

# 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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  - **NOTE, SDR HEVC Main 10 profile receivers already support BT.2020 colour!**

# Metadata Impractical for Complex TV Workflows

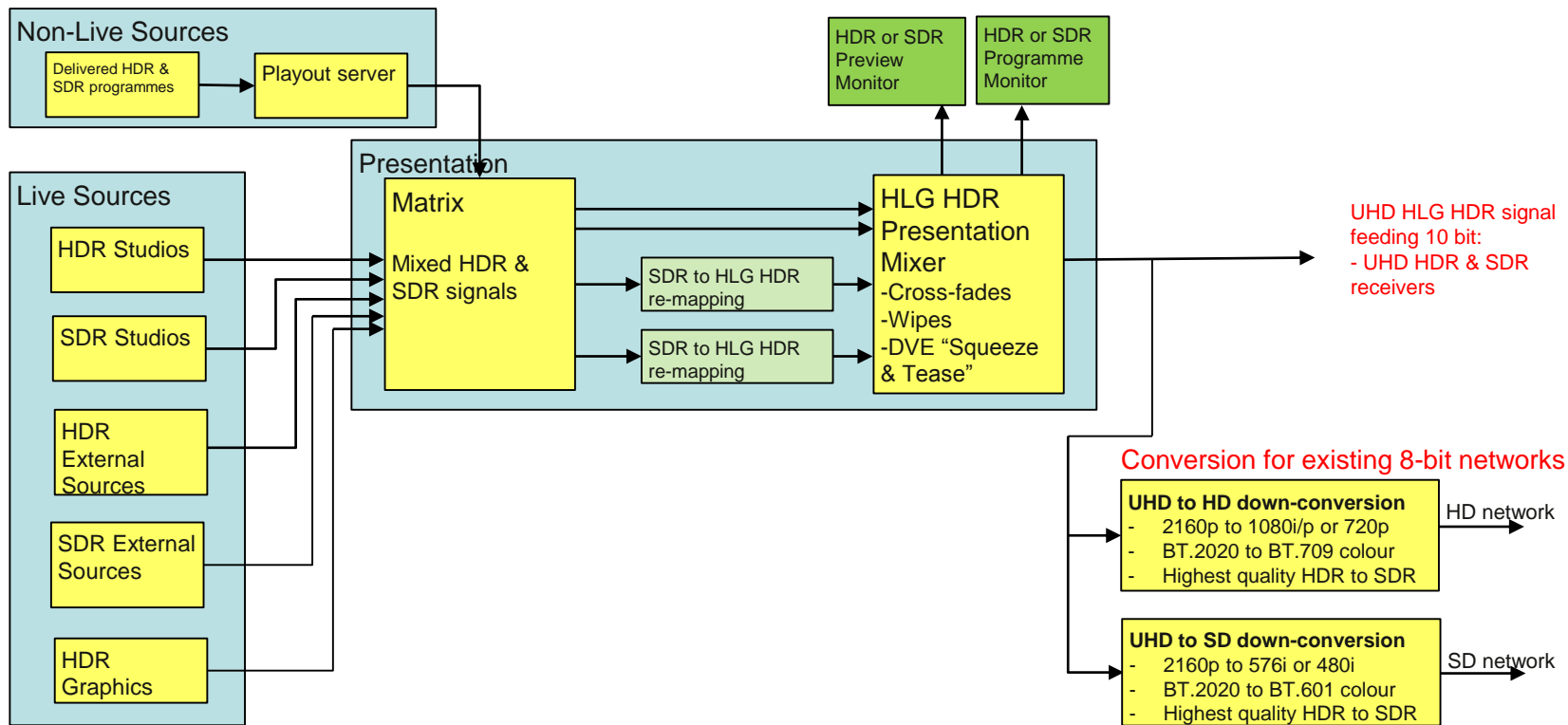


Even with just programme based metadata we can not:

