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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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TECHNICAL REPORT OF MEASUREMENT METHODS –

High Dynamic Range Video

FOREWORD

International Standard IEC XXXXX has been prepared by subcommittee AGS-SS9: HDR, of IEC technical committee TC100.

The text of this standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this publication the stability date is 20XX.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

INTRODUCTION

The market for the production and delivery of moving images has transitioned from film through analogue standard-definition video through digital HD video and now to 4K Ultra HD video. As the increase in resolution continues to 8K, the opportunity exists to increase the dynamic range of the video, including brighter peak luminance levels. This, in conjunction with Wide Colour Gamut, increases the volume of possible levels and colours, resulting in more realistic and hyper-realistic presentations.

IEC TC100 AGS SS9 (HDR) has identified a standardization opportunity related to measurement methods and test signal for HDR video. This report sets the groundwork for such an activity.

TECHNICAL REPORT OF MEASUREMENT METHODS –

High Dynamic Range Video

Scope

This Technical Report (TR) introduces the concept of High Dynamic Range (HDR) video, lists some of the related standards and activities, provides information about HDR in the marketplace, and proposes areas of HDR measurement that could be standardized by IEC TC100.

Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
High Dynamic Range
HDR
span of image luminances that is larger than normally possible for standard, high definition, and Ultra HD video

2.2
Standard Dynamic Range
SDR
span of image luminances that is normally possible for standard and high definition video

Note 1 to entry: Standard definition, high definition, and Ultra HD video systems are normally capable of producing luminances of 10 times that of an average mid-tone at the top (white) end of the range, and of 0.01 times that of an average mid-tone at the bottom (black) end of the range.

2.3
Wide Colour Gamut
WCG
range of colours in a colour space that covers a large percentage of visible colours

EXAMPLE ITU-R BT.2020 [2] is considered to provide WCG while BT.709 [3] does not.

Overview

3.1 Historical background

Still and moving pictures were initially captured and displayed with chemical processes, typically on film. The dynamic range varied by process and was limited by the maximum density achievable on the reproduction medium for representation of dark areas and by the minimum density achievable on the reproduction medium in representation of bright areas. Though there are hard limits with this technology, the processes involved resulted in the limits being approached gradually, with dynamic range expansion in the mid-tones, and dynamic range compression at the extremes.

Electronic images were initially captured and displayed using analogue means. Electronic noise limits the representation of dark areas and defined limits can clip the bright areas. Though a wire can carry much more than a 1 V signal (which represents 100% white in some systems), various equipment in the processing chain might apply a hard clip. There is no natural compression as the signal approaches the white limit. Dynamic range compression is generally performed in the camera or in post-production with specialized equipment.

Today, most image capture, storage, and processing is based on digital technology. Dark details are limited by the noise and quantization error. White levels have a hard limit at the defined maximum white code value. Similar to analogue electronic techniques, dynamic range expansion in the mid-tones and compression at the extremes is performed by in-camera processing or in post-production.

Picture levels were standardized during the analogue time frame. Peak white for displays was defined as 48 cd/m^2 for the cinema and 100 cd/m^2 for video presentation in mastering suites under controlled, low-level lighting conditions. These standardized levels were retained during and after the transition from analogue to digital equipment and techniques.

NOTE Consumer televisions have higher peak luminance, typically around 350 cd/m^2, in order to allow for bright viewing conditions.

In order to optimize the use of signal levels, a gamma curve is applied between signal and display. This was done naturally by cathode ray tube displays and is done electronically in typical flat panel displays. The gamma equation is as follows:

$$V_{out} = AV_{in}^{\gamma}$$

ITU-R BT.1886[1] defines gamma (γ) as 2.4 and screen luminance for white as 100 cd/m2 for standard dynamic range high definition video.

3.2 Scene vs. Display Ranges

Images are captured in a variety of conditions – from the dark reaches of Pluto to the intense light levels of the sun. The captured ranges of these images are normalized by controlling exposure levels. The high dynamic range system covered by this report is not intended to capture Pluto and the Sun at a single exposure image; however, an HDR system allows the captured range of those two separate images to include deeper black levels above the noise level and brighter white levels without clipping. An HDR system preserves those larger ranges through display to the viewer. This requires higher bit-depths, displays capable of higher luminance peaks, and carefully designed transfer functions to optimize the relationship between signal and presentation.

