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SUPPORTIVE DOCUMENT TO USWP6C-03

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R BT.[S/H DR MON]

A reference viewing environment for HDR and SDR monitoring in a single-master production environment

NBCUniversal for NABA

The North American Broadcasters Association (NABA) supports the U.S. delegation's working document which specifies technical recommendations for UHD production where High Dynamic Range (HDR) and Standard Dynamic Range (SDR) images or displays are in close proximity. To avoid eye adaption issues, a unified reference white level is established between HDR and SDR.

We support the U.S. delegation contribution to establish an updated reference viewing environment working document for newer displays that can provide improved capabilities for both peak luminance, dark detail, and bit depth. While viewing environment recommendations have progressed for HDR displays, they have not for those same displays that support SDR.

This recommendation builds upon work defined in ITU-R BT.2100, ITU-R BT.2408, SMPTE ST 2080-3:2017 and others into a single document which unifies and updates the reference viewing environments of both HDR and SDR.

The attachment in this supporting document includes previous work that is very similar to the U.S. delegation working document and is meant to reinforce the primary contribution.

RECOMMENDATION ITU-R BT.XXX

A reference viewing environment for HDR and SDR programme master monitoring in a single-master production environment

(2023)

Scope

This Recommendation describes a set of best practices for "single-master" (i.e., content is produced in HDR and SDR is subsequently derived) HDR/SDR programme master monitoring environments where the core production is HDR and generates simultaneous HDR and SDR outputs. This method is made possible by producing HDR and SDR using unified reference white levels. It provides optimized HDR and SDR output with consistent results from one facility to another when viewing the same material on today's HDR and SDR TVs that use a typically higher luminance level.

With the advent of HDR video formats and current SDR TV, desktop display and mobile device viewing practices, there is an opportunity to preserve the original artistic intent by reestablishing a more realistic SDR luminance level so that shadows and midtones appear closer to the content creator's goals.

The ITU Radiocommunication Assembly,

considering

that typical luminance levels for non-reference SDR TV viewing conditions are closer to double the level in traditional reference viewing environments described in Recommendation ITU-R BT.2035 (100 cd/m^2) since the constraints of a CRT's luminance limits no longer exist;

that modern displays provide much better darker detail than the surround luminance level defined in BT.2035 (described as 10% of reference white or 10 cd/m^2 if SDR reference white is 100 cd/m^2);

that SMPTE ST 2080-3:2017 has an updated surround luminance level at ≤5 cd/m^2 created for more modern displays which allows for improved darker detail perception with historical explanations of the older surround levels and why they should be changed (See SMPTE ST 2080-3:2017 Annex A);

that close proximity (side-by-side) viewing of both HDR and SDR is possible in "single-master" UHD productions;

that close proximity viewing will cause eye adaption issues unless a unified reference white level is established between displayed HDR and SDR images,

recommends

1 that for critical evaluation of HDR and SDR program material or completed programmes in close proximity, the characteristics of a reference viewing condition described in Annex 1 should be used to create a unified reference white level in order to preserve the original artistic intent for both the HDR and SDR images;

2 that for the greatest degree of displayed image uniformity, similar display technologies be used between facilities when comparisons are to be made.

ANNEX 1

Overview

The intent of this Recommendation is to provide guidance for close proximity HDR and SDR display matching within a “single-master” UHD production.

1 Reference viewing conditions

The reference environment for close proximity viewing is intended to provide a more consistent perceptual experience which can be replicated from one facility to another. This programme master monitoring viewing environment is intended as a guideline for a practical implementation.

Table 1 specifies reference viewing levels for single-master production where SDR and HDR displays are in close proximity. Please reference Recommendation ITU-R BT.2100 Table 3 for the HDR Reference Viewing Environment.

TABLE 1

Reference viewing levels for SDR and HDR displays in close proximity

Reference for items 1-2, 6 are from BT.2100 Table 3; item 3 from SMPTE ST 2080-3:2017; items 4-5 from Rec. ITU-R BT.2408-6.

