HDR and WCG Video Broadcasting Considerations

By Mohieddin Moradi
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OUTLINE

- Elements of High-Quality Image Production
- Color Gamut Conversion (Gamut Mapping and Inverse Gamut Mapping)
- Gamma, OETF, EOTF, OOTF, PQ and HLG HDR
- HDR & SDR Mastering, Mapping, Tone Mapping and Inverse Tone Mapping
- Static and Dynamic Tone Mapping
- Backwards Compatibility
- HDR and WCG Production Equipment
- DVB UHD Phases
- HDR Metadata and HDR Standards
- PQ10 and HLG10 Distribution Standards
- Different Distribution Scenarios
- HDR Ecosystem (Open Standard and Dolby Vision)
Elements of High-Quality Image Production

Q1  Spatial Resolution (HD, UHD)
Q2  Temporal Resolution (Frame Rate) (HFR)
Q3  Dynamic Range (SDR, HDR)
Q4  Color Gamut (BT. 709, BT. 2020)
Q5  Coding (Quantization, Bit Depth)
Q6  Compression Artifacts

Not only more pixels, but better pixels

Total Quality of Experience (QoE or QoX) = f(Q_1, Q_2, Q_3, ...)
Q1: Spatial Resolution

SD (PAL) 720 x 576 0.414MPs
HDTV 720P 1280 x 720 0.922 MPs
HDTV 1920 x 1080 2.027 MPs
Digital Cinema 2K 2048 x 1080 2.21 MPs
UHDTV 1 3840 x 2160 8.3 MPs
4K 4096 x 2160 8.84 MPs
UHDTV 2 7680 x 4320 33.18 MPs
8K 8192 x 4320 35.19 MPs

Wider viewing angle
More immersive
Q2: High Frame Rate (HFR)

Conventional Frame Rate

- Motion Blur
- Motion Judder

High Frame Rate

- Wider viewing angle
- Increased perceived motion artifacts
- Higher frame rates needed
  50fps minimum (100fps being vetted)
Q3: Wide Color Gamut

- Deeper Colors
- More Realistic Pictures
- More Colorful
Q4: **High Dynamic Range**

Standard Dynamic Range

High Dynamic Range

(More Vivid, More Detail)
Q5: Quantization (Bit Depth)

- More colours
- More bits (10-bit)
- Banding, Contouring

8 bits 256 Levels

10 bits 1024 Levels
Major Elements of High-Quality Image Production

Spatial Resolution (Pixels)
HD, FHD, UHD1, UHD2

Quantization (Bit Depth)
8 bits, 10 bits, 12 bits …

Temporal Resolution (Frame rate)
24fps, 30fps, 60fps, 120fps …

Color Space (Gamut)
From BT 709 to Rec. 2020

Dynamic Range (Contrast)
From 100 nits to HDR

4K/8K (Higher Resolutions)

Bit Depth

High Frame Rate

WCG (Wide Color Gamut)

HDR (High Dynamic Range)
Carrying HDR and WCG to Home

Acquisition and Production → Post Production → Contribution → Distribution
Brief Summary of ITU-R BT.709, BT.2020, and BT.2100

- ITU-R BT.709, BT.2020 and BT.2100 address transfer function, color space, matrix coefficients, and more. The following table is a summary comparison of those three documents.

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<tr>
<th></th>
<th>ITU-R BT.709</th>
<th>ITU-R BT.2020</th>
<th>ITU-R BT.2100</th>
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<tr>
<td><strong>Spatial Resolution</strong></td>
<td>HD</td>
<td>UHD, 8K</td>
<td>HD, UHD, 8K</td>
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<td><strong>Framerates</strong></td>
<td>24, 25, 30, 50, 60</td>
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<td><strong>Interlace/Progressive</strong></td>
<td>Interlace, Progressive</td>
<td>Progressive</td>
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<td><strong>Color Space</strong></td>
<td><strong>BT.709</strong></td>
<td><strong>BT.2020</strong></td>
<td><strong>BT.2020</strong></td>
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<td><strong>Dynamic Range</strong></td>
<td>SDR (BT.1886)</td>
<td>SDR (BT.1886)</td>
<td>HDR (PQ, HLG)</td>
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<td><strong>Bit Depth</strong></td>
<td>8, 10</td>
<td>10, 12</td>
<td>10, 12</td>
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<td><strong>Color Representation</strong></td>
<td>RGB, YCbCr</td>
<td>RGB, YCbCr</td>
<td>RGB, YCbCr, ICTCP</td>
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</tbody>
</table>
HDR & SDR End-to-End Production Workflows
Color Gamut Conversion (Gamut Mapping and Inverse Mapping)

