International Telecommunication Union

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Radiocommunication Sector of ITU

Recommendation ITU-R BT.814-4
(07/2018)

Specifications of PLUGE test signals and alignment procedures for setting of brightness and contrast of displays

BT Series

Broadcasting service (television)

International Telecommunication Union

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R BT.814-4*

Specifications of PLUGE** test signals and alignment procedures for setting of brightness and contrast of displays

(1992-1994-2007-2017-2018)

Scope

This Recommendation defines test signals and alignment procedures for the adjustment of displays used for programme production and monitoring. The signal may be used to set displayed image values for standard definition television, high definition television and ultra high definition television including the PQ and HLG high dynamic range television systems.

Keywords

PLUGE, display adjustment, HDR, HDR-TV, brightness, contrast

The ITU Radiocommunication Assembly,

considering

a) that precision picture monitors are used in a variety of applications including subjective laboratory testing and control room monitoring of operational systems;

b) that variations in the set-up and adjustment of displays may lead to variations in displayed pictures;

c) that special signals that assist with the set-up and adjustment of monitors have been developed and have been in operational use for many years,

recommends

1 that the PLUGE test signal (see Note 1) described in Annex 1 should be used for setting of displays used for subjective assessments, and for operational monitoring of systems described in Recommendations ITU-R BT.1700[1] and ITU-R BT.601[2];

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* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in the year 2018 in accordance with Resolution ITU-R 1.

** The term, PLUGE, was originally derived from "Picture Line Up Generating Equipment".

1 Recommendation ITU-R BT.1700 – Characteristics of composite video signals for conventional analogue television systems.

2 Recommendation ITU-R BT.601 – Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios.

2 that the PLUGE test signal described in Annex 2 should be used for setting of displays used for subjective assessments, and for operational monitoring of systems described in Recommendations ITU-R BT.709[3], ITU-R BT.2020[4] and ITU-R BT.2100[5];

3 that the procedure to be followed for the use of the PLUGE test signal should be as described in Annex 3,

further recommends

that further studies on methods for black level adjustment of HDR displays be conducted and that informative Annexes 4 and 5 of this Recommendation be updated to reflect improved methods.

Annex 1
(normative)

Specifications of PLUGE signal for SDTV

The PLUGE signal (see Fig. 1) is composed of:

a) three closely spaced narrow vertical stripes on the left-hand side of the picture. The central vertical stripe is at waveform black level. The left-hand stripe is slightly darker, and the right-hand stripe is slightly lighter than the central stripe;

b) a broad bar signal located on the right-hand side of the picture. It is divided into four areas, one at white level and the other three at descending grey levels. This grey scale is in approximately equal steps, as seen by eye, over a contrast range of 30:1. The peak white area is sufficiently large to enable the peak luminance to be set by a measuring instrument;

c) a uniform background surrounding the vertical stripes and the broad bar described above. Two different levels for this background are specified according to the application:
   - for operational monitoring the background level is set to signal black level;
   - for subjective assessments the background level is set to the grey level shown in Table 1. This background level has been optimized to give a picture display of subjective quality similar to that used in sequences used in subjective assessment.

