

Hybrid Log-Gamma HDR

Update for MPEG's
HDR/WCG AHG Vancouver
Meeting

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BBC | Research & Development



Overview

1. Hybrid Log-Gamma (HLG) motivation
2. Opto-optic transfer functions
3. Scene-referred & display-referred systems
4. Latest BBC Results
5. Distribution of HLG signals
6. Summary

I Hybrid Log-Gamma (HLG) motivation

HLG Enables Easy Migration to HDR Production & Distribution

- Delivers high quality HDR pictures
 - independent of the display
 - requires no metadata
- Provides compatible picture on SDR screens
- **Production:** compatible with existing 10-bit infrastructure and equipment
 - can be mixed, resized & compressed using conventional tools
 - only requires HDR cameras and HDR displays in critical monitoring areas
- **Distribution:** single HEVC Main 10 Profile bitstream serves both HDR and SDR displays

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- **Distribution:** single HEVC Main 10 Profile bitstream serves both HDR and SDR displays
 - **NOTE, SDR HEVC Main 10 profile receivers already support BT.2020 colour!**

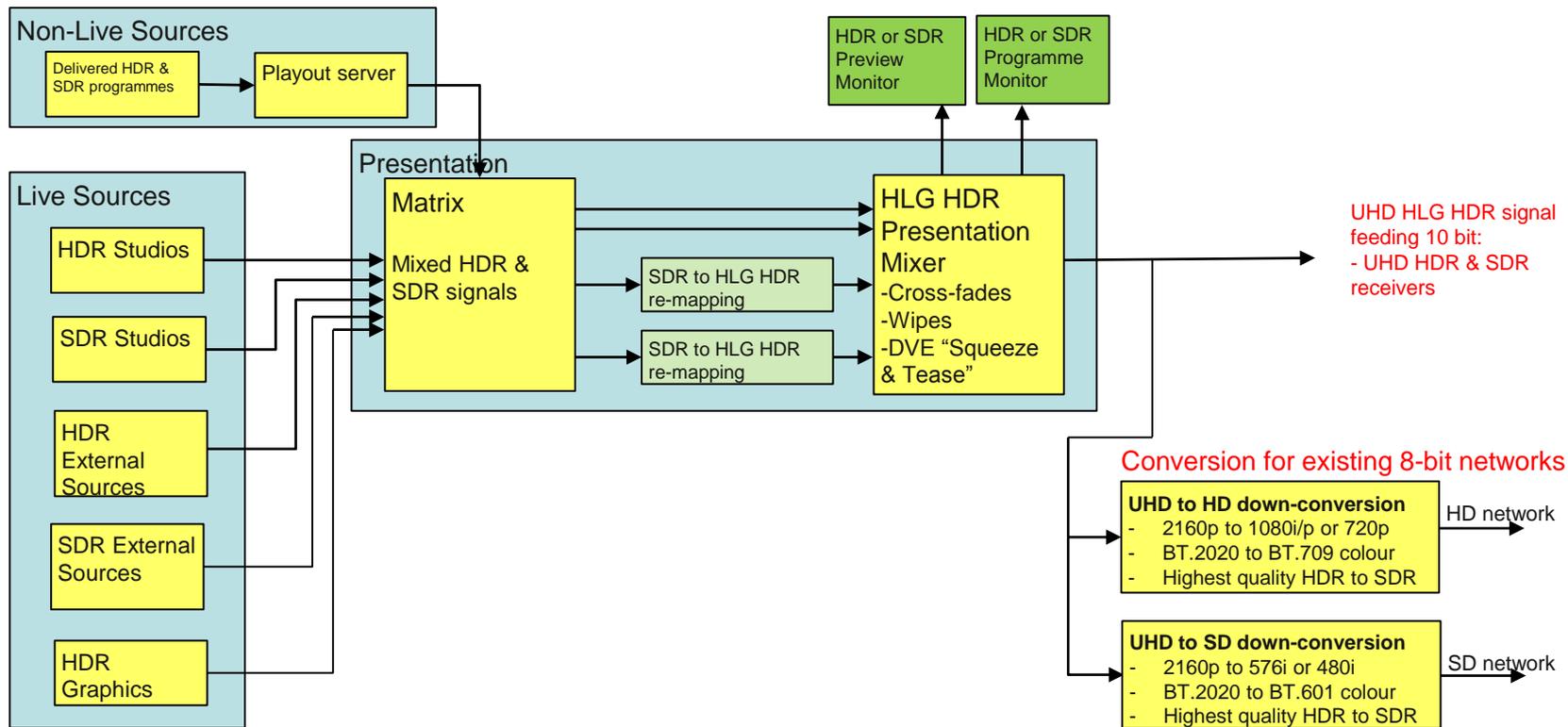
Metadata Impractical for Complex TV Workflows



Even with just programme based metadata we can not:

- Mix between programmes
- Use a DVE (Digital Video Effects)
- Easily add graphics

Separate HDR to SDR Down-Conversion for Existing HD & SD Networks



2 Opto-optic transfer functions

High-Level Diagram of TV Systems



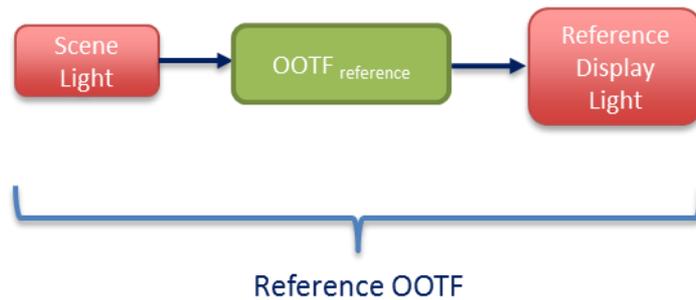
Opto-Optic Transfer Function

Scene light \neq displayed light

Role of the Opto-Optic Transfer Function (OOTF)