	Parameter	Values
1	Surround and periphery	Neutral grey at D65
2	Luminance of surround 1	≤ 5 cd/m^2
3	Visible reflections on the display 2	≤ 50% the level of the luminance value of the surround
4	Reference White of PQ, HLG (1 000 cd/m^2 Peak White), and SDR displays (Method A) 3	203 cd/m^2
5	Reference White of HLG (400-600 cd/m^2 Peak White) and SDR displays (Method B) 3	100-137 cd/m^2
6	Minimum luminance of display (black level)	≤ 0.005 cd/m^2

1 - “Surround” is the area surrounding behind a display that can affect the adaptation of the eye, typically the wall or curtain behind the display; “periphery” is the remaining environment outside of the surround. This value is a change from the level specified in BT.2035 (10 cd/m^2 or 10% of reference white). Instead, 5 cd/m^2 is used which matches the value in BT.2100 for HDR where reference white is 203 cd/m^2. This change was motivated by improved capabilities in newer displays (e.g., improved darker detail).

2- This parameter describes conditions on the display and surrounds that may cause display reflections or lift the minimum black level and is associated with BT.2035 parameter “Room Illumination”.

3- Reference White serves as an anchor between HDR and SDR using two different methods of HDR to SDR conversion. These reference white levels reflect the two different tone mapping methods described in BT.2408 for “single-master” workflows.

2 Reference viewing environments for critical viewing of HDR and SDR programme material in close proximity for a single-master UHD production

2.1 Recommendations for HLG and SDR displays that are in close proximity

HLG is a relative transfer function. Special care should be taken to unify reference white for close proximity viewing between HDR and SDR. SDR is also a relative transfer function so the SDR peak white for Method A and B (described later in this document) for HDR-to-SDR conversion methods are the same during final SDR viewing.

SDR's relative transfer function is adjusted by using the Lw value (contrast control) in Recommendation ITU-R BT.1886 to apply a linear scaling factor to the luminance levels. When an SDR displays nominal peak white luminance is adjusted to 203 cd/m^2, a linear scaling factor of 2.03 is used.

HLG uses a variable gamma to apply a non-linear adjustment to displays with different peak brightness capabilities. Since HLG is a relative transfer function, a reference display with a peak brightness of 1 000 cd/m^2 will have a reference white luminance level of 203 cd/m^2. If an HLG display's peak brightness is lower, the reference white will be relatively adjusted lower. If a production requires that the HDR and SDR displays be in close proximity, two different tone mapping methods (Method A & B) have been developed which allow HDR and SDR displays to reside in close proximity without issues related to eye-adaption so that consistent comparisons can be made.

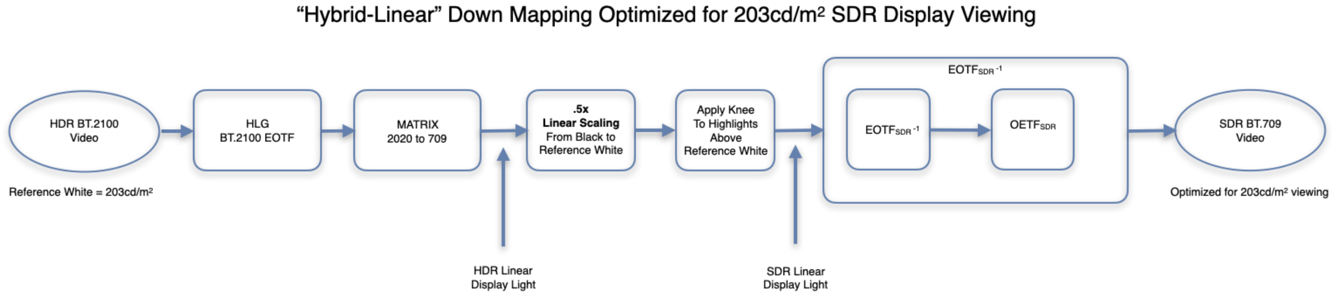
Some common use-cases for close proximity viewing of HDR and SDR include side-by-side HDR/SDR shading, when using multiview displays or for basic quality assessments.

