

Recommendation ITU-R BT.2163-0

(11/2023)

BT Series: Broadcasting service (television)

Objective measurement algorithm for evaluation of the brightness of high dynamic range television

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RA	Radio astronomy
RS	Remote sensing systems
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SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
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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.2163-0

**Objective measurement algorithm for evaluation of the brightness
of high dynamic range television^{1,2}**

(Question ITU-R 142-3/6)

(2023)

Scope

This Recommendation specifies a measurement algorithm for the purpose of determining the Image Level, based on mean image luminance, which may be useful for assessing the brightness of individual images. Further metrics, based on the Image Level, are Temporal Image Level and Image Level Response which may be useful in modelling the response of the human visual system to a sequence of images.

Keywords

Video measurement, brightness, television production, high dynamic range, HDR, television, HDR-TV, international programme exchange

The ITU Radiocommunication Assembly,

considering

- a) that high dynamic range television (HDR-TV) offers an extremely wide dynamic range of image luminance levels;
- b) that large jumps in brightness can be surprising to viewers;
- c) that monitoring of image brightness facilitates understanding of the viewer experience;
- d) that the state of human visual system adaptation is affected by the temporal sequence of images;
- e) that Recommendation ITU-R BT.2100 specifies two forms of HDR-TV, Perceptual Quantization (PQ) and Hybrid Log-Gamma (HLG), and that production in both formats is expected;
- f) that a nominal peak luminance of 1 000 cd/m² is commonly used for HLG reference displays;
- g) that reference surround environment conditions are specified in Table 3 of Recommendation ITU-R BT.2100;
- h) that existing video measurement methods employed in production do not provide a numeric value representing subjective image brightness;
- i) that, to facilitate the evaluation of subjective video brightness of programmes, standardized measurement methods are useful,

recognizing

that use of such algorithms will supplement, rather than replace, conventional waveform monitoring,

¹ This Recommendation is not a replacement for the guidance contained in Recommendation ITU-R BT.1702 which is for the protection of the vulnerable section of the viewing population who have photosensitive epilepsy, and who are therefore prone to seizures triggered by flashing lights, including certain types of flashing television images.

² The algorithms may need to be revised after testing on a wider variety of moving images and when tested in conjunction with a metering specification that is currently under development.

recommends

- 1 that when a measure of subjective brightness of a high dynamic range image, produced as per Recommendation ITU-R BT.2100, is required to facilitate programme production and exchange, the Image Level algorithm specified in Section 1 may be used;
- 2 that the Temporal Image Level measurement algorithm, specified in § 2, may be used to assess the contribution of an image sequence to viewer adaptation;
- 3 that the approximation to the response of the eye, Image Level Response, specified in § 3, may be useful for evaluating the significance of changes in brightness within a programme,

further recommends

- 1 that this Recommendation should not be used as a tool in brightness regulation, impose operator restrictions or limit content creation;
- 2 that due to limited verification of algorithms with moving images, the ITU-R may wish to consider early updates and improvements to this Recommendation.

1 Image Level measurement algorithm

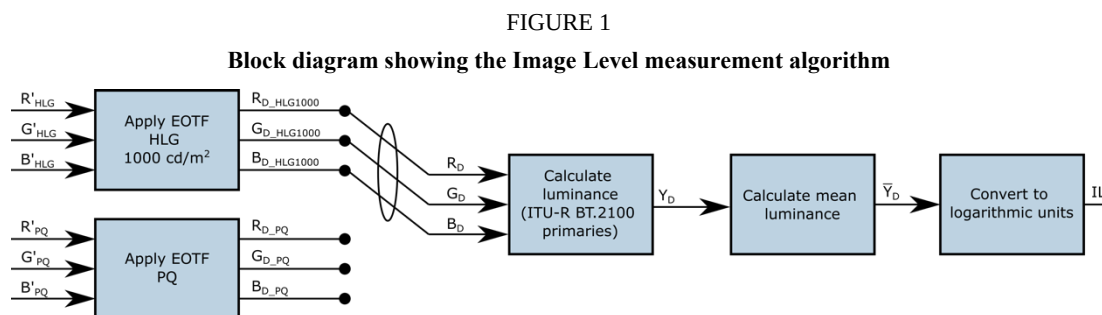
This section specifies the Image Level (IL) measurement algorithm, which may be useful for assessing overall image brightness. The IL algorithm is the basis of the other metrics specified in this Recommendation in §§ 2 and 3.