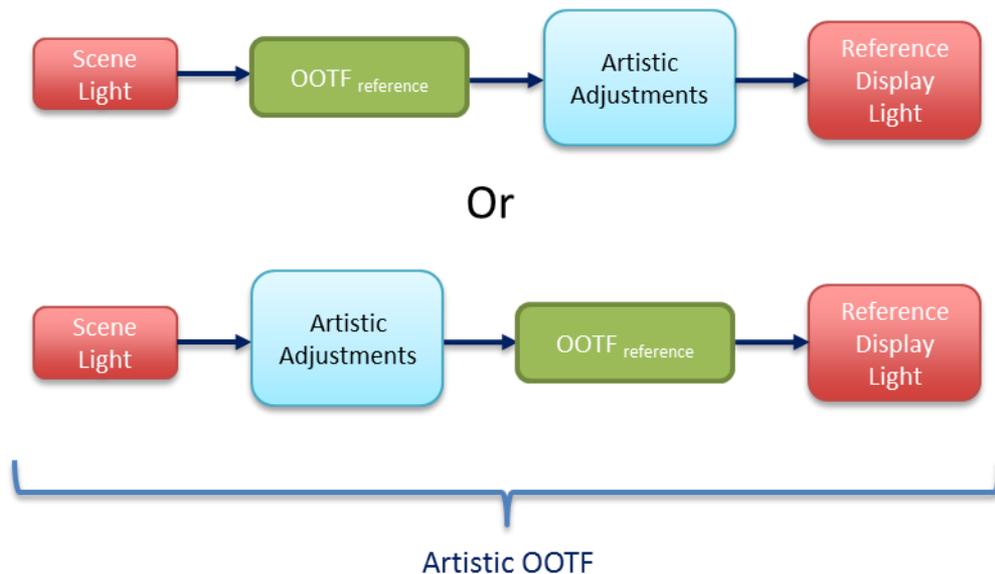
- Compensates for changes in tonal perception as the eye adapts to different environments
- Depends on,
 - brightness of the surround
 - peak brightness of the display
- Conventional “gamma law” known to work well as OOTF for both movies and TV:
 - Movies (negative/print) “gamma” 1.6 to 1.8
 - SDR TV,
 - “gamma” 1.2 in dim grading environment
 - “gamma” 1.1 in brighter domestic environment

Reference Environments



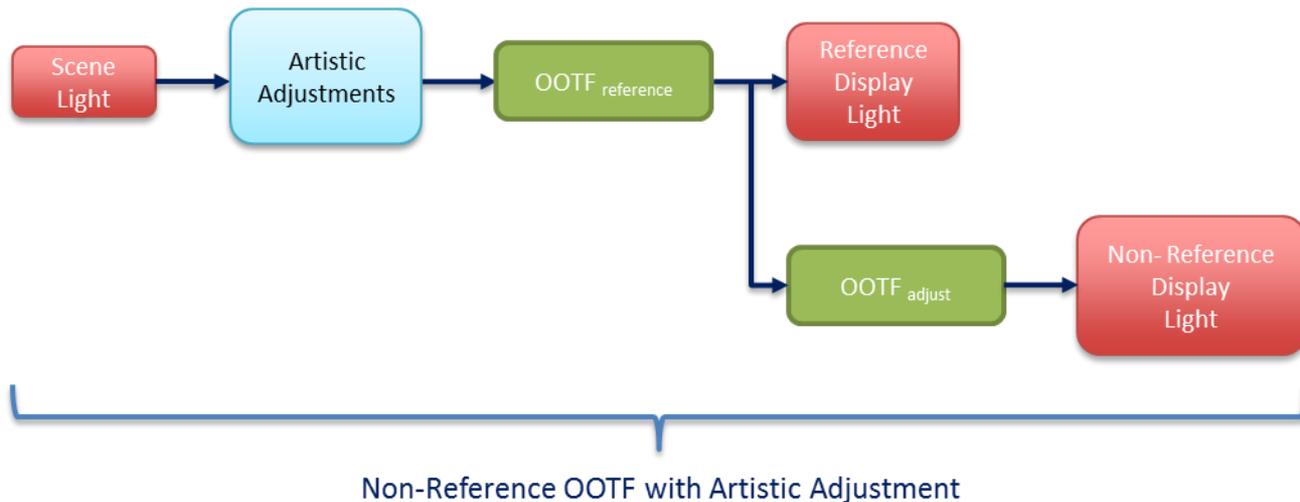
- OOTF_{reference} designed to produce “natural” images on a reference display in the reference viewing environment