- 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



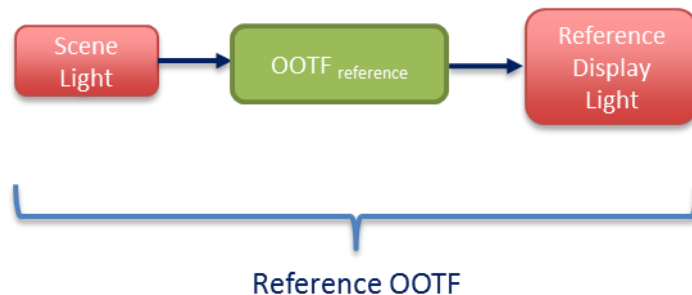
Opto-Optic Transfer Function

Scene light  $\neq$  displayed light

# Role of the Opto-Optic Transfer Function (OOTF)

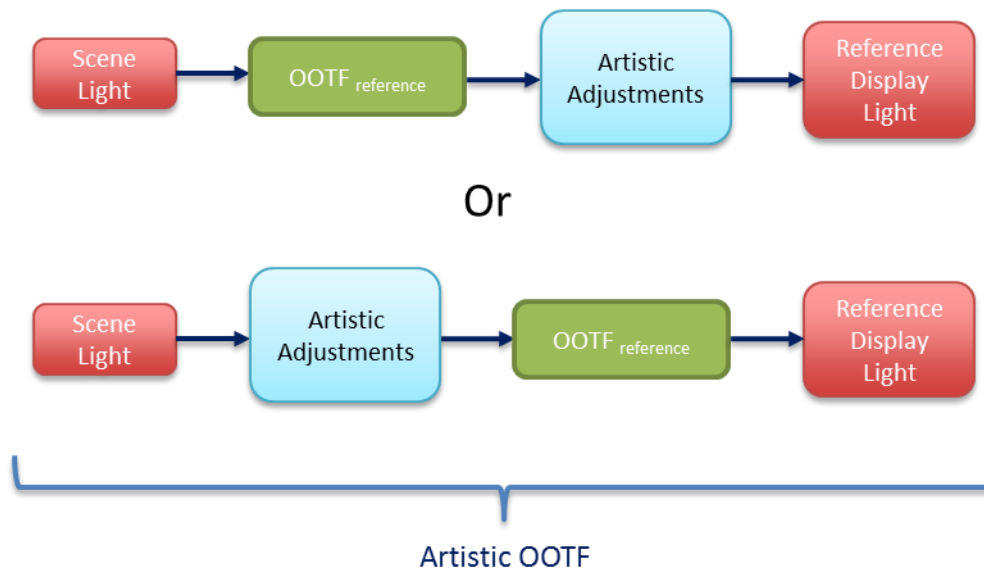
- Compensates for changes in tonal perception as the eye adapts to different environments
- Depends on,
  - brightness of the surround
  - peak brightness of the display
- Conventional “gamma law” known to work well as OOTF for both movies and TV:
  - Movies (negative/print) “gamma” 1.6 to 1.8
  - SDR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

# Reference Environments



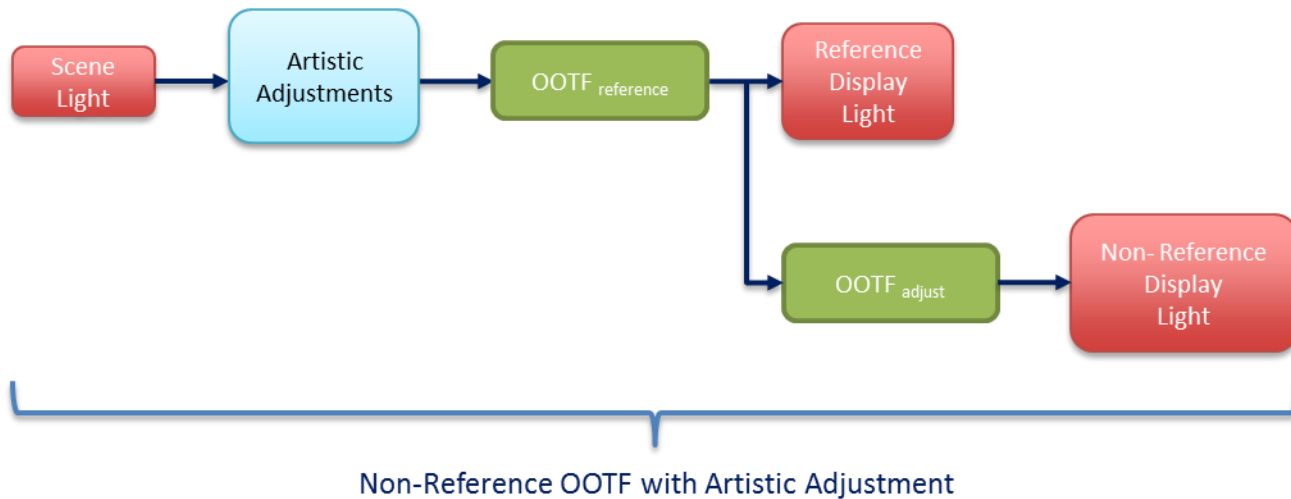
- OOTF<sub>reference</sub> designed to produce “natural” images on a reference display in the reference viewing environment