RGB 100% Color Bar
Rec. 709
Rec. 2020

Wide Color Space (ITU-R Rec. BT.2020) 75.8%, of CIE 1931

Color Space (ITU-R Rec. BT.709) 35.9%, of CIE 1931
Transformation from a Wider Gamut Space to a Smaller One

Three Approaches:

I. Clipping the RGB (clipping distortions)
II. Perceptual gamut mapping (more computations and possibly changing the ‘creative intent’)
III. Leaving the RGB values as they are and let the screen think that they relate to primaries of ITU-R BT.709.

Without any corrections (gamut mapping), the image appear less saturated.

Munsell Chart

J Munsell Chart in BT.2020 as perceived on a BT.709 display
Smaller Gamut Space in a Wide Gamut Display

- Without any corrections color saturation will be increased.

**Munsell Chart**

<table>
<thead>
<tr>
<th>A</th>
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<tr>
<td>J</td>
<td>Munsell Chart in BT.709 as perceived on a BT.2020 display</td>
<td></td>
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</table>
Gamma, EOTF, OETF

- **Opto-Electronic Transfer Function (OETF):** Scene light to electrical signal
- **Electro-Optical Transfer Function (EOTF):** Electrical signal to scene light
Gamma, EOTF, OETF

- **Opto-Electronic Transfer Function (OETF):** Scene light to electrical signal
- **Electro-Optical Transfer Function (EOTF):** Electrical signal to scene light

The CRT EOTF is commonly known as gamma
OOTF (Opto-Optical Transfer Function)

- Adjustment or Artistic Intent (Non-Linear Overall Transfer Function)
- System (total) gamma to adjust the final look of displayed images (Actual scene light to display luminance Transfer function)
- The “reference OOTF” compensates for difference in tonal perception between the environment of the camera and that of the display specification (OOTF varies according to viewing environment and display brightness)
On a flat screen display (LCD, Plasma,..) without OOTF, it appears as if the black level is elevated a little.

To compensate the black level elevation and to make images look closer to CRT, a display gamma = 2.4 has been defined under BT.1886.

As a result, OOTF = 1.2
OOTF Position

- Perceptual Quantization (PQ) (Optional Metadata)
- Hybrid Log-Gamma (HLG)

For viewing in the end-user consumer TV, a display mapping should be performed to adjust the reference OOTF on the basis of mastering peak luminance metadata of professional display:

OOTF is implemented within the display and is aware of its peak luminance and environment (No metadata)
Scene-Referred and Display-Referred

**Scene-Referred:**
- The HLG signal describes the **relative** light in the scene
- Every pixel in the image represents the **light intensity** in the captured scene
- The signal produced by the camera is **independent of the display**
- The signal is specified by the camera OETF characteristic

**Display-Referred:**
- The PQ signal describes the **absolute output light** from the mastering display
- The signal is specified by the display EOTF
Code Levels Distribution in HDR

Uniform Code Words for Perceived Brightness

- BT.709 with 8 bit code levels
- BT.709 with 10 bit code levels
- DICOM Part 14
- Perceptual Quantiser, SMPTE ST 2084:2014
- BBC HDR Proposal - 10 bit code levels
PQ EOTF

Minimum Detectable Contrast (%) = \frac{\text{Minimum Detectable Difference in Luminance}}{\text{Luminance}} \times 100 = \frac{\Delta L}{L} \times 100

Code words are equally spaced in perceived brightness over this range nits.
Code Words Utilization by Luminance Range in PQ

- PQ headroom from 5000 to 10,000 nits = 7% of code space
- 100 nits is near the midpoint of the code range
Hybrid Log-Gamma (HLG) HDR-TV

ITU-R Application 2, ARIB B67 (Association of Radio Industries and Businesses)

\[ E' = \text{OETF}[E] = \begin{cases} \sqrt{3E} & 0 \leq E \leq \gamma_0 \\ a \cdot \ln(12E-b) + c & \gamma_0 < E \leq 1 \end{cases} \]

**Signal Value**
- Linear light
- SDR gamma curve
- SDR with Knee
- HDR HLG

**E**: The signal for each color component \( \{R_s, G_s, B_s\} \) proportional to scene linear light and scaled by camera exposure, normalized to the range \([0:12]\).