Artistic Adjustments Can be Made to Enhance the Image

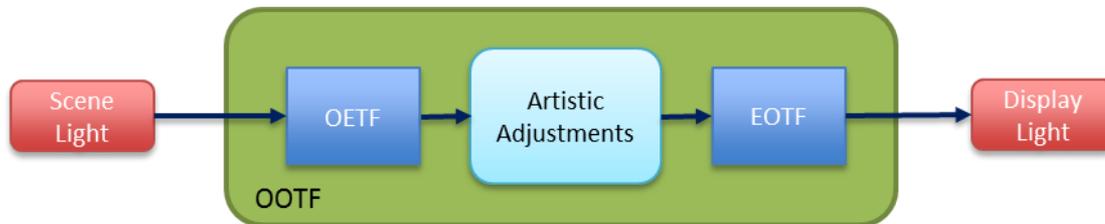


- Artistic adjustment can be applied either before or after the reference OOTF

OOTF Must be Adapted for Other Environments and Displays

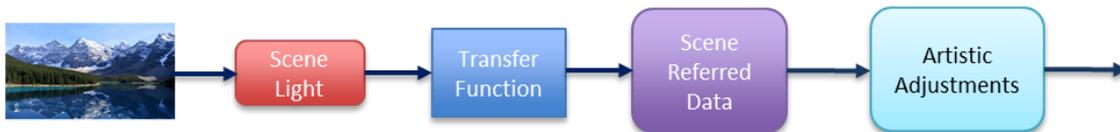


In General OOTF is Concatenation of OETF, Artistic Adjustments and EOTF



3 Scene-referred & display-referred systems

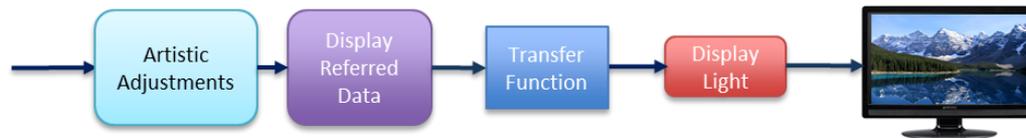
Scene-Referred Systems



Scene-referred signals represent the light in the scene (with or without artistic adjustment)

- Existing television systems
- Signals defined by their fixed OETF
 - The EOTF may change to match the viewing environment
- Examples ITU-R BT.601, BT.709, BT.2020, ARIB STD-B67 (defines HLG signal)

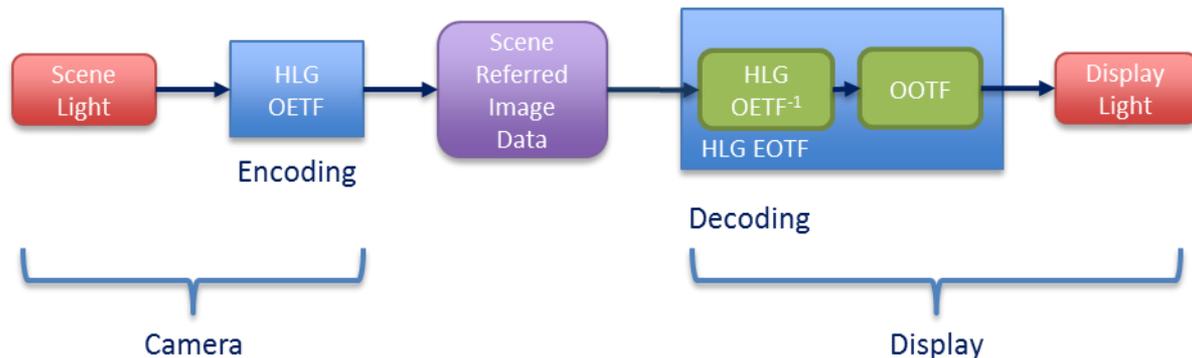
Display-Referred Systems



Display-referred signals represent the light emitted by the mastering display (with or without artistic adjustment)

- Defined by their fixed EOTF
- Examples SMPTE ST 2084, RP 431-2 (D-Cinema Quality - Reference Projector and Environment)

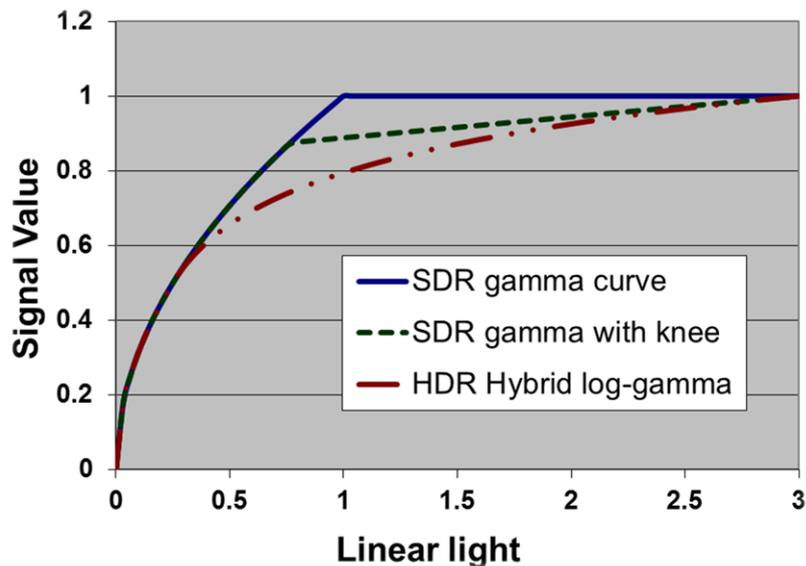
For “Scene Referred” Systems OOTF is Part of EOTF



Hybrid Log-Gamma End-to-End Chain

- As OETF does not change, no metadata is necessary

Hybrid Log-Gamma OETF Similar to SDR OETF with "Knee"



$$E' = \begin{cases} r\sqrt{E} & 0 \leq E \leq 1 \\ a \ln(E-b) + c & 1 < E \end{cases}$$