# Artistic Adjustments Can be Made to Enhance the Image

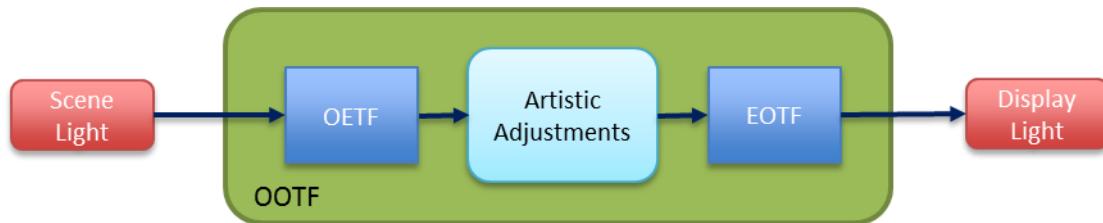


- Artistic adjustment can be applied either before or after the reference OOTF

# OOTF Must be Adapted for Other Environments and Displays

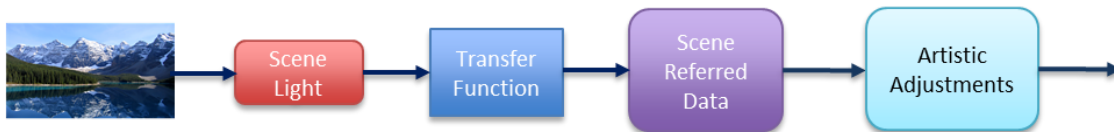


# In General OOTF is Concatenation of OETF, Artistic Adjustments and EOTF



### 3 Scene-referred & display-referred systems

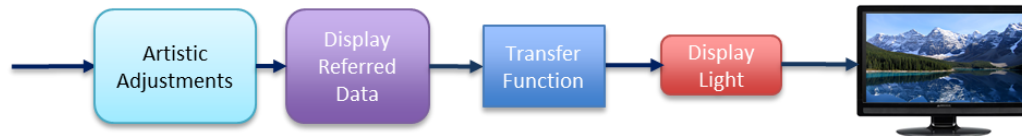
# Scene-Referred Systems



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)

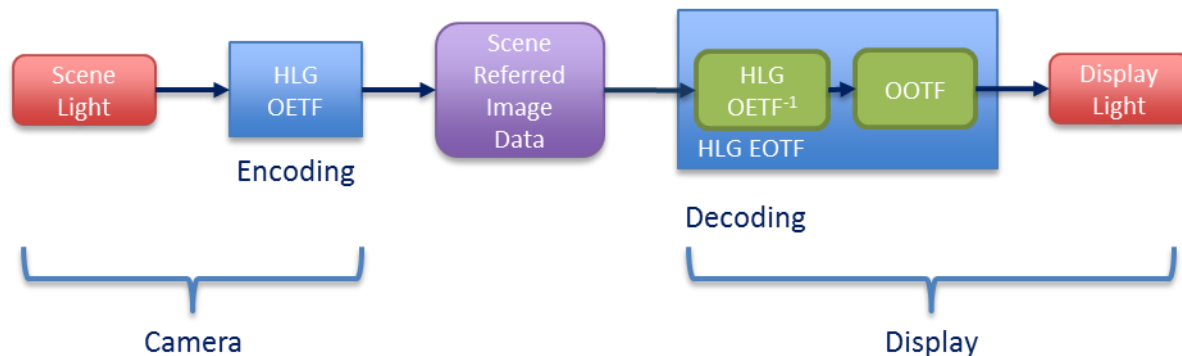
# Display-Referred Systems



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)

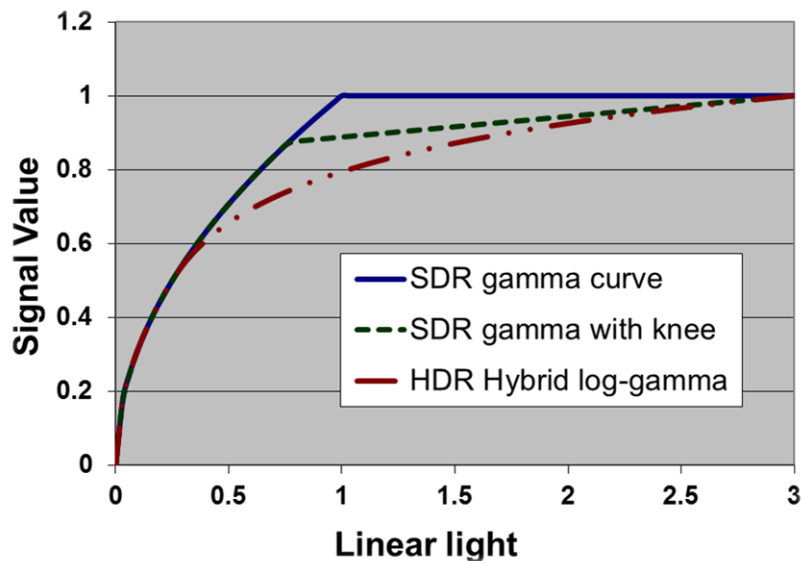
# For “Scene Referred” Systems OOTF is Part of EOTF