**E'**: The resulting non-linear HLG coded signal \( \{R', G', B'\} \) in the range \([0:1]\).

\[ a = 0.17883277, \ b = 0.28466892, \ c = 0.55991073 \]

**Less Code Words for Dark Area**

**More Code Words for Dark Area**
 HDR & SDR Mastering

Technical Grading
(Lift/Gain/Gamma)

Creative Grading
(Creative Intention)

Finishing for SDR
(SDR Master)

Finishing for HDR
(HDR Master)

SDR BT.709

HDR BT.2020
Tone Mapping and Inverse Tone Mapping

Tone Mapping (Down-conversion)
Limiting Luminance Range

HDR Signal (BT.2020) ➔ SDR Signal (BT.709 or BT.2020) ➔ SDR (BT.709 or BT.2020)

Inverse Tone Mapping (Up-conversion)
Expanding Luminance Range

SDR Signal (BT.709 or BT.2020) ➔ HDR Signal (BT.2020) ➔ HDR BT.2020

HDR

SDR

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Static and Dynamic Tone Mapping

- Optimized only for the brightest scene in the contents
- This avoids hard clipping of detail in the highlights
- It is not invariant under blind multiple round-trip conversions.

Static Tone Mapping (HDR10)
Static and Dynamic Tone Mapping

- Optimized for each scene in the contents
- Ex: frame-by-frame, or scene-by-scene basis (Varying the EETF based on statistics of the image).
- This approach could survive multiple round-trip conversions

Dynamic Tone Mapping

200 nit

1500 nit

4000 nit

500

500

1,500

4,000
Mapping

- During the transition from SDR to HDR production (More SDR Display) or due to content owner preference
- To preserve the “look” of the SDR content on HDR Display

- Display-referred mapping
  To preserve the colors and relative tones of SDR on HDR Display

- Scene-referred mapping
  To match the colors and lowlights and mid-tones of SDR camera with HDR camera.
Backwards Compatibility

- Most of encoder/decoder and TVs are SDR (encoders/decoders replacement !??)
- Dolby Vision, Technicolor, Philips and BBC/NHK are all backwards compatible.
- Backwards compatibility is less of an issue in over-the-top (OTT).

(Color Signal)

HDR Signal  \(\rightarrow\)  SDR UHDTV

ITU-R BT.709 color space

HDR metadata simply is ignored

(Limited compatibility)
HLG and PQ Backwards Compatibility with SDR Displays

- It has a degree of compatibility.
- Hue changes can be perceptible in bright areas of highly saturated color or very high code values (Specular)

- Both PQ and HLG provide limited compatibility
There is no Metadata other than Video Payload Identifier (VPID) in the SDI feed.

- Camera
- Lens (Performance Improvement)
- Monitor (Especially Reference Monitor)
- Waveform Monitor
- Pattern Generator
- CG and Graphic System
- Playout and Ingest, Recorder and Player (HDMI Ports (HDMI 2.b))
- Cross Converters, SDI to HDMI Converter, HDMI to SDI Converter (HDMI 2.b)
- HDMI Ports (HDMI 2.b) (Multi viewer, Scan Converter, …)

- Video Production Switcher
- Digital Glues, Embedder and De-Embedder

- Lighting
Ex: Benefit of 4K Lens for WCG and HDR

- Both HD and 4K lens covers BT.2020.
- Improve the transparency of Blue in 4K lens
- Better S/N ratio.