Where,

E is proportional to light intensity

E' is the non-linear signal

r is the reference level, 0.5

$a = 0.17883277$,

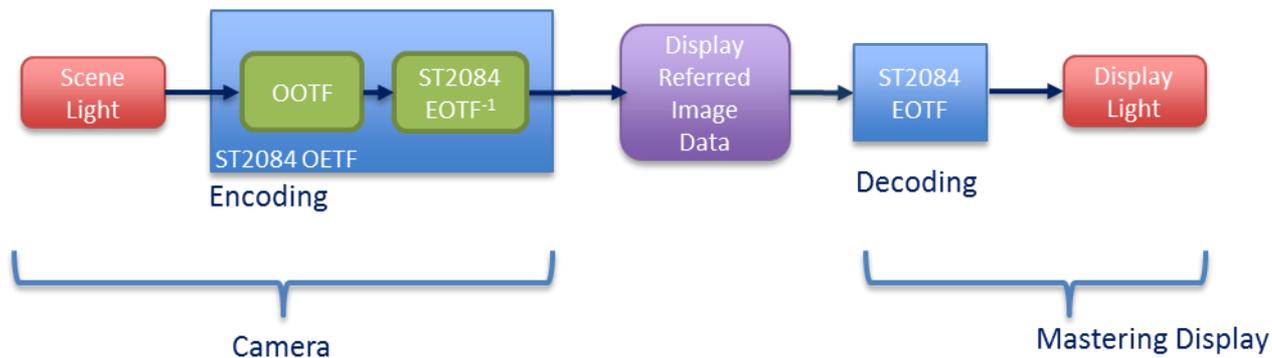
$b = 0.28466892$,

$c = 0.55991073$.

Role of the Opto-Electronic Transfer Function (OETF)

- Originally intended to make visibility of camera and channel noise more uniform
- Today,
 - camera noise controlled by signal processing within camera
 - OETF designed to minimize visibility of “banding” artefacts
 - BBC and NHK combined their OETF approaches at ITU-R
 - HLG OETF now standardised as ARIB STD-B67

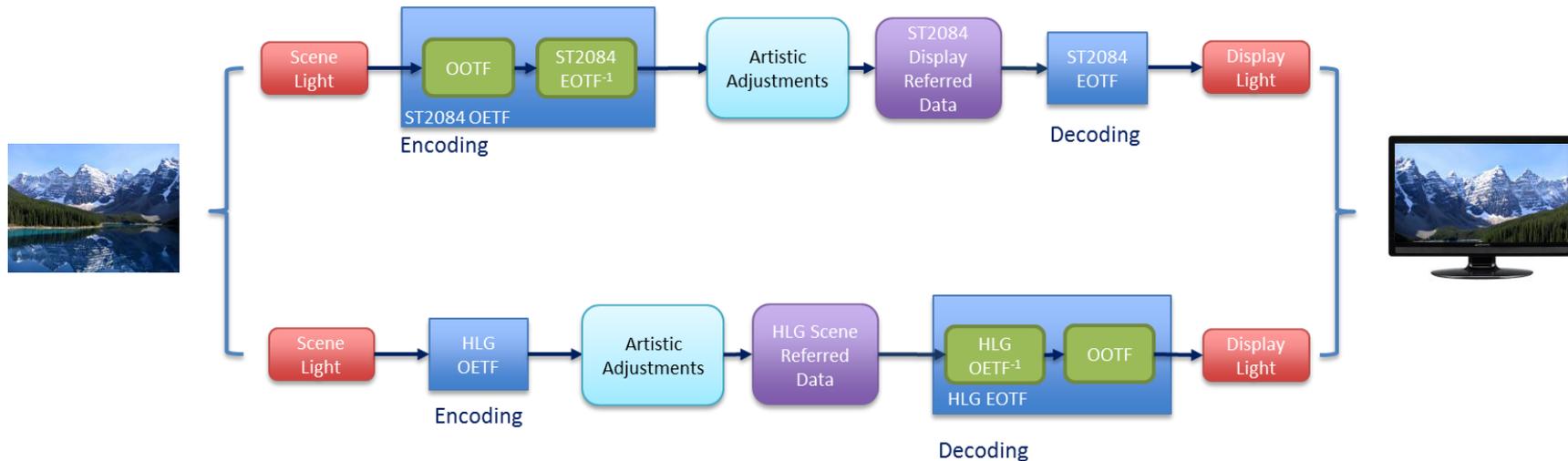
For “Display Referred” Systems (e.g. SMPTE ST 2084) OOTF is Part of the OETF