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

$a = 0.17883277$ ,

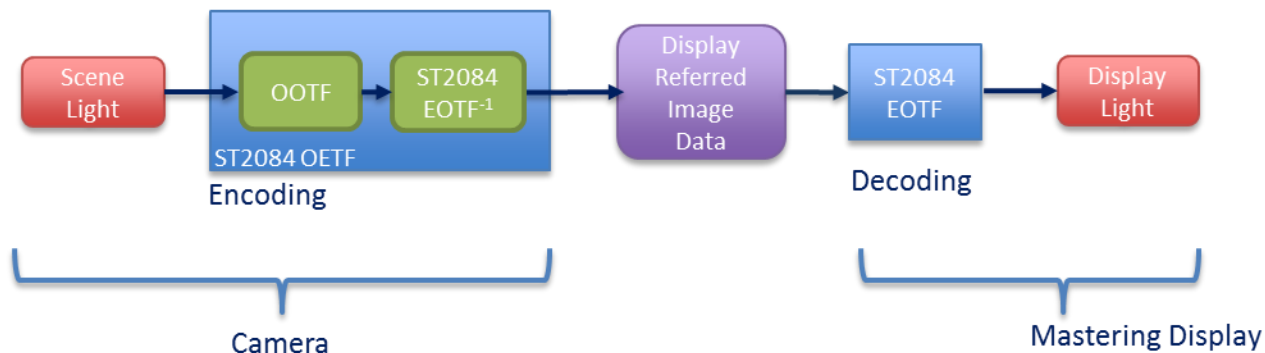
$b = 0.28466892$ ,

$c = 0.55991073$ .

# 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

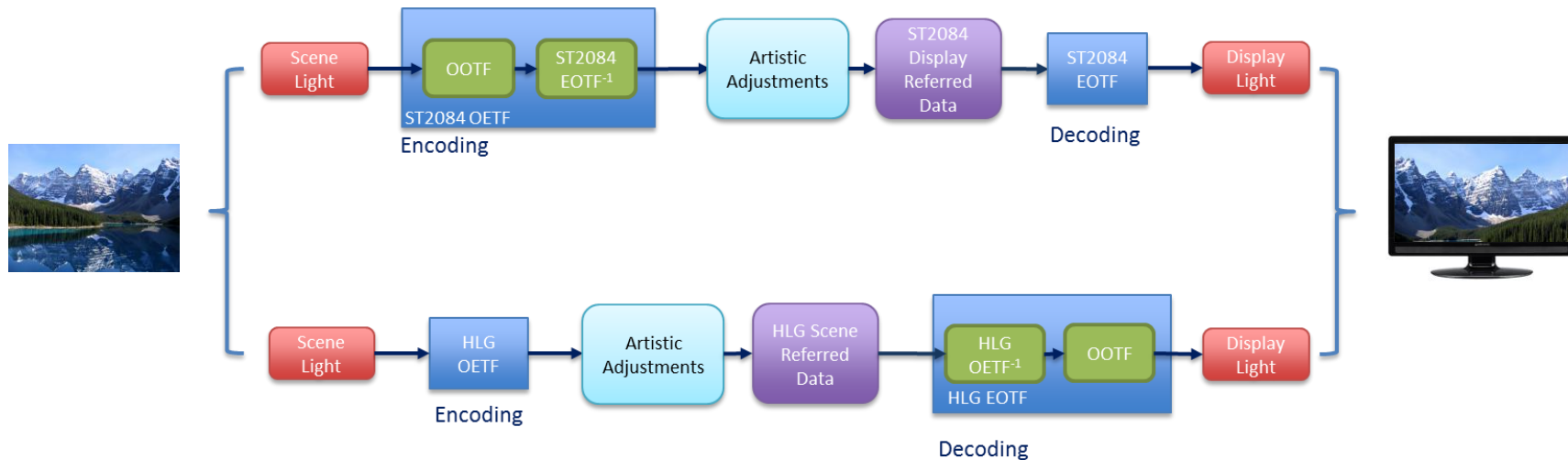
# For “Display Referred” Systems (e.g. SMPTE ST 2084) OOTF is Part of the OETF



