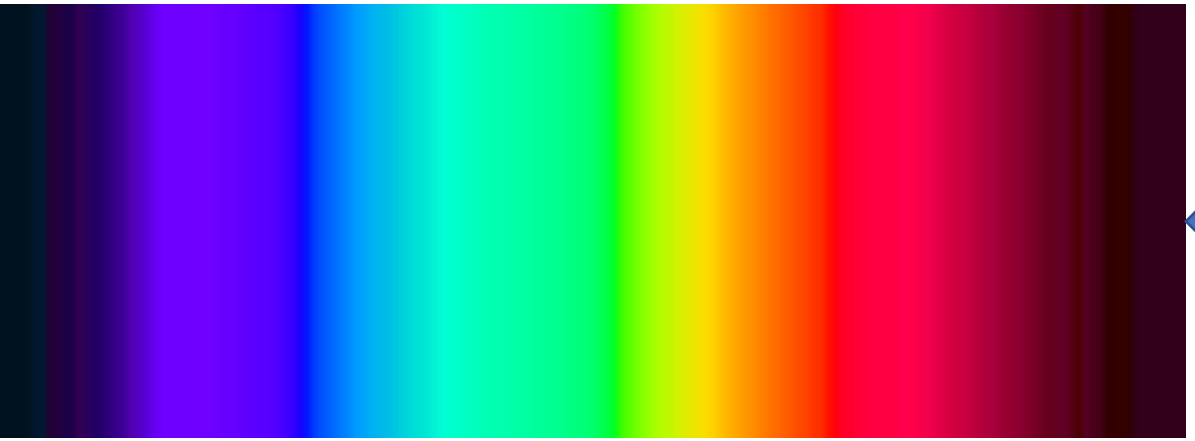
HDR Signaling? Is there a problem here?

- **SMPTE 2110 (and also SDI and every file format and codec) use numbers to represent color values.**
- **There are thousands of ways to do this, and *dozens of them* are in use in different corners of the television industry**
- **How do we know what a given tuple of "pixel data" means?**



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By: Phrood - Own work (Public Domain)

HDR Signaling – How does SDI do it?

- If its 525@29.97, or 625@25 then probably its ITU Rec 601
  - Typical today is 4:2:2/10 bits, but 8-bit also existed
  - 525 and 625 are slightly different R, G, B values
  - RGB 4:4:4 systems also exist

Item	Characteristics				
	Parameter		625		525
2.6.1	Chromaticity coordinates, CIE 1931[1]		x	y	x	y
	Primaries	Red	0.640	0.330	0.630	0.340
		Green	0.290	0.600	0.310	0.595
		Blue	0.150	0.060	0.155	0.070
2.6.2	Assumed chromaticity for equal primary signals – Reference white		D_{65}			
			x		y	
	$E_R = E_G = E_B$		0.3127		0.3290	
2.6.3	Opto-electronic transfer characteristics before non-linear precorrection		Assumed linear			
2.6.4	Overall opto-electronic transfer characteristic at source[3]		$E = (1.099\,L^{0.45} - 0.099)$ for $1.00 \geq L \geq 0.018$ $E = 4.500\,L$ for $0.018 > L \geq 0$ where: L: luminance of the image $0 \leq L \leq 1$ for conventional colorimetry E: corresponding electrical signal.			

$$D'_Y = \mathrm{INT}\left[\,0.299\,D'_R + 0.587\,D'_G + 0.114\,D'_B\,\right]$$

$$D'_{CB} = \mathrm{INT}\left[\frac{-0.299\,D'_R - 0.587\,D'_G + 0.886\,D'_B}{1.772} \times \frac{224}{219} + 2^{n-1}\right]$$

$$D'_{CR} = \mathrm{INT}\left[\frac{0.701\,D'_R - 0.587\,D'_G - 0.114\,D'_B}{1.402} \times \frac{224}{219} + 2^{n-1}\right]$$

HDR Signaling – how does SDI do it?