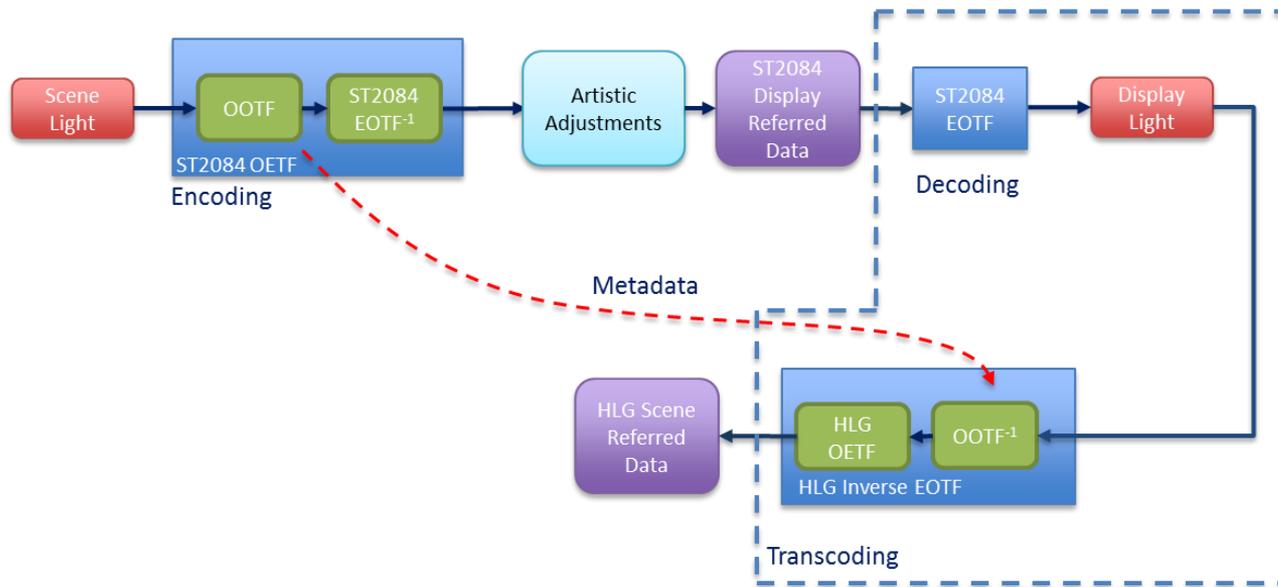
ST2084 End-to-End Chain

- A fundamentally different approach
- OOTF (and hence OETF) will vary to accommodate mastering display and environment

End-to-End Both HDR Systems Identical in Mastering Environment



Transcoding from ST 2084 to HLG Therefore Straightforward, but BBC Believes Requires Metadata



When Converting from Display- to Scene-Referred it may be Beneficial to Apply Noise Modifier

- Annex 2 to ITU-R Document 6C/5 I I-E (BT.HDR-TV PDNR), Annex 2 “Adjusting the signal to limit camera noise at low signal levels”

This annex recommends limiting the slope of the OETF, defined in table 3b-1, by applying the following function to the signal derived from a camera sensor:

$$M(E) = \frac{s^2 E^2}{(s^2 - 1)E + 1}$$

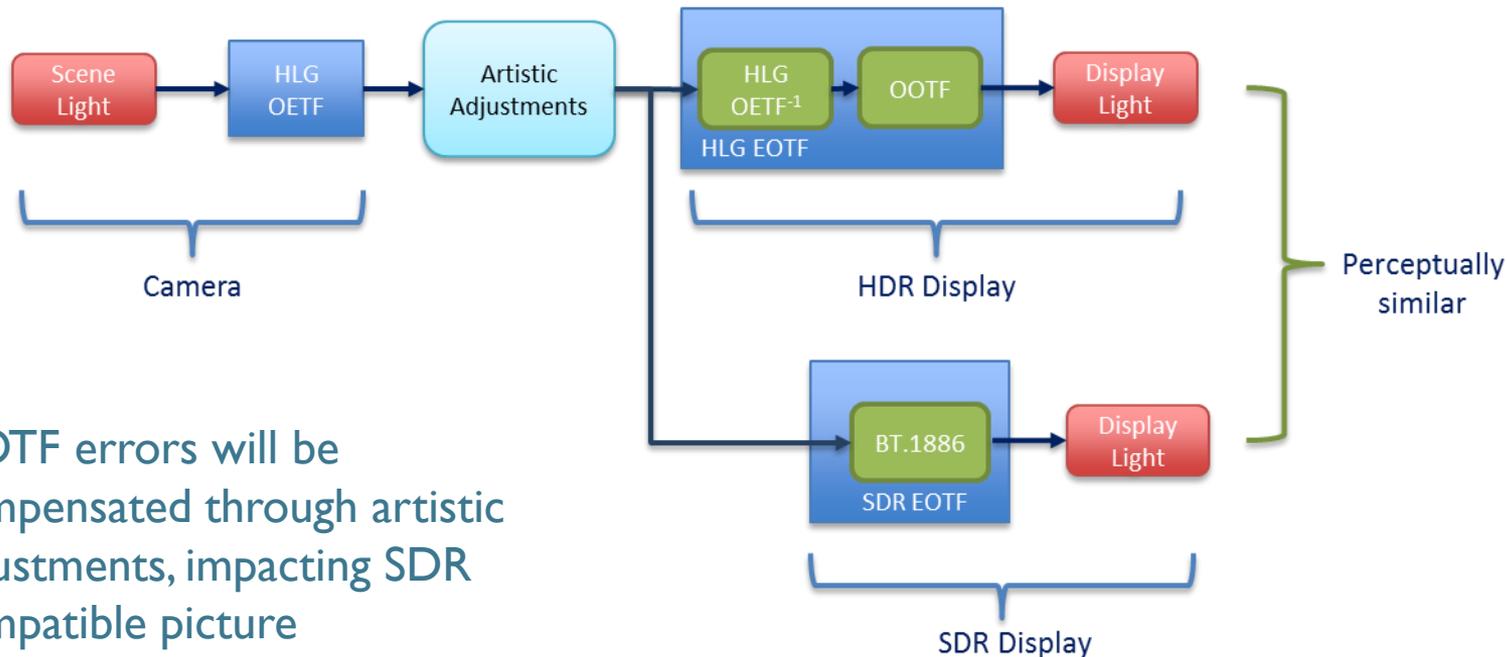
The video signal from the camera, E' , thus becomes:

$$E' = \text{OETF}(M(E))$$

This annex further recommends that the limiting parameters, s , used should have a value of $s=64$