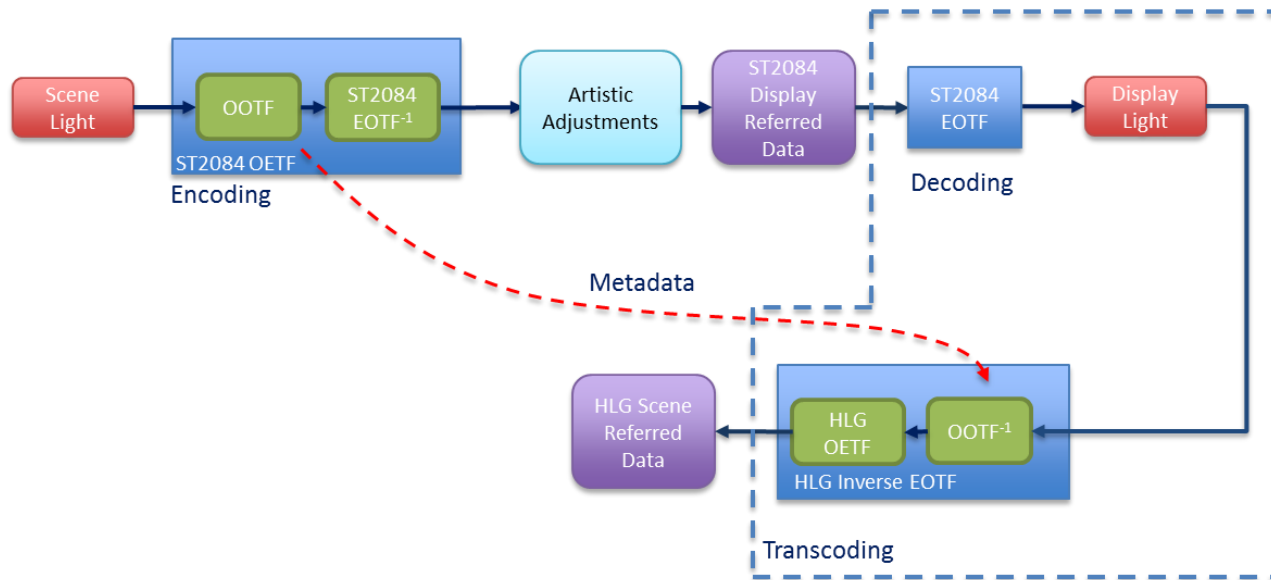
## ST2084 End-to-End Chain

- 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/511-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:

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

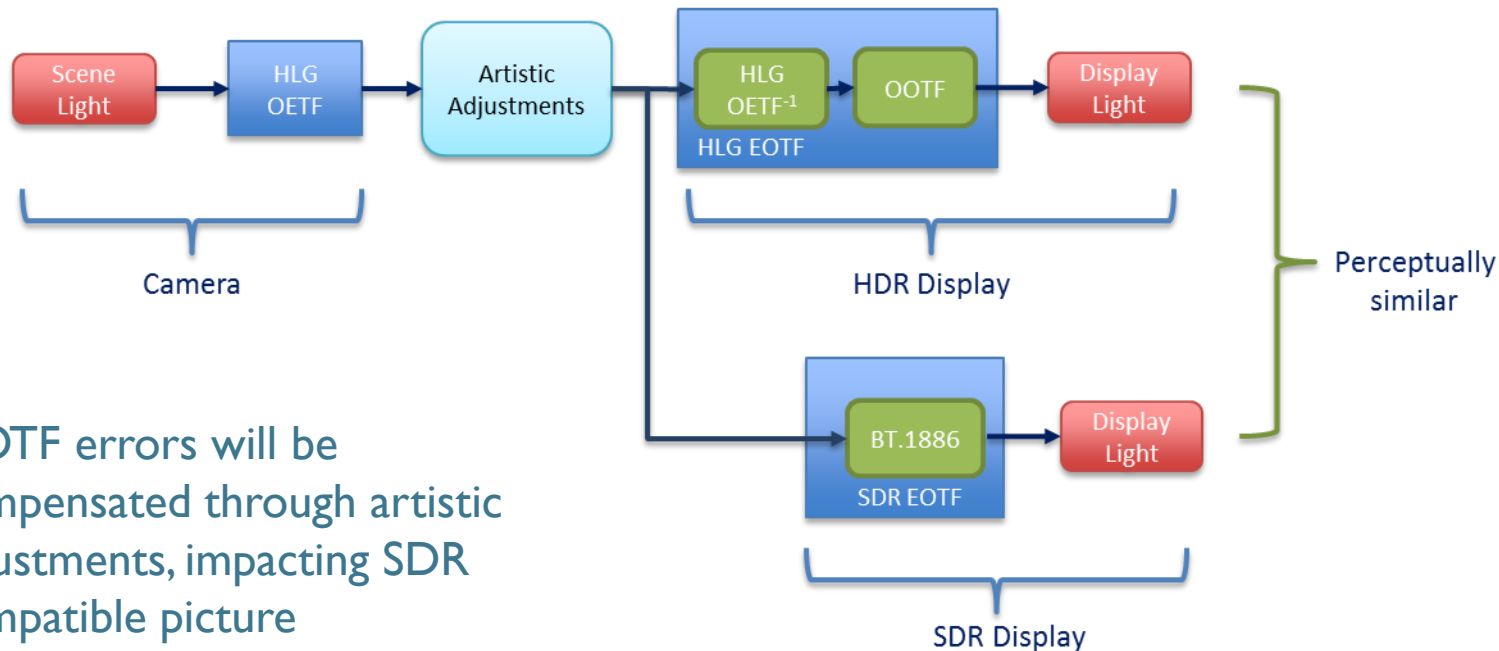
The video signal from the camera,  $E'$ , thus becomes:

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

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

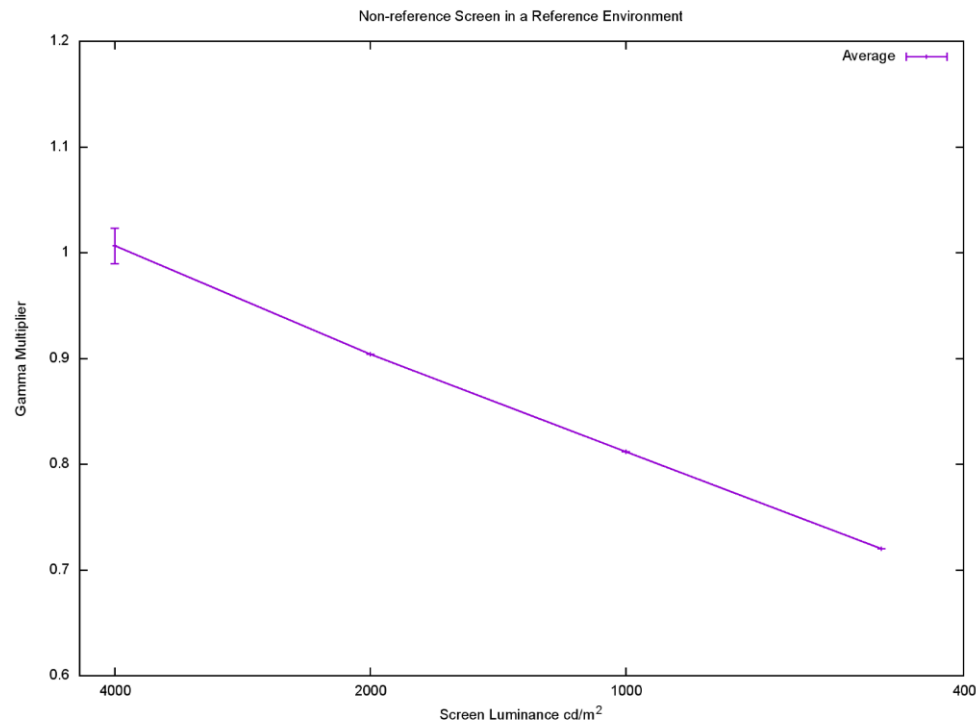
## 4 Latest BBC results

# OOTF<sub>reference</sub> Will Impact the HLG Compatible Image



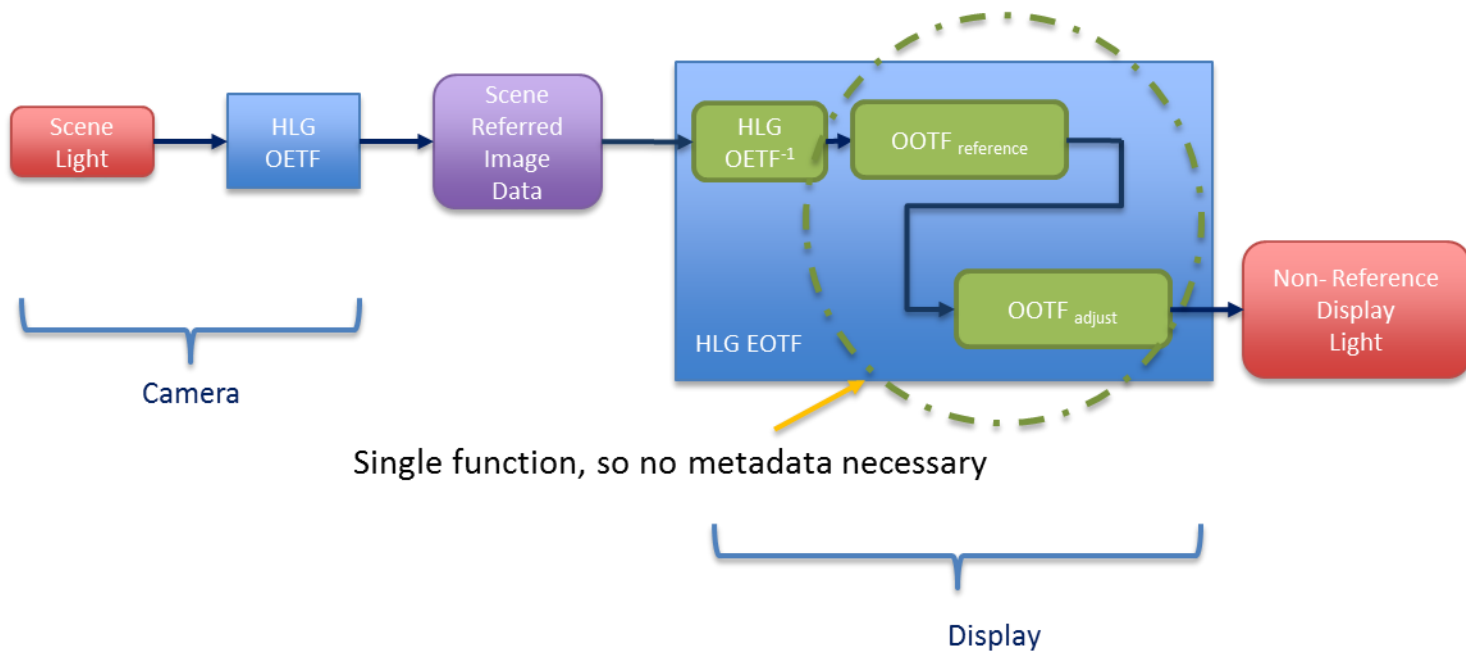
- OOTF errors will be compensated through artistic adjustments, impacting SDR compatible picture