In essence, HDR relates to a system and signal definition that can represent an increased dark to bright range of a high dynamic range display, rather than trying to capture the full-range of extreme luminance differences found in nature.

A display with an increased dynamic range enables a fuller representation of the scene. Today, highly controlled scene lighting is generally used to keep faces bright, limit overly bright areas that would otherwise be “blown out”, and to light dark areas such that textures remain visible. In addition, electronic dynamic range compression is used to ensure that the information is well-represented by the signal. In naturally lit scenes, such as in sports, news, and documentaries, heavy dynamic range compression is often used and/or the signal is clipped, given that the lighting is generally not under the control of the content creator. For today’s SDR video systems, the content creator must balance clipping at the extremes with making images dull through strong lighting or electronic compression.

For high-value content, adjustment of the dynamic range and colours can be controlled separately in various spatial regions of each frame by using dynamic masks. Image grading with dynamic masks can be complex and time consuming and is not practical in some situations, like live sports broadcasts and electronic news gathering.

On the other hand, with an HDR system, the content creator can preserve bright, specular highlights, source lighting, and sunlit areas with minimal clipping while also presenting well-displayed faces and deeply dark textures. The result can be a more compelling visual experience than offered by SDR systems. The result can also be more representative of reality and can reduce the need for time-consuming, manual adjustments.

3.3 HDR Ranges

There are practical limits on peak white levels, related to viewers and to displays. Excessively high peak luminance levels could be uncomfortable for the viewer and implementation of such a display might be impractical. For these reasons, there is no need for an HDR system to be able to represent near-infinite brightness.

Some HDR signal range approaches, such as SMPTE ST 2084 [2], can represent up to 10 000 cd/m^2 for peak white on mastering suite displays. Other proposals, including one from BBC [10], extend the current dynamic range by a smaller amount. HDR mastering displays currently exist that provide up to 4 000 cd/m^2, while others have peaks of less than 1 000 cd/m^2. The consumer HDR market is just emerging. Content producers are debating targets for peak levels. Various groups have debated minimum peak levels to be considered “HDR. There is no consensus threshold for HDR minimum peak luminance or for black or dark detail levels.

“HDR” is also a distinguishing characteristic for content. HDR is not simply SDR content presented on a display with a brighter white (or darker black). HDR content is created assuming it will be presented on a display which can support a higher peak white to mid-tone ratio, and possibly a higher mid-tone to maximum black ratio. Current HDR content creation tends to maintain traditional average mid-tone levels around 10 cd/m^2, resulting in peak white to mid-tone ratios typically in excess of 50.

However, this Technical Report does not seek to define a threshold for the minimum peak luminance of HDR systems and displays, other than to say that HDR supports a significantly larger range of levels than provided by the current SDR system.

HDR Standards and Related Activities

4.1 SMPTE

4.1.1 10E Study Group on HDR Ecosystem

This Study Group is developing a report on HDR that focuses on professional applications and excludes Digital Cinema. The group is considering definitions, gaps in the ecosystem, affected standards, and areas for future investigation.

4.1.2 ST 2084:2014

ST 2084:2014 (High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays) [3] specifies an EOTF characterizing high-dynamic-range reference displays used primarily for mastering non-broadcast content. This standard also specifies an Inverse-EOTF derived from the EOTF. A peak reference display luminance level of up to 10 000 cd/m^2 is supported.

4.1.3 ST 2086:2014

ST 2086:2014 (Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images) [5] specifies the metadata items to specify the colour volume (the colour primaries, white point, and luminance range) of the display that was used in mastering video content. The metadata is specified as a set of values independent of any specific digital representation.

This standard is applicable to three-color additive display systems, such as RGB displays.

This standard does not specify the measurement methodologies and procedures for capturing the parameters of the metadata as well as any description of the mastering environment. Additionally, this standard does not fully specify all the information that would be necessary to preserve the creative intent on displays with colour volumes different from the mastering display colour volume. As a specific example, this standard does not specify the Electro-Optical Transfer Function (EOTF) of the mastering display since it does not affect the colour volume.