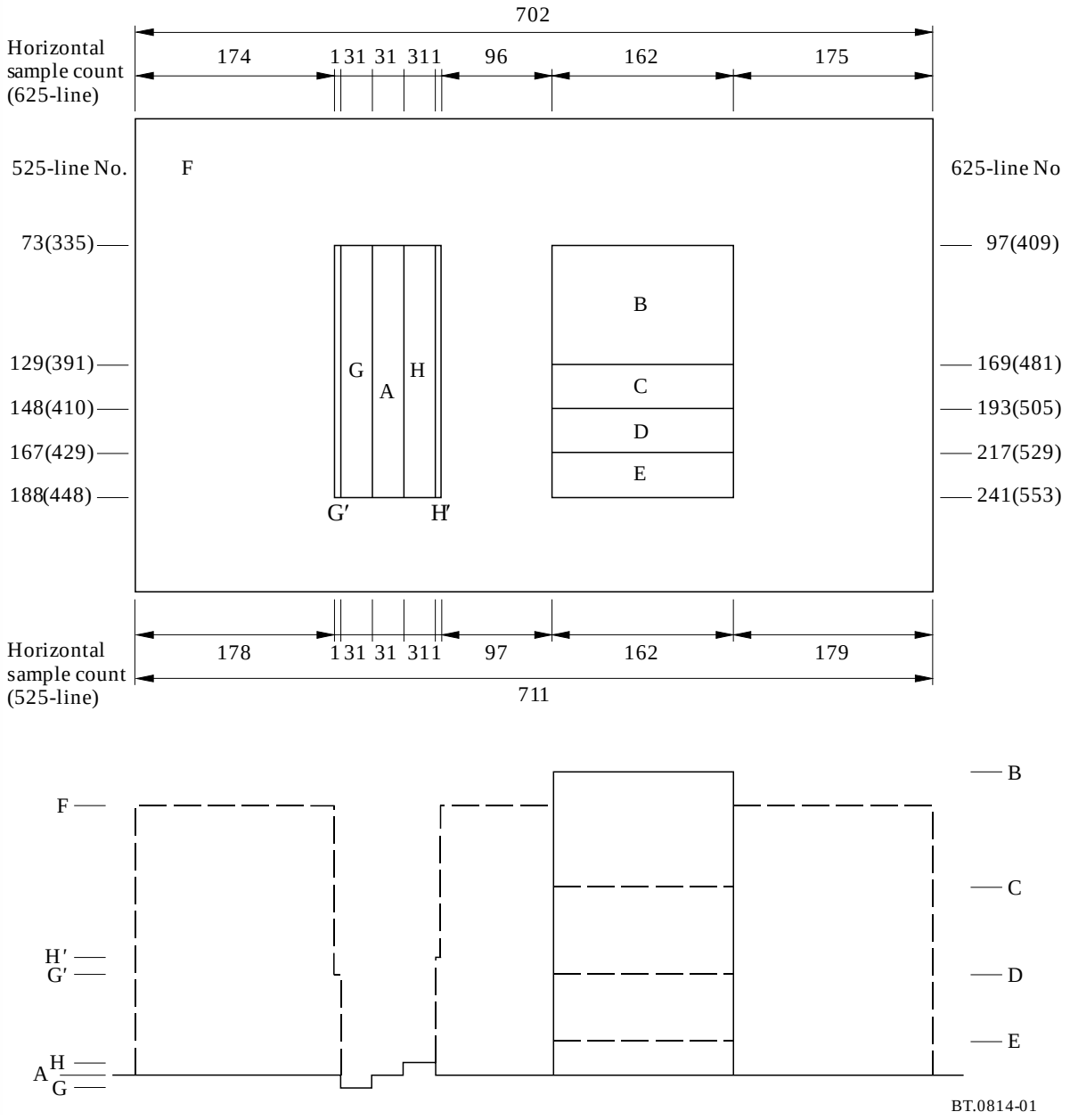
[3] Recommendation ITU-R BT.709 – Parameter values for the HDTV standards for production and international programme exchange.

[4] Recommendation ITU-R BT.2020 – Parameter values for ultra-high definition television systems for production and international programme exchange.

[5] Recommendation ITU-R BT.2100 – Image parameter values for high dynamic range television for use in production and international programme exchange.

FIGURE 1

PLUGE active field and waveform



To take account of the characteristics of the human eye, the luminance specified for the vertical stripes described in c) is slightly different for the two applications (see Table 1).

To ensure that in analogue composite systems the colour decoder of a display is working in its colour mode, it is recommended that a standard colour burst is included in the analogue waveform.

The horizontal sample count is less than the 720 horizontal samples defined in Recommendation ITU-R BT.601. The PLUGE signal should be centred within the active line of digital and analogue systems ±2 samples.