The input to the IL measurement algorithm is a non-linear Recommendation ITU-R BT.2100 HLG or PQ signal, $R'G'B'$, in the range [0:1].

The algorithm consists of four stages:

- 1 conversion to linear display light;
- 2 calculation of the luminance component;
- 3 calculation of the mean display luminance;
- 4 conversion to logarithmic units.

Figure 1 shows a block diagram of the algorithm.



1.1 Conversion to linear display light

For HLG signals $R'G'B'_{\text{HLG}}$, the HLG EOTF specified in Recommendation ITU-R BT.2100, Table 5 is applied, using a value of 1.2 for γ as specified in Note 5f to Table 5 of Recommendation ITU-R BT.2100 for a display with a nominal peak luminance of 1 000 cd/m^2 . The resulting signal is display linear light $R_D G_D B_D_{\text{HLG}}$ in the range [0:1 000] cd/m^2 .

For PQ signals $R'G'B'_{\text{PQ}}$, the PQ EOTF specified in Recommendation ITU-R BT.2100, Table 4 is applied. The resulting signal is display linear light $R_D G_D B_D_{\text{PQ}}$ in the range [0:10 000] cd/m^2 .

Hereafter the component linear display light signal is referred to as $R_D G_D B_D$, irrespective of whether the signal originated as HLG or PQ.

1.2 Calculation of the luminance component

The linear displayed luminance signal Y_D is calculated using the equation

$$Y_D = 0.2627R_D + 0.6780G_D + 0.0593B_D$$

An approximate method is described in Annex 1.

1.3 Calculation of the mean display luminance

The mean display luminance $\bar{Y}_D$ for the video frame, in units of cd/m^2 , is then calculated.

$$\bar{Y}_D = \frac{1}{H \times V} \sum_{h=0}^{H-1} \sum_{v=0}^{V-1} Y_D(h, v)$$

where:

- $Y_D(h, v)$: linear displayed luminance of the pixel value at horizontal position h , vertical position v
- H : number of horizontal pixels
- V : number of vertical pixels.

1.4 Conversion to logarithmic units

The mean display luminance in cd/m^2 is converted to base 2 logarithmic units, with a normalization value of 1 cd/m^2 .

NOTE – A mean display luminance of 1 cd/m^2 produces an IL value of zero.

$$IL = \log_2 \frac{\bar{Y}_D}{1}$$

Background research for this algorithm is supplied in Annex 2.

2 Temporal Image Level algorithm

Viewing a sequence of images affects the adaptation state of a human observer and therefore the perceived impact of the Image Level. The Temporal Image Level (TIL)³ may be useful for assessing image brightness over time. The TIL is calculated as follows:

$$TIL(t) = \begin{cases} IL(t) & \text{if } t = 0 \\ TIL(t-1) \left(1 - \frac{1}{\tau+1}\right) + IL(t) \left(\frac{1}{\tau+1}\right) & \text{if } t > 0 \end{cases}$$

where t is the frame number starting with 0, and τ is the characteristic time of decay, a constant which is set to:

$$p(t) = \begin{cases} 1 & \text{if } t = 0 \\ IL(t) - TIL(t-1) & \text{if } t > 0 \end{cases}$$

³ The TIL algorithm has only been verified under limited conditions with mostly static image content such as those described in Annex 4. The TIL algorithm may need to be revised after testing on a wider variety of moving images.

$$\tau = \begin{cases} 22 \frac{f}{24} & \text{if } p(t) \geq 0 \\ 800 \frac{f}{24} & \text{if } p(t) < 0 \end{cases}$$

where:

f : framerate (in Hz) of the video.

The derivation of the functional form of TIL is shown in Annex 3, and the time of decay value choices are described in Annex 4.