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



- 4000, 2000, 1000 and 500  $\text{cd/m}^2$  on SIM2 display
- 5  $\text{cd/m}^2$  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  $\text{cd/m}^2$  adjustment using OLED display
- Independent of “reference” OOTF

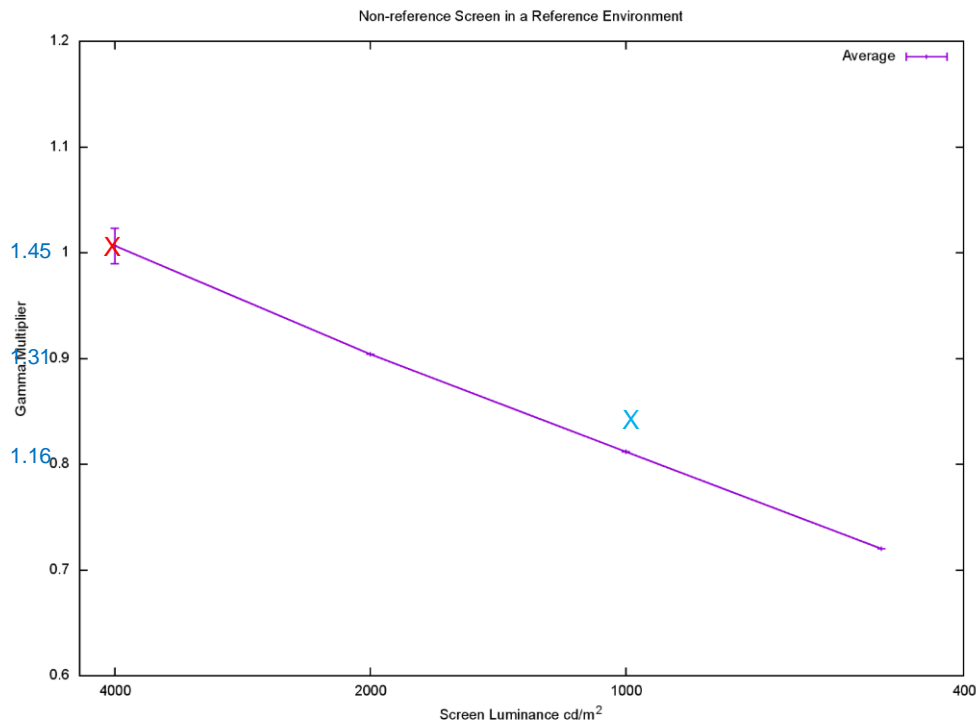
# For HLG, $\text{OOTF}_{\text{reference}}$ & $\text{OOTF}_{\text{adjust}}$ Combined So No Metadata