- 4K lens can cut the flare and reduce black floating even in a backlit conditions.
- Black floating is more noticeable in HDR.
- Same object and same white level, but black level of
- HD: 21.9% (HD lens reduces dynamic range!)
- Full 4K: 11.6%
Ex: Color Bar Test Pattern for HDR TV Systems

- 100% colour bars
- 75% colour bars
- 40% colour bars
- 0% colour bars

BT. 709 colour bars
Ramp (-7% - 109%)
Stair (-7%, 0%, 10%, 20%, ..., 90%, 100%, 109%HLG)
Ex: HDR Heat-map Tool in Waveform Monitor

- User presets for SDR & HDR modes
- Selectable background grey /color
- Identify shadows, mid-tones or specular highlights
## HDR & HDMI

<table>
<thead>
<tr>
<th>Feature</th>
<th>HDMI 1.0</th>
<th>1.1</th>
<th>1.2-1.2a</th>
<th>1.3-1.3a</th>
<th>1.4-1.4b</th>
<th>2.0-2.0b</th>
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<tbody>
<tr>
<td>Full HD Blu-ray Disc and HD DVD video</td>
<td>Yes</td>
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<td>Consumer Electronic Control (CEC)</td>
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<td>Super Audio CD (SACD)</td>
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</table>

### HDMI 2.0a supports ST2084 (PQ) and ST2086 (Mastering Display Color Volume Metadata)

### HDMI 2.0b followed up on HDMI 2.0a and added support for HLG and the HDR10

### The HDMI 2.1 Specification will supersede 2.0b will support dynamic metadata and High Frame Rate

- **Audio return channel (ARC)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **4 audio streams**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **2 video streams (Dual View)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **Hybrid Log-Gamma (HLG)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **Static HDR (HDR static metadata)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **Dynamic HDR (HDR dynamic metadata)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: Yes
  - 2.1: Yes

- **Enhanced audio return channel (eARC)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes

- **Variable Refresh Rate (VRR)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes

- **Quick Media Switching (QMS)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes

- **Quick Frame Transport (QFT)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes

- **Auto Low Latency Mode (ALLM)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes

- **Display Stream Compression (DSC)**
  - 1.0: No
  - 1.1: No
  - 1.2-1.3a: No
  - 1.4-1.4b: No
  - 2.0-2.0b: No
  - 2.1: Yes
Carrying HDR and WCG to Home
## Specifications for UHDTV Broadcasting

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<th>ITU Text</th>
<th>Specification</th>
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<td><strong>Video signal</strong></td>
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<tr>
<td>Spatial format</td>
<td>Rec. ITU-R BT.2020</td>
<td>7680×4320, 3840×2160</td>
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<td>Frame frequency</td>
<td>Rec. ITU-R BT.2100</td>
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<td>Rec. ITU-R BT.2100</td>
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<td>Transfer function</td>
<td>Rec. ITU-R BT.2100</td>
<td>PQ, HLG</td>
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<tr>
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<td>Rec. ITU-T H.265</td>
<td>SDR</td>
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<td>Coding</td>
<td>Rec. ITU-R BT.1870</td>
<td>MPEG-H HEVC</td>
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<td>Coding</td>
<td>Rec. ITU-R BT.2073</td>
<td>MPEG-2 AAC, MPEG-4 AAC, MPEG-4 ALS</td>
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<td>Speaker configuration</td>
<td>Rec. ITU-R BS.2051</td>
<td>Channel-based (0+2+0 – 9+10+3), object-based</td>
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<td>Audio signal</td>
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<td>Coding</td>
<td>Rec. ITU-R BS.1196</td>
<td>IBB, HTML5</td>
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<td>Multimedia</td>
<td>Rec. ITU-R BT.2075</td>
<td>Closed captions</td>
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<td>Rec. ITU-T H.222.0</td>
<td>MPEG-2 TS</td>
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<td>Rep. ITU-R BT.2342</td>
<td>MMT/TLV</td>
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<td>Rec. ITU-R BT.1852</td>
<td>DVB-S2</td>
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<td>Rec. ITU-R BO.1784</td>
<td>ISDB-S3</td>
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<td>Satellite transmission</td>
<td>Rec. ITU-R BO.2098</td>
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</tbody>
</table>
World’s First: HDR Trial with Sky Germany (2015)