2.1.1 Method A – Hybrid-Linear HDR-to-SDR Tone Mapping

This method anchors HDR and SDR Reference White at 203 cd/m^2, in the case where a content creator prefers to create SDR content optimized for 203 cd/m^2 viewing and the HDR and SDR displays will be in close proximity.

To accomplish this, we use the capabilities defined in BT.1886 and latitude described in Recommendation ITU-R BT.2129 so that the SDR display's peak white luminance level is linearly scaled to 203 cd/m^2.

The HDR-to-SDR conversion will convert the HLG source using display-light conversion with a linear-scaling factor applied from HDR black to reference white, while HDR highlights above reference white are compressed with a knee, such that the resulting SDR signal graphic white level is optimized for viewing at 203 cd/m^2 with some preservation of HDR highlights.



In the case where a 600 cd/m^2 HLG display is used and HDR and SDR reference white is anchored at 203 cd/m^2, the HLG display must be adjusted using the contrast control so that the reference white is 203 cd/m^2. The gamma should not be adjusted. If there are highlights above the display's peak luminance capabilities, there will be some loss of visible highlight detail on the display although that information remains in the signal itself.

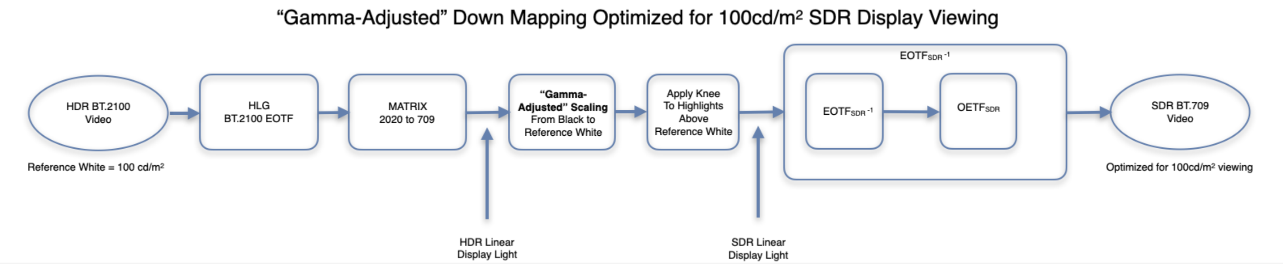
Method A gain-stages optimally for SDR 203 cd/m^2 viewing during HDR-to-SDR display-light conversion. Today's typically higher luminance TVs will match very closely to the HDR images from black to reference white.

2.1.2 Method B – Gamma-Adjusted HDR-to-SDR Tone Mapping

This method anchors HDR and SDR Reference White levels at 100 cd/m^2, in the case where a content creator prefers to create SDR content optimized for 100 cd/m^2 viewing and the HDR displays will be in close proximity.

For close proximity viewing, a 600 cd/m^2 or 400 cd/m^2 HLG display will use the relative nature of HLG to lower the reference white to 137 cd/m^2 or 100 cd/m^2, respectively, to scale the entire luminance range.

An HDR-to-SDR conversion uses a gamma-adjusted display-light conversion to create an SDR signal with shifted shadows and midtones to achieve an appropriate match with the lower luminance HLG display that is in close proximity.



2.2 Matching HLG and SDR displays that are in close proximity

HLG and SDR are both relative image display formats. When an HLG display's peak brightness changes, so does the reference white. This requires a change in value for and SDR display that is close proximity. The display luminance values in Table 2 below have been selected to provide unified reference white levels between both HDR and SDR displays while in close proximity.