3 Image Level Response algorithm

The Image Level Response (ILR) is used to model the response of the human visual system to the luminance of an image. It may be useful for assessing the instantaneous level of viewer annoyance arising from changes in Image Level, for example at a shot-change. It does not model the decay in subjective annoyance following a change in brightness. However, it may provide a useful input to metering devices that, when combined with other measures specified in this document, could model that decay. It is dependent on both the luminance of the image and the level of adaptation of the eye. In a Recommendation ITU-R BT.2100 reference environment, this response can be approximated using the IL and TIL quantities as follows:

$$ILR = \frac{(2^{IL})^{n_c}}{(2^{IL})^{n_c} + (2^{TIL})^{n_c}}$$

where:

ILR : approximate response of the human visual system

n_c : constant equal to 0.57.

Annex 1 (informative)

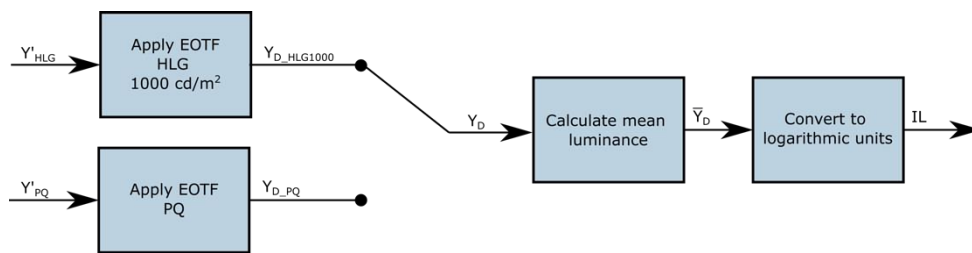
Approximation of the display luminance calculation for simplified hardware implementation

This Annex describes an approximate method of calculating the display luminance component, Y_D , that simplifies the implementation of the IL algorithm described in § 1. Where hardware resources are restricted, this method could be implemented in devices that are used for a visual aid only. Saturated colours might give rise to lower measurement values using this approximation. Devices using this method would not be suitable for numerical analysis of the IL values, and hence would not need to log IL values.

Figure 2 shows a block diagram of the approximate algorithm. Its input is a non-linear HLG or PQ luma signal, Y' , in the range [0:1]. If the signal is IC_{TCB} , the I signal can be used in place of Y' in the diagram below.

FIGURE 2

Block diagram showing the approximate IL measurement algorithm



Conversion to approximate⁴ linear display light

For HLG signals Y'_{HLG} , the HLG EOTF specified in Recommendation ITU-R BT.2100, Table 5 is applied directly on Y'_{HLG} , using a value of 1.2 for γ as specified in Note 5f to Table 5 of Recommendation ITU-R BT.2100 for a display with a nominal peak luminance of 1 000 cd/m². The resulting signal approximates display linear light Y_{D_HLG} in the range [0:1 000] cd/m².

For PQ signals Y'_{PQ} , the PQ EOTF specified in Recommendation ITU-R BT.2100, Table 4 is applied directly on Y'_{PQ} . The resulting signal approximates display linear light Y_{D_PQ} in the range [0:10 000] cd/m².

The approximate linear display light signal is referred to as Y_D , irrespective of whether the signal originated as HLG or PQ.

The approximate value of Y_D is then used in the remaining calculations described in §§ 1.2 and 1.3.

Annex 2 (informative)

Objective metrics for brightness measurement in high dynamic range television

This Annex describes background research that has informed development of the Image Level algorithm described in § 1. After an overview of related work, a subjective test is described that established values to use as brightness data for a set of test images. These values are then used to test a number of potential objective metrics for measuring image brightness.

Related work

There is an extensive body of work on brightness perception and adaptation, and this is described in BBC White Paper 341 [1].

Experiment to establish brightness values for test images

The term *brightness* denotes “the extent to which an area appears to exhibit light” ([2], p. 69). It is distinct from *lightness*, which relates to the apparent reflectance of an object, regardless of how it is lit ([2], p. 70). Brightness is a subjective quantity that cannot be measured directly, so a subjective test methodology to create a set of ground truth brightness measurements is developed. The intention

⁴ Note that to calculate the display luminance accurately, the EOTFs in Recommendation ITU-R BT.2100 are applied on $R'G'B'$ signal components, not on the luma component as described here.