*HLG: Hybrid Log-Gamma (ITU-R Application 2)
HDR Ecosystem

Capturing/Post-production

- **Capturing**
  - HDR camera (Sony F65/F55)
  - **Editing**
    - plug-in tool (Baselight, ...)
    - FHD-HDR monitor (SIM2, Pulsar)
    - 4K RGB-OLED monitor (Sony BVM-X300)

- **OETF/EOTF**
  - Barten model (absolute)
  - SMPTE ST2084 EOTF
  - Philips OETF
  - Gamma base (relative)
  - BBC/NHK @ITU (Hybrid log-gamma OETF)
  - BT.1886 EOTF

- **Transmission**
  - Separate stream
    - (MPEG regular)
    - HDR/SDR
    - Scalable codec
    - Dolby Layered
    - MPEG SHVC (MPEG)
    - Compatible stream
    - BBC/HyLG Philips
    - Technicolor

- **Displaying**
  - HDR Video
  - EOTF Video
  - Linear LDR

Transmitting

- Broadcast
- IP delivery
- Physical media
  - (BD, DVD, memory)

Displaying

- Panel correction
  - HDR
  - SDR

Panel correction

- Linear HDR
- EOTF HDR
- Linear LDR
- HDR Video
- SDR Video
- EOTF gamma
- Linear LDR
- Panel correction

Signal Processing

- Linear space convert
- EOTF (according to OETF)
- Display mapping
- HDR, WCG (disp. manufac.)
- Dolby Vision
- Proprietary system
  - (Dynamic Meta)

HDR panel

- High brightness
- High power LED
  - (Toshiba, Pana, SS)
- XDR (Sony)
- High contrast
- W-OLED (LG)
- LD algorithm
  - (Toshiba, Pana, SS)
- XDR (Sony)
HDR Ecosystem and Technologies (Open Standard)

Capturing/Post-production
- Capturing/Editing
- Game
- Native Contents
- Raw Data
- Film
- CG Comp
- Still image
- Edit

Transmission
- Transmission
- Broadcast
- IP delivery
- Physical media
- (BD, DVD, memory)
- Enc
- Dec
- HDR Video
- EOTF HDR
- Linear HDR
- HDR

Displaying
- Processing
- Panel correction
- HDR

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OETF

[CTA] HDR10 Media Profile
- OETF (following EOTF)
- Single layer regular stream

HDR10 Static Metadata: SMPTE. 2086, MaxFALL, MaxCLL

Signal Processing
- ST2084 EOTF
- Display mapping

[ITU-R] Application-2 suggestion
- Hybrid Log-Gamma
- Single layer regular stream
- EOTF (following OETF)
- Display mapping
HDR Ecosystem and Technologies (Dolby Vision with License Fee)

Capturing/Post-production
- Capturing/Editing
- Video mastering

Transmission
- Transmitting
- Processing
- Displaying

Displaying
- Broadcast
- IP delivery
- Physical media (BD, DVD, memory)

Editing
- Native Contents
- Raw Data
- Film scan
- Still image
- Game GFX

OETF
- Edit
- CG Comp
- HDR master
- SDR master
- OETF gamma
- SDR Video
- HDR Video
- HDR HDR

Transmission
- Enc
- Dec
- HDR Video
- EOTF Video
- Linear LDR
- Panel correction

Signal Processing
- HDR Panel
- SDR

Dolby Vision
- proprietary grading tool
  (Enhanced layer, SDR, dy-meta)
- ST2084-1
  dual layer proprietary stream
- ST2084 EOTF
- Proprietary Display mapping
  (w/ Dynamic meta)
- Dolby Vision Certification
HDR and WCG in Versatile Video Coding (VVC) for Contribution and Distribution

- 50% bitrate saving – Direct-to-home
- 30% bitrate saving – Contribution

MPEG-2 VIDEO
1994

AVC
2003

HEVC
2013

VVC
2020
(JVET)

≈50% bitrate saving – Direct-to-home
≈30% bitrate saving – Contribution

2020
HDR Standards

- 4K Ultra Blu-ray
- Netflix
- Amazon
- VUDU
- YouTube Red
- UltraFlix
- PlayStation Video
- ULTRA
- Fandango
- Google play
- DirecTV
- Dish
- Xfinity