TABLE 2
HLG and SDR display gamma and luminance values for close proximity viewing

HDR-to-SDR Tone Mapping	HLG Nominal Peak-White Display Luminance (cd/m^2)	SDR Nominal Peak White Display Luminance (cd/m^2)	Method
Hybrid-Linear Tone Mapping	1 000 (Gamma 1.2)	203	A
Gamma-Adjusted Tone Mapping	600 (Gamma 1.11)	137	B
Gamma-Adjusted Tone Mapping	400 (Gamma 1.03)	100	B

2.3 Recommendations for PQ and SDR displays that are in close proximity

PQ is an absolute HDR format. A reference display that is capable of 600 cd/m^2 in PQ will display reference white at 203 cd/m^2. Since reference displays do not utilize tone mappers, a PQ display would have an additional 400 cd/m^2 of highlights above the reference white level before it starts clipping. If there are highlights above the display's peak luminance, there will be some loss of visible highlight detail on the display although highlights will remain in the signal itself. The display luminance values in Table 3 below have been selected to provide unified reference white levels between both HDR and SDR displays while in close proximity.

TABLE 3
PQ and SDR display gamma and luminance values for close proximity viewing

HDR to SDR Tone Mapping	PQ (cd/m^2)	SDR (cd/m^2)	Method
Hybrid-Linear Tone Mapping	1 000	203	A
Gamma-Adjusted Tone Mapping	600	203	B
Gamma-Adjusted Tone Mapping	400	203	B

3 International Exchange for SDR transmission

3.1 International Exchange for SDR transmission where HDR signals exist

Where the original HDR signals exist, a distribution partner can use either tone mapping method (Method A or B) to support their preferred SDR transmission viewing optimization dependent on what their specifications require as long as the recommended tone mapper and SDR display luminance were used during shading (see Table 4 below).

[*Author's note: Pending BT.2408-6 approval in ITU-R SG 6, this document will reference BT.2408 directly instead of including Table 4 in this document.*]

TABLE 4

Display luminance vs. tone mapping

	“Single-Master” UHD HDR-SDR Best Practice For Monitoring			
			“Gamma Adjusted” Down mapper	“Hybrid-Linear” Down Mapper
Production/Transmission	A	SDR BT.1886 Program Master Monitoring	HDR -> SDR “Gamma-Adjusted” Downmapper Optimized for 100cd/m² (BT.1886/BT.2035)	HDR -> SDR “Hybrid-Linear” Downmapper Optimized for 203cd/m² (BT.1886/
	B	SDR Transmission Monitoring	HDR -> SDR “Gamma-Adjusted” Downmapper Optimized for 100cd/m² (BT.1886/BT.2035)	HDR -> SDR “Hybrid-Linear” Downmapper Optimized for 203cd/m² (BT.1886/
TV’s	C1	SDR TV (More Typical) 203cd/m² Luminance	Slightly Brighter [1]	Very Good Match [2]
	C2	SDR TV (Limited) 100cd/m² Luminance	As intended	Slightly Darker [3]
	D	HDR Transmission Look	As intended	As Intended

3.2 International Exchange for SDR transmission where only SDR signals exist

Given that there are two common tone mapping methods, where the only difference is a slight shift in shadows and midtones, it is useful for the stakeholders to discuss the mastering display color volume (MDCV) during the creation of the content and prior to distribution.

Since there are two methods for tone mapping, proper identification of the method used is recommended to ensure optimal viewing depending on which method is used.

Tables 5 and 6 provide examples for file exchange that would embed SMPTE ST 2086 static metadata to identify SDR MDCV (whether it was optimized for 100 or 203 cd/m^2 viewing). This allows subtle format conversion to occur based on the equations described in BT.2408 Annex X. The examples include MDCV for both 100 and 203 cd/m^2 based on tables in ITU-T Series H Supplement 19.

AVC, HEVC codecs, MXF, QuickTime, MP4 wrappers support carriage of SMPTE ST 2086 for SDR but it is not currently in common use or documented in standards, so they require updating.