TABLE 1

Levels of waveform

	Operational monitoring			Subjective assessment monitoring		
	Level % mV digital			Level % mV digital		
	625-line	525-line		625-line	525-line	
A black level	0% 0 mV (16)64	0% 0 mV (16)64	7.5% 54 mV (16)64	0% 0 mV (16)64	0% 0 mV (16)64	7.5% 54 mV (16)64
B white level	100% 700 mV (235)940	100% 714 mV (235)940	100% 714 mV (235)940	100% 700 mV (235)940	100% 714 mV (235)940	100% 714 mV (235)940
C grey level 3	63.0% 441 mV (154)616	63.0% 450 mV (154)616	65.8% 470 mV (154)616	63.0% 441 mV (154)616	63.0% 450 mV (154)616	65.8% 470 mV (154)616
D grey level 2	35.2% 246 mV (93)372	35.2% 251 mV (93)372	40.0% 286 mV (93)372	35.2% 246 mV (93)372	35.2% 251 mV (93)372	40.0% 286 mV (93)372
E grey level 1	15.1% 105 mV (49)196	15.1% 108 mV (49)196	21.4% 153 mV (49)196	15.1% 105 mV (49)196	15.1% 108 mV (49)196	21.4% 153 mV (49)196
F background level	0% 0 mV (16)64	0% 0 mV (16)64	7.5% 54 mV (16)64	70.3% 492 mV (170)680	70.3% 502 mV (170)680	72.5% 518 mV (170)680
G black stripe level	–1.8% –13 mV (12)48	–1.8% –13 mV (12)48	5.8% 42 mV (12)48	–2.7% –19 mV (10)40	–2.7% –20 mV (10)40	5.0% 35 mV (10)40
G' mid-level between black stripe and background levels	NA	NA	NA	33.8% 237 mV (90)360	33.8% 237 mV (90)360	38.8% 277 mV (90)360
H grey stripe level	1.8% 13 mV (20)80	1.8% 13 mV (20)80	9.2% 66 mV (20)80	2.7% 19 mV (22)88	2.7% 20 mV (22)88	10.0% 72 mV (22)88
H' mid-level between grey stripe and background levels	NA	NA	NA	36.5% 256 mV (96)384	36.5% 256 mV (96)384	41.3% 295 mV (96)384

Note 1 – The 10 bit digital levels are defined as the primary values, and the rest are derived. The 8 bit digital levels are in parentheses.

Note 2 – Digital levels are expressed in the same way as described in Recommendation ITU-R BT.601.

Note 3 – For the subjective assessment monitoring waveform, mid-levels between stripes and background are introduced to avoid ringing due to the sharp transition of the waveform.

Note 4 – NA: the mid-level is not applied, and the level for this area is the same as the background.

Annex 2
(normative)

PLUGE for HDTV, UHDTV and HDR-TV systems[6]

A PLUGE signal for HDTV, UHDTV and HDR displays is shown in Figs 2 and 3. Corresponding sample numbers (horizontal) are given in Table 4 and line numbers are given in Table 5 for HDTV SDR and HDR image formats and sample numbers (vertical) are given in Table 6 for UHDTV SDR and HDR image formats. Code values of signal levels are given in Table 2 for SDR and in Table 3 for HDR.

The central Higher level patch is used to set the luminance level of the display by means of the user gain control.

In the case of HDR, the code value of the central Higher level patch is identical for both PQ and HLG. This differs from that of the peak white luminance level of PLUGE signals for SDR.

Two types of signal can be used to set the brightness of the black level of the display by means of the user black level lift control.

The signal on the left-hand side of the picture consists of narrow horizontal stripes (a width of 10 scanning lines for HDTV, 20 samples (vertical) for 4K UHDTV, and 40 samples (vertical) for 8K UHDTV). The stripes extend from approximately 2% above the black level of the waveform to approximately 2% below the black level. The signal on the right-hand side of the picture consists of two coarse stripes (a width of 144 lines for HDTV, 288 samples (vertical) for 4K UHDTV, and 576 samples (vertical) for 8K UHDTV) one stripe is approximately 2% above black level the other is approximately 2% below black level. This signal is suitable for setting display values.

TABLE 2

Code values for HDTV and UHDTV (SDR)

Parameter values, Figs 2 and 3 for SDR	8-bit digital value	10-bit digital value	12-bit digital value
Higher level	235	940	3 760
Black level	16	64	256
Slightly lighter level	20	80	320
Slightly darker level	12	48	192

[6] Sample and line numbers are as represented in Recommendation ITU-R BT.709 for HDTV and as in Recommendation ITU-R BT.2020 for UHDTV.