- If its 1080i@29 or 1080i@25, then ITU Rec 709 applies
- If its 1080p@29 or 1080p@25, then ITU Rec 709 probably applies
- If its 1080p@59 or 1080p@50, then ITU Rec 709 *might apply*
- Typically, 4:2:2/10 bit, but 4:4:4/10 and even 4:4:4/12 also exist

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	

$$D'_Y = \mathrm{INT}\left[\,0.2126D'_R + 0.7152D'_G + 0.0722D'_B\,\right]$$

$$D'_{CB} = \mathrm{INT}\left[\left(-\frac{0.2126}{1.8556}D'_R - \frac{0.7152}{1.8556}D'_G + \frac{0.9278}{1.8556}D'_B\right)\cdot\frac{224}{219} + 2^{n-1}\right]$$

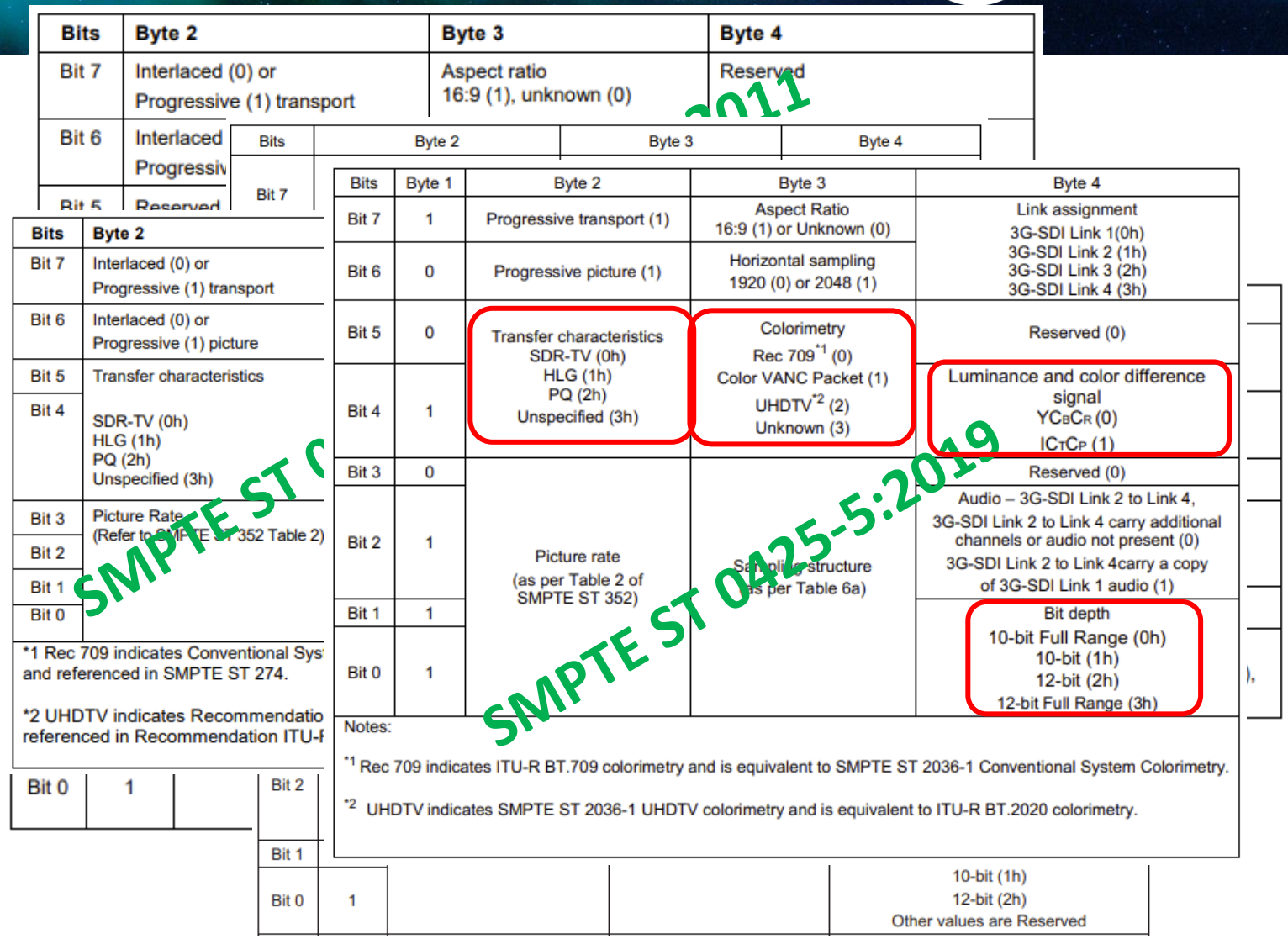
$$D'_{CR} = \mathrm{INT}\left[\left(\frac{0.7874}{1.5748}D'_R - \frac{0.7152}{1.5748}D'_G - \frac{0.0722}{1.5748}D'_B\right)\cdot\frac{224}{219} + 2^{n-1}\right]$$

HDR Signaling – Might Apply? ??