TABLE 5

Method A – Example SDR mastering display colour volume metadata for 203 cd/m²

	System identifier		**BT709x203n05**
Mastering display properties defined according to SMPTE ST 2086	Colour primaries {xR,yR} (red) Colour primaries {xG,yG} (green) Colour primaries {xB,yB} (blue)		{0.6400, 0.3300} {0.3000, 0.6000} {0.1500, 0.0600}
	White point chromaticity {x,y}		{0.3127, 0.3290} (D65)
	Maximum luminance [cd/m²]		203
	Minimum luminance [cd/m²]		0 (for unknown)
HEVC or AVC MDCV SEI message Rec. ITU-T H.265 | ISO/IEC 23008-2	Display_primaries_x[2]/y[2] (red) Display_primaries_x[0]/y[0] (green) Display_primaries_x[1]/y[1] (blue)		{32000, 16500} {15000, 30000} {7500, 3000}
	White_point_x/y		{15635, 16450}
	max/min_display_mastering_luminance		{2030000, 0}
SMPTE MXF parameters SMPTE ST 2067-21	MasteringDisplayPrimaries	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01010000
		Coded decimal (red, green, blue)	{32000, 16500} {15000, 30000} {7500, 3000}
	MasteringDisplayWhitePoint Chromaticity	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01020000
		Coded decimal	{15635, 16450}
	MasteringDisplayMaximum Luminance	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01030000
		Coded decimal	2030000
	MasteringDisplay□Minimum Luminance	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01040000
		Coded decimal	0 (for unknown)

TABLE 6
Method B – Example SDR mastering display colour volume metadata for 100 cd/m²

	System identifier		BT709x100n05
Mastering display properties defined according to SMPTE ST 2086	Colour primaries {xR,yR} (red) Colour primaries {xG,yG} (green) Colour primaries {xB,yB} (blue)		{0.6400, 0.3300} {0.3000, 0.6000} {0.1500, 0.0600}
	White point chromaticity {x,y}		{0.3127, 0.3290} (D65)
	Maximum luminance [cd/m²]		100
	Minimum luminance [cd/m²]		0 (for unknown)
HEVC or AVC MDCV SEI message Rec. ITU-T H.265 | ISO/IEC 23008-2	Display_primaries_x[2]/y[2] (red) Display_primaries_x[0]/y[0] (green) Display_primaries_x[1]/y[1] (blue)		{32000, 16500} {15000, 30000} {7500, 3000}
	White_point_x/y		{15635, 16450}
	max/min_display_mastering_luminance		{1000000, 0}
SMPTE MXF parameters SMPTE ST 2067-21	MasteringDisplayPrimaries	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01010000
		Coded decimal (red, green, blue)	{32000, 16500} {15000, 30000} {7500, 3000}
	MasteringDisplayWhitePoint Chromaticity	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01020000
		Coded decimal	{15635, 16450}
	MasteringDisplayMaximum Luminance	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01030000
		Coded decimal	1000000
	MasteringDisplayMinimum Luminance	Registration identifier	urn:smpte:ul:060e2b34.0101010e.04200401.01040000
		Coded decimal	0

References

[1] MovieLabs, “MovieLabs Best Practices for Mapping BT.709 Content to HDR10 for Consumer Distribution v1.0”, https://movielabs.com/download/938/.

[2] SMPTE ST 2080-3:2017 - Reference Viewing Environment for Evaluation of HDTV Images, https://ieeexplore.ieee.org/document/7918583.

[3] SMPTE ST 2086:2018 - Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images, https://ieeexplore.ieee.org/document/8353899.

[4] Rec. ITU-T H.Sup19 - Usage of video signal type code points, https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13895&lang=en.

Glossary

Hybrid-Linear SDR Down Mapper – An HDR-to-SDR tone mapper optimized for 203 cd/m^2 SDR viewing which uses display light conversion to map HDR black-to-reference white using a linear scaling of 50% for optimal gain staging for higher luminance SDR displays and then applies a proprietary knee for HDR above reference white.

Gamma-Adjusted SDR Down Mapper – An HDR-to-SDR tone mapper optimized for 100 cd/m^2 SDR viewing which uses display light conversion to map HDR black-to-reference white with a gamma adjustment to compensate for darker SDR displays and then applies a proprietary knee for HDR above reference white.

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