HDR Support Status
IFA 2017
HDR Standards

Dynamic Metadata for Color Transform (DMCVT)

Dolby Vision, HDR10+ (License-free Dynamic Metadata), SL-HDR1, Technicolor (PQ)

Static Metadata (Mastering Display Color Volume (MDCV) Metadata+ MaxCLL+ MaxFALL)

HDR10 (PQ + static metadata)

PQ10 (+ Optional static metadata)

No Metadata

HLG10, PQ10 (without metadata)
HDR Metadata and HDR/SDR Signal ID

1. Static metadata
   - **ST.2086**: profile of master monitor (min/max luminance, colorimetry)
   - **MaxFALL**: max frame-average in the stream
   - **MaxCLL**: max light level of a pixel in the stream
   - **PQ (ST.2084)**

   This metadata is generated at packaging for distribution (after the clip is completed).

2. Dynamic metadata
   - **ST.2094**: HDR to SDR tone-map (and color-space conversion)
   - **Dolby-Vision**, **Technicolor, Phillips**

   In post-production, these metadata can be generated at HDR to SDR grading (tone-mapping) i.e. versioning.
   This metadata may be used for end-user’s CE device to create SDR from HDR stream by each vendor’s proprietary hardware or software tools.

3. HDR/SDR signal ID
   To identify
   - OETFs (inv)PQ, HLG or R.709
   - Color Space R.2020, P3 or R.709
   - flags are (will be) defined for:
     - **SDI, HDMI** (VPIID)
     - **MXF, IMF** (Transfer Chara)
     - **AVC, HEVC** (VUI, SEI)

   This metadata is to be used for sink devices to have automatic signal OETF/Color Space detection.
   Sony will support this metadata when standardized.
**DVB UHD Phases and HDR Delivery**

**Resolution, 14bit, Scalability**

- **Phase 3**
  - 12bit, HFR, BT.2020, HDR, 4:2:2, 4:4:4,
  - Abject based audio

- **Phase 2**

- **Phase 1**
  - (specified by DVB, Jan. 14)

**2160p 100/120**
- Bit depth: 10 bit, 12 bit, 14 bit
- Color space: Rec. 2020
- Dynamic range: HDR
- Subsampling: 4:2:0, 4:2:2 and 4:4:4
- Audio: beyond 5.1 or object based
- Scalability: Yes
- Coding: HEVC Main 10

**2160p 50/60**
- Bit depth: 8 - 10 bit
- Color space: Rec. 709, optional: BT.2020
- Dynamic range: SDR
- Subsampling: 4:2:0
- Audio: Existing DVB toolbox
- Coding: HEVC Main 10

**2020p 100/120**
- Bit depth: 10 bit, 12 bit
- Color space: BT.2020
- Dynamic range: HDR
- Subsampling: 4:2:0, 4:2:2 and 4:4:4
- Audio: beyond 5.1 or object based
- Scalability: Yes
- Coding: HEVC Main 10

**Scalebility DVB UHD Phases and HDR Delivery**

- **2020+**
- **2017/2018**
- **2014/2015**
PQ10 & HLG10 HDR Systems in DVB Phase 2

- PQ10: PQ OETF, BT.2020, 10-bit, non-constant luminance YCbCr, narrow range
- HLG10: HLG OETF, BT.2020, 10-bit, non-constant luminance YCbCr, narrow range

**PQ10 (+ optional metadata)**

- Single layer HEVC Main10 Bitstream
- Bitstream is not backwards compatible to DVB-UHD phase 1 receivers

**HLG10**

- Single layer HEVC Main10 Bitstream
- Bitstream decodable by DVB-UHD phase 1 receivers as Standard Dynamic Range
### HDR information in HEVC Main 10 Profile (or H.264/MPEG-4 AVC)

- **VUI**: Video Usability Information
- **SEI**: Supplemental Enhancement Information
- **Alternative transfer characteristics**: In order to serve both SDR and HDR receivers with a single stream in the case of HLG