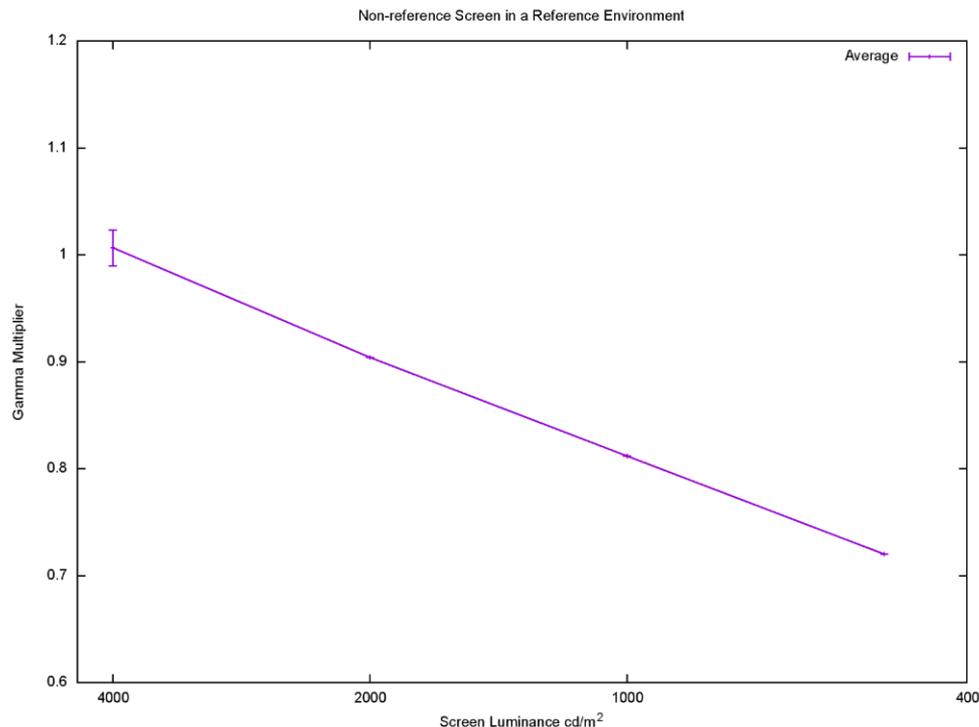
4 Latest BBC results

OOTF_{reference} Will Impact the HLG Compatible Image



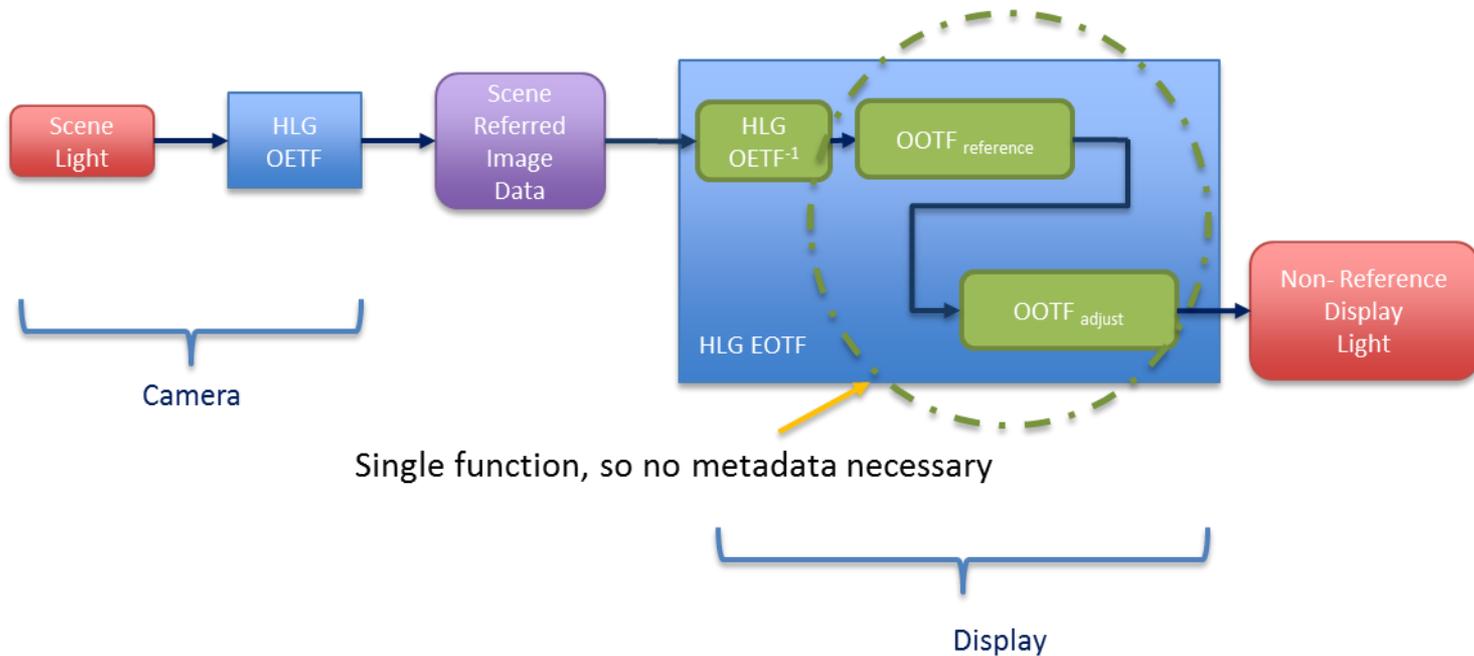
- OOTF errors will be compensated through artistic adjustments, impacting SDR compatible picture

OOTF Adjustments for Non-Reference TV Production/Consumer Displays & Environments