- SMPTE introduced Video Payload ID (VPID) to capture the emerging variations of SDI – including colorspace and transfer characteristics
- VPID is required on 1080p50 & 1080p59 signals (and above)
- VPID is rare on 1080i and below

What is this VPID thing anyway?

- SD-SDI was simple enough
- HD-SDI was just faster bits
- SMPTE ST 425-1 defined it first, but only for 3GSDI
- SMPTE ST 352:2013 generalized it for SD & HD
- 425-1 revised twice since
- 425-5 defines it for UHD
  - In 2014
  - Then again in 2015
  - Then perfectly in 2019



Bits	Byte 2	Byte 3	Byte 4
Bit 7	Interlaced (0) or Progressive (1) transport	Aspect ratio 16:9 (1), unknown (0)	Reserved
Bit 6	Interlaced Progressiv		
Bit 5	Reserved		

2011

Bits	Byte 2	Byte 3	Byte 4
Bit 7			

Bits	Byte 2
Bit 7	Interlaced (0) or Progressive (1) transport
Bit 6	Interlaced (0) or Progressive (1) picture
Bit 5	Transfer characteristics
Bit 4	SDR-TV (0h) HLG (1h) PQ (2h) Unspecified (3h)
Bit 3	Picture Rate (Refer to SMPTE ST 352 Table 2)
Bit 2	
Bit 1	
Bit 0	

*1 Rec 709 indicates Conventional Sys and referenced in SMPTE ST 274.

*2 UHDTV indicates Recommendatio referenced in Recommendation ITU-

SMPTE ST

Bits	Byte 1	Byte 2	Byte 3	Byte 4
Bit 7	1	Progressive transport (1)	Aspect Ratio 16:9 (1) or Unknown (0)	Link assignment 3G-SDI Link 1(0h) 3G-SDI Link 2 (1h) 3G-SDI Link 3 (2h) 3G-SDI Link 4 (3h)
Bit 6	0	Progressive picture (1)	Horizontal sampling 1920 (0) or 2048 (1)	
Bit 5	0	Transfer characteristics SDR-TV (0h) HLG (1h) PQ (2h) Unspecified (3h)	Colorimetry Rec 709*1 (0) Color VANC Packet (1) UHDTV*2 (2) Unknown (3)	Reserved (0)
Bit 4	1			Luminance and color difference signal YCBCR (0) ICTCP (1)
Bit 3	0	Picture rate (as per Table 2 of SMPTE ST 352)	Sampling structure (as per Table 6a)	Reserved (0)
Bit 2	1			Audio – 3G-SDI Link 2 to Link 4, 3G-SDI Link 2 to Link 4 carry additional channels or audio not present (0) 3G-SDI Link 2 to Link 4carry a copy of 3G-SDI Link 1 audio (1)
Bit 1	1			Bit depth 10-bit Full Range (0h) 10-bit (1h) 12-bit (2h) 12-bit Full Range (3h)
Bit 0	1			

Notes:

*1 Rec 709 indicates ITU-R BT.709 colorimetry and is equivalent to SMPTE ST 2036-1 Conventional System Colorimetry.

*2 UHDTV indicates SMPTE ST 2036-1 UHDTV colorimetry and is equivalent to ITU-R BT.2020 colorimetry.

SMPTE ST 0425-5:2019

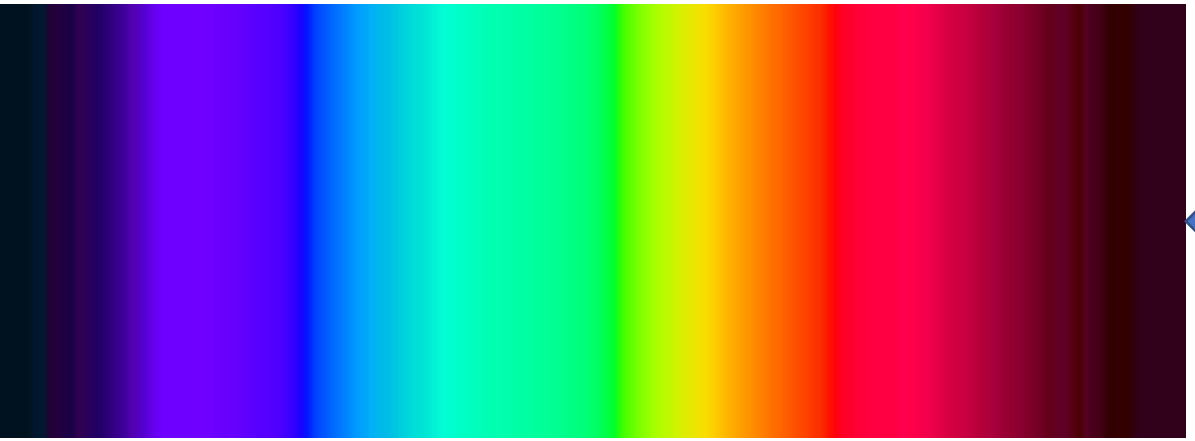
Bit 0	1			10-bit (1h) 12-bit (2h) Other values are Reserved