This standard only defines the mastering display colour volume metadata items. System-specific solutions for storing, packaging, transmission, and end-use of this metadata are allowed, however the specification of these solutions is outside the scope of this standard.

4.1.4 ST 2036-1

ST 2036-1:2013 Ultra High Definition Television — Image Parameter Values for Program Production defines a family of progressive image sample structures of 3840 × 2160 or 7680 × 4320 with an aspect ratio of 16×9, called Ultra High Definition Television (UHDTV).

The current version does not include HDR.

4.2 CEA-861.3

CEA-861.3 (HDR Static Metadata Extensions) [7] extends CEA-861-F (A DTV Profile for Uncompressed High Speed Digital Interfaces) [8] by specifying static High Dynamic Range (HDR) metadata extensions using an additional InfoFrame and EDID CEA data block. Recommendations regarding the usage of static HDR metadata are also provided. These data structures allow signalling of SMPTE ST 2084 HDR EOTF [3] and SMPTE ST 2086 Mastering Display Metadata [5], while containing provisions for future HDR EOTFs and metadata. It is anticipated that these data structures will be extended to include additional EOTF and HDR metadata capabilities in future versions of CEA-861-F. The requirements of this standard are in addition to and complement CEA-861-F. All devices compliant to CEA-861.3 also comply with CEA-861-F, except that this standard deprecates and replaces Table 5 and Table 46 of CEA-861-F.

In addition to the Mastering Display Metadata of SMPTE ST 2086, CEA-861.3 defines and can signal MaxCLL (Maximum Content Light Level) and MaxFALL (Maximum Frame-average Light Level) in order to provide information about content luminance levels.

4.3 HDMI 2.0a

In April 2015, the HDMI Forum announced release of the HDMI 2.0a specification, which includes references to CEA-861.3 [7] and supports HDR video.

4.4 ITU-R

4.4.1 BT.2020-1

Recommendation BT.2020 (Parameter values for ultra-high definition television systems for production and international programme exchange) [2] was released in 2012 and updated in 2014. It specifies a Wide Colour Gamut (WCG) space that covers 75.8% of the CIE 1931 colour space. For comparison, BT.709 [3], which is used for HDTV production, covers 35.9% of the CIE 1931 colour space.

The BT.2020 colour space is generally seen as a natural complement to HDR video. BT.2020 also specifies 4K and 8K Ultra HD resolutions.

4.4.2 HDR

ITU-R is currently developing a new recommendation related to HDR.

4.5 ICDM

The ICDM (International Committee for Display Metrology) has an international membership and has meetings in various countries, but it is not formally international with participation by member countries (like IEC, ISO, or ITU), nor is it formally accredited as an SDO. It is hosted by SID (Society for Information Display) at http://icdm-sid.org. Membership is free and there is no charge for its standard, the IDMS (Information Display Measurement Standard.) [10]

Though the group is not formally accredited, it has been effective. The IDMS is well-established as a reference for display measurement. It does not, however, specifically cover HDR at this time.

HDR Content

5.1 General

There have been HDR announcements across all delivery platforms, including cinema, packaged media, online streaming services, broadcast, and redistribution.

5.2 Cinema

In the US, Disney released “*Tomorrowland*” and “*Inside Out*” in HDR in 2015 to a small number of theatres that have implemented Dolby Cinema.

5.3 Ultra HD Blu-ray™

In May 2015, the Blu-Ray Disc Association (BDA) announced that the Ultra HD Blu-ray (4K) specification is complete and has revealed the related logo. Licensing begins in the summer of 2015.

The BDA released a technical white paper [12] in August, 2015 that describes Ultra HD Blu-ray™. It states that “The Ultra HD Blu-ray™ can support video at 3840 × 2160 (4K/UHD) at up to 60 frames per second progressively and High Dynamic Range (HDR) video.” The paper does not cite the specific HDR technology used or the target peak luminance levels.

The release of media and players is determined by individual BDA licensees. Multiple technology news companies speculate product availability before the end of 2015.

5.4 Streaming Media

5.4.1 Amazon

Amazon.com is now streaming HDR content, stating, *“The full season of “Mozart in the Jungle” and pilot episode of “Red Oaks,” both Amazon Original series, are now available in HDR and many more series and movies will be available in the near future.”*

5.4.2 Netflix

Netflix has announced that it will deliver HDR video in 2015. The services original series, *“Marco Polo”*, was produced for HDR distribution.