TABLE 3

Narrow range code values for HDR

Parameter values, Figs. 2 and 3 for HDR	10-bit digital value	12-bit digital value
Higher level[1, 2]	399	1 596
Black level	64	256
Slightly lighter level	80	320
Slightly darker level	48	192

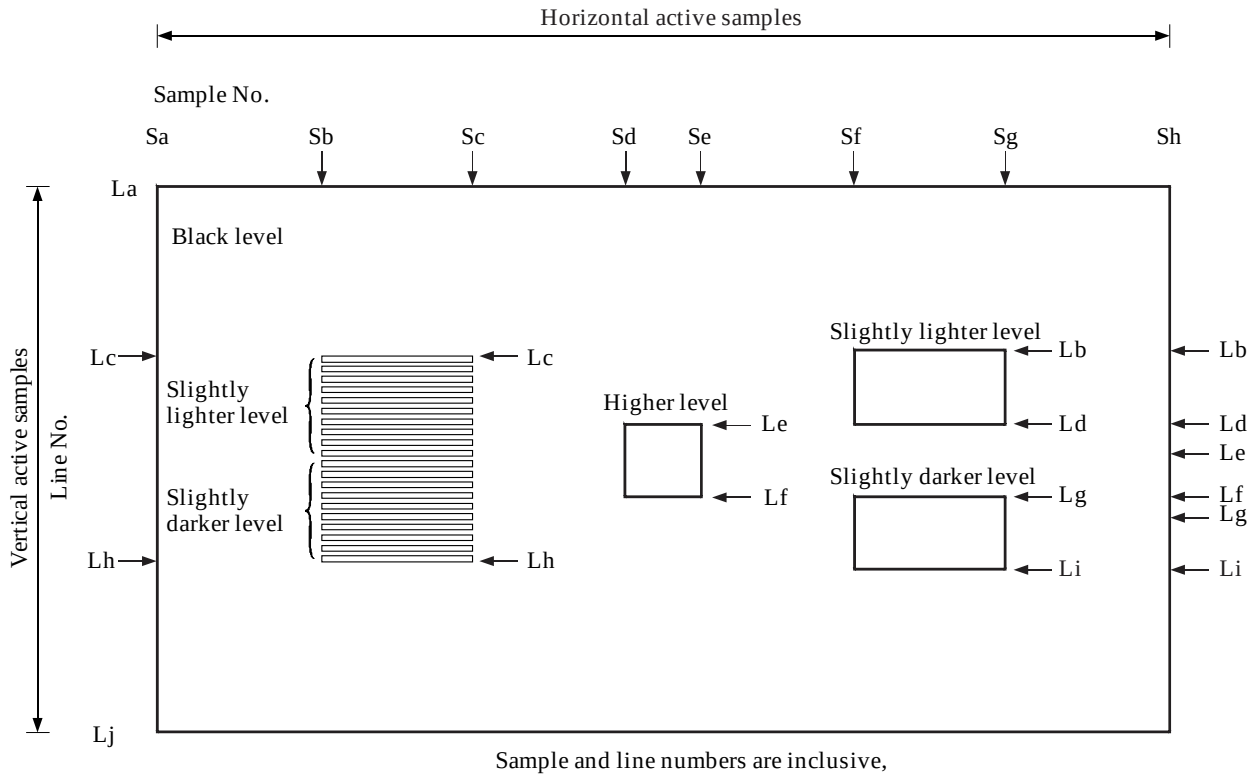
Note 1 – This level corresponds to 38.2% PQ and HLG and results in the same luminance for both PQ and HLG signals (approximately 27 cd/m^2) when displayed on a PQ display or on an HLG display with peak luminance of 1 000 cd/m^2 (a "1 000 cd/m^2 display").