Bit 2			
Bit 1			

✘ Not Every Piece of Equipment gets it right – for some value of “right”

Describing light with numbers

- **Transfer Characteristic (OETF/EOTF, linear to nonlinear)**
- **Colorspace (R’ G’ B’ → Y’ Cb’ Cr’) (or X’Y’Z’ or I’Ct’Cp’ or…)**
- **Sampling – 4:4:4, 4:2:2, 4:2:0, and bit depth**



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2110-20 developed an extensible lingo

- colorimetry = [BT601, BT709, BT2020, BT2100, ST2065-1, ST2065-3, …]
- sampling = [YCbCr-4:2:2, YCbCr-4:4:4, RGB, XYZ, KEY, …]
- depth = [8, 10, 12, 16, 16f]
- TCS = [SDR, HLG, PQ, LINEAR, ST2065-1, DENSITY, …]
- RANGE = [NARROW, FULL, FULLPROTECT]

- There is a huge space of permutations of the above, with a sparse set of operating points that are used in reality
- ***This lingo for describing the signal could outlive ST2110-20 itself***
  - Also used for JPEG-XS and other emerging new format descriptions

ST 2110 – data –vs- metadata

- In ST 2110-20, pixel data is transported in a tight-packed format inside the IP datagrams.
- The “decoder ring” (metadata) for parsing, understanding and using the pixel data is sent ahead of time in the SDP, so the receiver knows what its getting

- But what if the metadata (the decoder ring) changes ?
  - Structural changes (width, height, sampling, bit depth, frame rate)
  - Interpretation changes (Colorimetry and TCS)
  - HOW DOES THE RECEIVER FIND OUT THE NEW METADATA?

HDR Signaling and Controllers

- In ST 2110-x environments, generally there is a “broadcast controller”
  - Finds and Inventories the endpoints through AMWA IS-04 and other means
  - Makes connections of senders to receivers using IS-05 and other means
- To be effective in the real world, the controller must also handle:
  - Tracking changes of the senders (metadata changes)
  - Propagating these changes to all current receivers rapidly
- Note that changes to metadata might make a signal unsuitable for certain receivers – and receiver can object to the new signal

2110-40, VPID, and dynamic sigaling

- ST2110-40 transports ANC data (generically) over IP
  - And VPID is technically an ANC data packet
- Should VPID be transported over 2110-40?
  - Opinions vary – and there are arguments both ways on this point
  - 2110-20 is clear that the SDP must reflect correct data
  - 2110-40 is a separate essence and does not necessarily follow the video
- We cannot have a garbage-in garbage-out world
  - Devices that produce SDI output are responsible for their output VPID
  - A VPID on -40 may not be relevant for the output (format conversion, etc)
- SDP can express combinations that are not representable in SDI VPID
- Receivers should trust the SDP more than anything that comes in -40

What about dynamic HDR metadata?

- HLG is a “fixed” system with no metadata, perfect for production
- PQ can be fixed also, and in production environments likely is
- Recently VANC packets have been defined for dynamic metadata
  - Colorimetry VANC packet
  - HDR metadata packets

- These add additional information that is NOT in the SDP, and should be carried in 2110-40, and used by receivers which understand them

HDR Signaling – to sum up

- SDI can do what it can do
- 2110-20 & SDP can express more different formats, extensibly
- VPID in -40 doesn’t replace the need to follow the SDP (so why…?)
- HDR dynamic metadata can be routed alongside the video with -40 since it supplements (but should not contradict) the SDP

Any Questions?

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