<table>
<thead>
<tr>
<th>HEVC Main10 Profile bitstream elements</th>
<th>Application value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PQ10</td>
</tr>
<tr>
<td>VUI</td>
<td></td>
</tr>
<tr>
<td>colour_primaries</td>
<td>9 (BT.2020 [3] space)</td>
</tr>
<tr>
<td>transfer_characteristics</td>
<td>16 (PQ)</td>
</tr>
<tr>
<td>matrix_coeffs</td>
<td>9 (Y’C_B C_R Non-constant luminance)</td>
</tr>
<tr>
<td>SEI</td>
<td></td>
</tr>
<tr>
<td>alternative_transfer_characteristics()</td>
<td>(Not present in bitstream)</td>
</tr>
<tr>
<td>preferred_transfer_characteristics()</td>
<td>18</td>
</tr>
</tbody>
</table>

**The SEI message is ignored by legacy SDR receivers**

(14) SDR ITU-R BT.2020 OETF

It applies correct EOTF (Backward compatibility)

[3] High Dynamic Range and/or High Frame Rates Bit streams are not intended to be used with BT. 709 color primaries.
### Two Methods of Signaling the HLG Transfer Function

**Video Stream**

- **SDR T.F indicator is signaled in the VUI**
  - (transfer_characteristics=14)

- **HDR T.F indicator is sent over HDMI**
  - (18 in the VUI)

- **SDR T.F indicator is sent over HDMI**
  - (14 in the VUI)

- **HDR T.F indicator is sent over HDMI**
  - (18 in the SEI)

- **SDR T.F indicator is signaled in the SEI**
  - (preferred_transfer_characteristics=18)

- **HLG T.F indicator is signaled in the SEI**
  - (preferred_transfer_characteristics=18)

#### HEVC
- **HLG Aware STB or Decoder**

### HDR T.F Indicator
- **It applies correct EOTF and gives backward compatibility feature of HLG. “Viewable SDR Pictures”**

### SDR Display
- **It may produce acceptable results on SDR displays**

14 ≠ 18 From “preferred_transfer_characteristic=18” it recognize that the bit stream is coded with HLG (actual transfer characteristics is HLG)
### Signaling Transfer Function, Color Space and Matrix Coefficients

<table>
<thead>
<tr>
<th>Color Volume</th>
<th>Color Primary (Logical)</th>
<th>Transfer Function (Logical)</th>
<th>Color Representation</th>
<th>Minimum Bit Depth (bpc)</th>
<th>MPEG Color Primary Index Value</th>
<th>MPEG Transfer Function Index Value</th>
<th>MPEG Conversion Matrix Index Value</th>
<th>AVC/HEVC Codec Tiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDR/BT.709</td>
<td>BT.709-5</td>
<td>BT. 1886</td>
<td>Y’Cb’Cr’ NCL</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>MPEG MAIN 8-bit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BT. 1886</td>
<td>R’G’B’ 4:4:4</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SDR/WCG</td>
<td>BT. 1886</td>
<td>Y’Cb’Cr’ NCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BT. 1886</td>
<td>R’G’B’ 4:4:4</td>
<td>10</td>
<td>1 or 14*</td>
<td>9</td>
<td></td>
<td>HEVC Main10 and Main12</td>
</tr>
<tr>
<td>HDR/WCG</td>
<td>BT.2020-2</td>
<td>PQ (ST.2084 / BT. 2100)</td>
<td>Y’Cb’Cr’ NCL</td>
<td>10</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HLG / BT.2100</td>
<td>Y’CbCr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PQ (ST.2084 / BT. 2100)</td>
<td>IICICp</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HLG / BT.2100</td>
<td>IICICp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PQ (ST.2084 / BT. 2100)</td>
<td>R’G’B’ 4:4:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note that both “1” and “14” are valid values to signal SDR transfer function; for example, DVB documents require “1” when the color container is BT.709 and “14” when the color container is BT.2020.*
Different Distribution Scenarios

**Single-layer**
- HDR video coding using HEVC Main 10
- HDR-to-SDR mapping at the receiver side (real-time)
Different Distribution Scenarios

**Single-layer**
- HDR video coding using HEVC Main 10
- HDR-to-SDR mapping at the receiver side (real-time)
- Metadata from SDR master video to improve tone/color mapping and preserve artistic intent
Different Distribution Scenarios