Note 2 – Luminance value LH of the Higher level for an HLG display of peak luminance Lw is derived using the HLG EOTF in Table 5 of Recommendation ITU-R BT.2100 in conjunction with the system gamma obtained in accordance with Note 5e of Recommendation ITU-R BT.2100, and may be calculated as follows:

$$L_H = L_w \times 0.048748^{(1.2 + 0.42 \times \log_{10}(L_w/1000))}$$

FIGURE 2

PLUGE signal for adjusting black level



Sample and line numbers are inclusive,
e.g. the Higher levelbox Sd is the firstHigher levelsample
and Se is the lastHigher levelsample.

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TABLE 4

Sample numbers (horizontal) for corresponding image formats

Sample number (horizontal)	HDTV	4K UHDTV	8K UHDTV
Sa	0	0	0
Sb	312	624	1 248
Sc	599	1 199	2 399
Sd	888	1 776	3 552
Se	1 031	2 063	4 127
Sf	1 320	2 640	5 280
Sg	1 607	3 215	6 431
Sh	1 919	3 839	7 679

TABLE 5

Line numbers for HDTV image formats

Line number as per Rec. ITU-R BT.709	HDTV (interlaced)	HDTV (progressive)
La	21, 584	42
Lb	183, 746	366
Lc	194, 756	387
Ld	254, 817	509
Le	255, 818	510
Lf	326, 889	653
Lg	327, 890	654
Lh	388, 950	776
Li	398, 961	797
Lj	560, 1 123	1 121

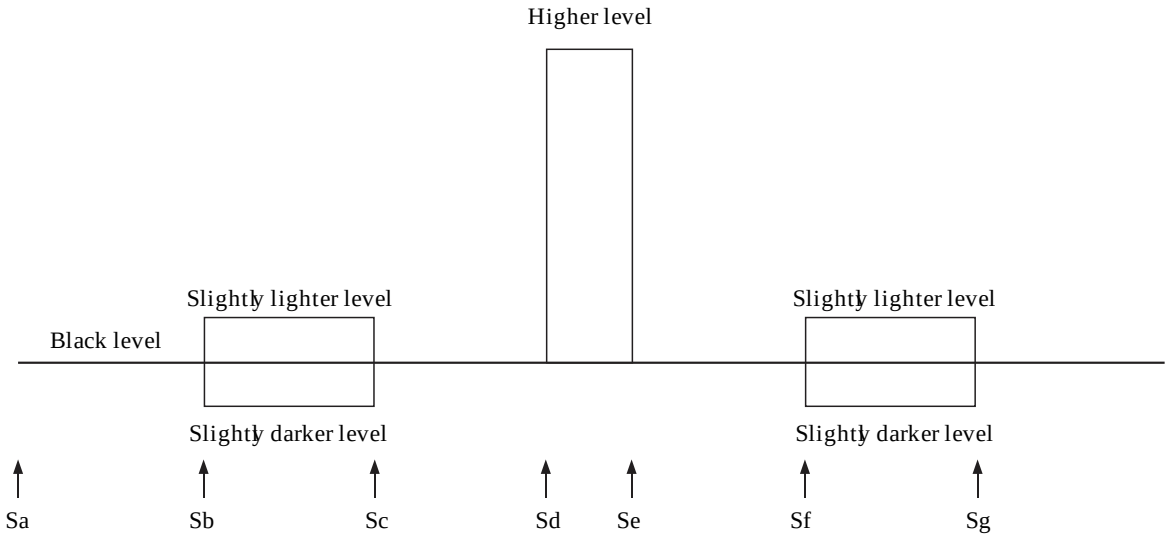
TABLE 6

Sample numbers (vertical) for UHDTV image formats

Sample number (vertical) as per Rec. ITU-R BT.2020	4K UHDTV	8K UHDTV
La	0	0
Lb	648	1 296
Lc	690	1 380
Ld	935	1 871
Le	936	1 872
Lf	1 223	2 447
Lg	1 224	2 448
Lh	1 469	2 939
Li	1 511	3 023
Lj	2 159	4 319

FIGURE 3

Analogue waveform of the signal for adjusting black level



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Annex 3
(normative)

Procedure for use of PLUGE test signals

1 Standard Dynamic Range (SDR) Television

The adjustments described below are very dependent on the viewing conditions and it is preferable to conform to the conditions for viewing distance and ambient illumination contained in Recommendations ITU-R BT.2022 and ITU-R BT.2035:

– the user gain control (legacy “contrast” control) is adjusted such that the centre of the white area (100% video level) reaches the desired luminance of the display;

– the user black level lift control (legacy “brightness” control) is adjusted such that the blackest stripe just disappears, whilst the brighter stripe remains visible.