- 4000, 2000, 1000 and 500 cd/m² on SIM2 display
- 5 cd/m² surround
- OOTF adjustment made through changes to system gamma on luminance - preserves hue and saturation as gamma changes
- Viewers asked to match “reference” and “test” images by changing system gamma
- Peak brightness of “reference” and “test” images one stop apart to minimise eye adaption
- Consistent results for 1000 to 500 cd/m² adjustment using OLED display
- Independent of “reference” OOTF

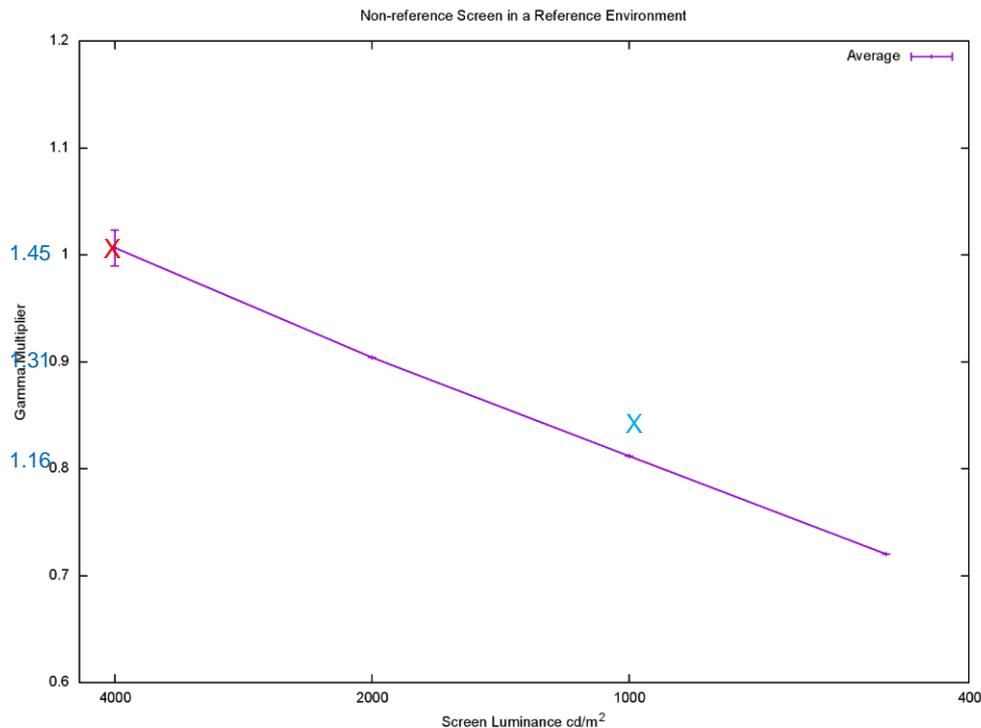
For HLG, $OETF_{reference}$ & $OETF_{adjust}$ Combined So No Metadata



OOTF for “Reference” Display and Environment

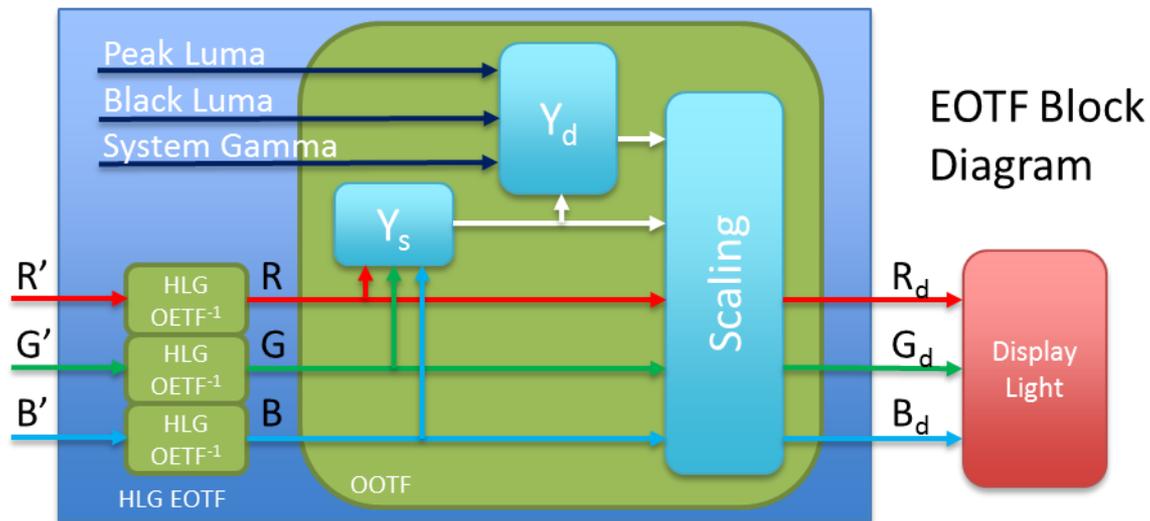
- First test set-up
 - 14 Mark Fairchild test images
 - “Gamma” function applied to luminance
 - 6 expert viewers asked to adjust gamma for most “natural” image on 4000 cd/m² SIM2 display
- Results
 - Wide variation between viewers
 - Some images very difficult to judge without a reference
 - Average for viewers (discarding 3 hardest images) 1.26 to 1.50
- Conclusions
 - Personal preference a large factor that is difficult to ignore
 - Most natural images may be produced with a lower gamma, but most pleasing image usually requires a higher gamma
 - Better to determine gamma for “reference” OOTF by optimising quality of SDR image