# OOTF for “Reference” Display and Environment

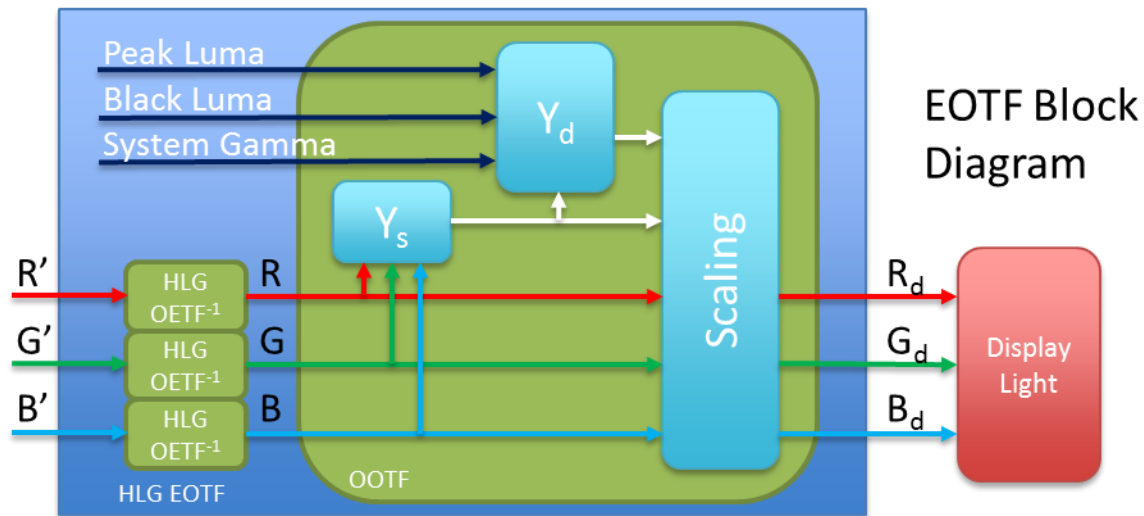
- First test set-up
  - 14 Mark Fairchild test images
  - “Gamma” function applied to luminance
  - 6 expert viewers asked to adjust gamma for most “natural” image on 4000 cd/m<sup>2</sup> SIM2 display
- Results
  - Wide variation between viewers
  - Some images very difficult to judge without a reference
  - 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



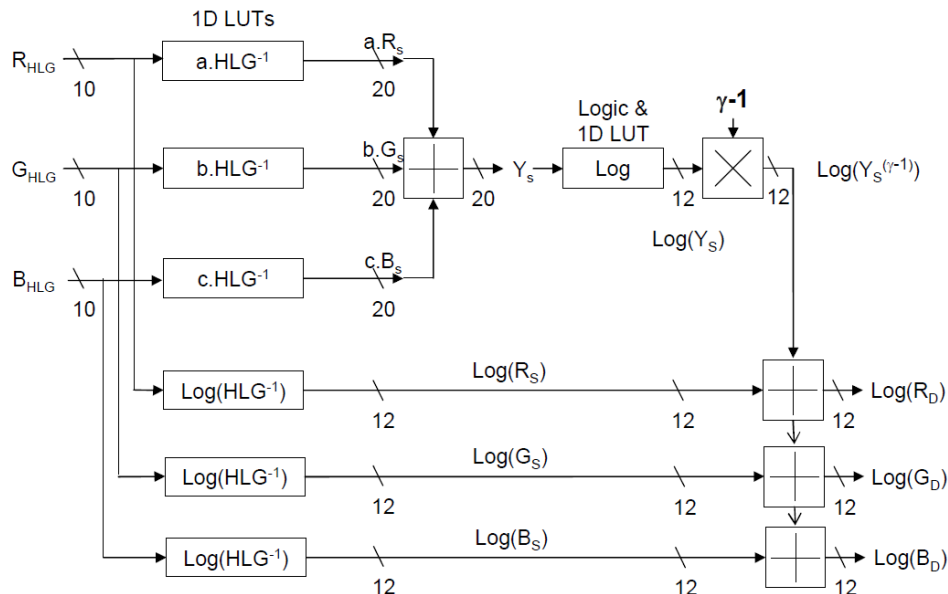
- Only 5 viewers
- Uncontrolled lighting
- Only 4 test images
  - Best SDR for 4000  $\text{cd/m}^2$  SMI2 display,  $\gamma \approx 1.45$
  - Best SDR for 1000  $\text{cd/m}^2$  OLED display  $\gamma \approx 1.27$
- More formal tests planned for this week
- Preliminary results consistent with earlier 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



Note: Intermediate bit depths are approximate

$$R_D = \alpha Y_s^{\gamma-1} R_s + \beta$$

$$G_D = \alpha Y_s^{\gamma-1} G_s + \beta$$

$$B_D = \alpha Y_s^{\gamma-1} B_s + \beta$$

$$\text{where } Y_s = aR_s + bG_s + cB_s$$

## 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