**Single-layer**
- SDR video coding using HEVC
- SDR-to-HDR mapping at the receiver side (real-time)
Different Distribution Scenarios

Single-layer
- SDR video coding using HEVC
- SDR-to-HDR mapping at the receiver side (real-time)
- Metadata from HDR master video to improve inverse tone/color mapping and preserve artistic intent

![Diagram showing different distribution scenarios involving HDR and SDR videos, HEVC encoding and decoding, and inverse tone/color mapping.](image-url)
Different Distribution Scenarios

**Single-layer**
- SDR video obtained by HDR-to-SDR tone/color mapping
- SDR video coding using HEVC
- SDR-to-HDR mapping at the receiver side (real-time)
Different Distribution Scenarios

Dual-layer, Simulcast

- Simulcast (independent coding) of SDR and HDR video sequences
- Not optimal in terms of bandwidth
**Different Distribution Scenarios**

**Dual-layer, Scalable coding**

- Dual-layer, scalable coding
- Quality can be Dynamic Range and WCG (PSNR or Quality Scalability in Encoder)

```
Input Video (HDR, WCG)  
\[+\]  
\(\text{Tone/Color Mapping} (SDR, BT.709)\)  
\(-\)  
\(\text{Base Layer Encoder} (\text{Low Quality Encoding})\)  
\(\text{Base Layer Decoder} \)  
\(\text{Enhancement layer Encoder} (\text{Distortion Encoding})\)  
\[\text{MULTIPLEXER}\]  
\(\text{Output Bit Stream}\)  
\(\text{Low Quality Vide} (\text{SDR})\)  
\(\text{BL Bit Stream}\)  
\(\text{High Quality Video} (\text{HDR, WCG})\)  
\(\text{BL + E.L Bit Streams}\)  
```

Distortion of Low Quality Encoding

E.L Bit Stream
Different Distribution Scenarios

Dual-layer, Scalable Coding

- Joint coding of SDR and HDR video sequences using SHVC (Scalable HEVC)
- Exploit better data redundancies

HDR Video → Scalable HEVC Main 10 Encoding → Scalable HEVC Main 10 Decoding → HDR Display

SDR Video → HEVC Decoding → SDR Display

One Bit Stream
Example of Single-layer Distribution

Technicolor-Philips SL-HDR1 (Advanced HDR)

MDCV: Mastering Display Color Volume

(MDCV + SL-HDR1 Metadata) (e.g. SEI message)

Input HDR

To linear-light
Gamut mapping

HDR-to-SDR conversion
SDR dynamic metadata

Encoding

Output SDR

Decoding SDR-to-HDR reconstruction Inverse gamut mapping To output format

Output HDR

bitstream incl. SEI for dynamic metadata

MDCV Metadata (e.g. ST 2086)

Example of Single-layer Distribution

Technicolor-Philips SL-HDR1 (Advanced HDR)

MDCV: Mastering Display Color Volume
Example of Dual-layer Distribution

Dolby Vision

Dual Layer: License Fee Required
(Base Layer + Enhancement Layer for HDR & SDR)

HDR Master
ST.2084-1 OETF

Dolby Vision Encode

Blu-Ray OTT Broadcast

Dolby Vision Decode

Current Decode

HDR

SDR

Dolby Vision Encoder

Artistic Intent

 HDR

 Tone mapping

 SDR

 SDR Enc

 Base Layer

 HDR Made of SDR

 Metadata

 MUX

 HDR Enc

 Residual Enc

 Residual data

 Enhance Layer

 Dolby Vision Decoder

Base Layer

SDR Dec

HDR Made of SDR

Metadata

Residual Dec

Residual data

HDR

SDR
Global Picture of Sony “SR Live” for Live Productions (FIFA World Cup 2018)

- 8 Cameras Dual output UHD/HDR and HD/SDR
- 11 Cameras Dual output HD/HDR and HD/SDR
- 21 Cameras Single output HD/SDR
- All Replays HD/SDR

Shading of all cameras is done on the HD/SDR (BT. 709)
Global Picture of “HLG-Live” for Live Productions

Shading of all cameras is done on the HD/SDR (BT. 709)

“SR” = Scene Referred
Questions?
Suggestions?
Discussion?