Preliminary Informal Results for Optimised OOTF



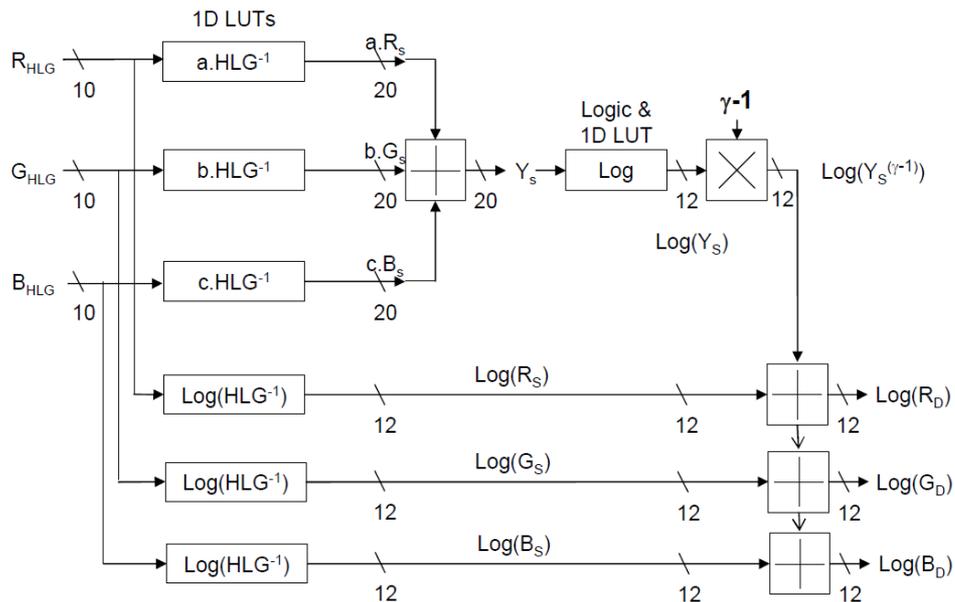
- Only 5 viewers
- Uncontrolled lighting
- Only 4 test images
 - Best SDR for 4000 cd/m² SMI2 display, $\gamma \approx 1.45$
 - Best SDR for 1000 cd/m² OLED display $\gamma \approx 1.27$
- More formal tests planned for this week
- Preliminary results consistent with earlier OOTF adjustment work

OOTF System Gamma Applied to Luminance Component within HLG EOTF



- Avoids hue and saturation distortions with different system gammas – critical in professional applications
- Mathematical equations in R&D White Paper <http://www.bbc.co.uk/rd/publications/whitepaper309>
- Conveniently implemented in 3D-LUT or combination of 1D-LUTs and adders

Example HLG EOTF Implementation Using I-D LUTs



$$R_D = \alpha Y_S^{\gamma-1} R_S + \beta$$

$$G_D = \alpha Y_S^{\gamma-1} G_S + \beta$$

$$B_D = \alpha Y_S^{\gamma-1} B_S + \beta$$

where $Y_S = aR_S + bG_S + cB_S$

5 Distribution of HLG signals

Backwards Compatible HLG Signalling in HEVC

- Broadcasters are likely to serve SDR and HDR receivers using the same channel
- VUI Signalling
 - **transfer_characteristics = 14 (BT.2020 10-bit) to satisfy legacy SDR receivers.**
 - colour_primaries = 9 (BT.2020)
 - matrix_coeffs = 9 (BT.2020 NCL)
 - video_full_range_flag = 0 (black at code value 64)
 - *Note: HDR signals will extend below code value 64 (sub-blacks) and above code value 940 (super-whites).*
- SEI Signalling to override VUI transfer_characteristics
 - hdr_compatibility_info on IRAP
 - **hdr_transfer_characteristic_idc = 18**

D.2.38 High dynamic range compatibility information SEI message syntax

+	
hdr_compatibility_info(payloadSize) {	Descriptor
hdr_transfer_characteristics_idc	u(8)
}	

HLG Signalling Over HDMI (Based on CEA 86I)

CEA-861.3

InfoFrame Type Code	InfoFrame Type = 0x07					
InfoFrame Version number	Version=0x01					
Length of Info Frame	Length of following HDR Metadata InfoFrame					
Data Byte 1	F17=0	F16=0	F15=0	F14=0	F13=0	EOTF (3 bits)
Data Byte 2	F27=0	F26=0	F26=0	F24=0	F23=0	Static_Metadata_Descriptor_ID (3 bits)
Data Byte 3	Static_Metadata_Descriptor					
...	...					
Data Byte n	...					

Table 2 Dynamic Range and Mastering InfoFrame

Data Byte 1 EOTF identifies the Electro-Optical Transfer Function (EOTF) used in the stream.

EOTF	EOTF of stream
0	Traditional gamma - SDR Luminance Range
1	Traditional gamma - HDR Luminance Range
2	SMPTE ST 2084 [2]
3	Future EOTF
4-7	Reserved for future use

Table 3 Data Byte 1 - Electro-Optical Transfer Function

Needs to be revised to HLG (ARIB STD-B67)

6 Summary

Main facts on HLG

- Supports a wide range of displays and environments
- No need for metadata as OOTF part of EOTF
 - hence signal is “display independent”
- Can be displayed unprocessed on SDR screen
- 10-bit signal compatible with SDR systems
- Production can use existing SDR infrastructure and monitoring displays
 - Only critical high quality monitoring requires HDR displays
- Straightforward evolutionary migration to HDR production
- Single layer HEVC Main10 Profile distribution to both HDR and SDR displays