2 High Dynamic Range (HDR) Television

The adjustments described below must be conducted in the following order and are very dependent on the viewing conditions. It is preferable to conform to the conditions for the reference viewing environment contained in Recommendation ITU-R BT.2100:

1. in the case of HLG only, the display’s system gamma control is adjusted in accordance with the target nominal peak luminance of the display, appropriate for the viewing environment, according to Note 5e of Recommendation ITU-R BT.2100;

2. for HLG only[7], the user black level lift control is first set to zero and the user gain control is then adjusted such that the centre of the Higher level area has the nominal luminance value corresponding to code value specified in Table 3;
3. in the case of HLG only, a further adjustment to the system gamma can be made to compensate for non-reference viewing environments. See Note 5f of Recommendation ITU-R BT.2100 and Annex 5;
4. for both PQ and HLG, the user black level lift control is adjusted such that the blackest stripe just disappears, whilst the brighter stripe remains visible. In a non-reference viewing environment, a black level control for a PQ display may be applied as described in Annex 4 with respect to the PQ EOTF specified in Recommendation ITU-R BT.2100.

Annex 4
(informative)

Black level control for PQ displays

To enable the PQ PLUGE adjustment, the signal E' that is applied in the PQ EOTF[8] may be replaced by the signal $\max(0, aE' + b)$:

$$F_D = \text{EOTF}[\max(0, aE' + b)]$$

where:

E': denotes a non-linear PQ colour value {R', G', B'}

F_D: is the luminance[9] of an adjusted displayed linear component {R_D, G_D, B_D} in cd/m^2

b: is the variable for user black level lift control

a: is an attenuation factor[10] that maintains a constant value of luminance $F_D = L_m$, for $E' = E'_m$, as b is adjusted:

$$a = 1 - b / \text{EOTF}^{-1}[L_m]$$

L_m: is the maximum rated luminance of the display

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[7] In the case of PQ, a user gain control is not required. This is because the display luminance is determined by the PQ EOTF, although the maximum displayable peak luminance will depend on the design capability of the display (the "maximum rated luminance").

[8] The PQ EOTF is specified in Recommendation ITU-R BT.2100.

[9] In this Recommendation, when referring to the luminance of a single colour component (R_D, G_D, B_D), it means the luminance of an equivalent achromatic signal with all three colour components having that same value.

[10] Without a compensating attenuation, an increase in b will cause an increase in F_D for all values of E'. Such an overall lift in luminance can cause pixels that were within the PQ monitor's luminance range to exceed that luminance range. If L_m is the maximum rated luminance for the display, application of the attenuation factor 'a' will, for $E' = E'_m$, cause F_D to maintain a constant value of L_m as 'b' is adjusted.

E'_m : is the value of E' that produces the maximum rated luminance for the display:

$$E'_m = \mathrm{EOTF}^{-1}[L_m]$$

Annex 5
(informative)

HLG display gamma adjustment in a non-reference viewing environment

Note 5f of Recommendation ITU-R BT.2100 recognises that the HLG display gamma may need to be reduced in brighter viewing environments, to compensate for the differences in the adaptation state of the eye. The following equation can be used to determine how the display gamma may be adjusted in non-reference viewing environments:

$$\gamma_{bright} = \gamma_{ref} - 0.076 \log_{10}(\frac{L_{amb}}{5})$$

where:

γ_{bright} : system gamma for display surrounds greater than 5 cd/m^2

γ_{ref} : system gamma for reference environment, calculated according to Recommendation ITU-R BT.2100-1 Note 5e

L_{amb} : ambient luminance level in cd/m^2.

By adjusting the display gamma to compensate for non-reference viewing environments in this way, more consistent results may be achieved in a wide range of production environments.