5.4.3 Other

Multiple additional streaming services have announced that they currently support or plan to support HDR.

5.5 Broadcast

ATSC, DVB, and ARIB are all considering HDR solutions. HDR broadcast content cannot be delivered until HDR broadcast standards are completed and deployed.

ARIB has standardized EIDRTV in ARIB STD-B67 [9] as a means for providing HDR along with 8K resolution.

Live sports, where the content producer has limited control of lighting, is likely to be an important use case for HDR broadcast TV.

5.6 Redistribution Platforms

In the US, there have been HDR announcements from major companies in the cable TV and satellite TV sectors.

These sectors are likely to deliver HDR movies and television shows first and live sports later, when they can redistribute broadcast TV content.

Measurement of HDR

6.1 General

Many signal and display measurement methods and test signals have been developed and standardized for standard dynamic range video. In some cases, these same techniques can be used directly in HDR systems. In other cases, they must be adapted to brighter peak levels, different average levels, and new transfer functions. Given that peak content signal levels and minimum peak luminance levels of displays are not established, adapting some of these test methods could be challenging.

There are generally two approaches to measuring displays. The first relates to testing the scientific limits of the display. Development of such test methods might be more appropriate in IEC TC110, which covers displays as components. The second relates to testing the display to ensure good human perception. This work could be done by TC100, which covers displays as integrated equipment complete with power supplies, input subsystems, and controls accessible to the end user. The product design engineer wants to know the scientific characteristics of the display component while the viewer wants to know that the picture will “look good” without having to pay for theoretical perfection.

As an example, a display might have a very bright peak, but the peak might not be attained if the integrated power supply is insufficient or if the display settings are set for low levels. A small power supply with high capacitive storage might allow a temporary bright burst, but might not provide a high-luminance result after stabilization.

6.2 Peak White

The most important new measurement for an HDR display is for Peak White. Well-known test signals for this test include Full-Screen White and Centre Box White with various sized white boxes over a black background. Due to power limiting in consumer TVs, using a Full-Screen White test signal might result in a lower measurement value than the absolute peak. Similarly, a Centre Box White test pattern with a tiny area of white might result in a higher measurement value that would be seen in typical usage.

Since some HDR TVs using LCD panels are expected to use a backlight with local area dimming, a range of size options for the white signal area might be advisable as a single size might align with the backlight zones for one display and intersect them on another. It could be allowable for the manufacturer or tester to determine the size, within specified limits.

Stabilization time must be considered for Peak White (as well as most other measurements) to ensure that the delivery of this level over an extended time interval.

6.3 Full-Screen Black

Black level measurements are well-established. Though HDR displays might provider finer control of levels in areas of low luminance than SDR displays, the measurement methods are not affected. Given that displaying a black screen is generally a low-power consumption condition, there is no concern about the size of the black area filling the screen.

As always, for black screen measurements, a controlled light environment is critically important. A plenum might be required to shield the measurement device from stray light. Also, with HDR displays, care needs to be exercised in choosing appropriate measurement instruments because black levels may be very low.

6.4 Contrast Ratio

Measuring contrast ratio in a way that is helpful to the viewer is challenging, even for standard dynamic range displays. Dynamic contrast ratio measurements allow separate measurement of black and white, which might not represent the contrast seen by the viewer on a single screen. Background area dimming displays can provide much higher contrast ratios within a single screen, and this advantage could be captured with the measurement.

6.5 Colour Gamut

Colour Gamut is often measured with full screen primary colours of red, green, and blue. For an HDR display, the intensity of these colours might be limited due to power limiting, though this might affect the luminance but not the colour point of these measurements. Some displays include more than three primaries, so it might be advisable to include measurement of secondary colours, cyan, magenta, and yellow.

6.6 White Point

Again the size of the white pattern could be considered for the white point measurement, as the colour point might vary with luminous intensity.

6.7 Other

Additional tests to be considered could include a loading test to determine the white clipping point, and an accuracy test to ensure linearity throughout the range.

In addition, there could be a need for new test signals for use in general calibration. For instance, there is no current Colour Bars signal standardized for HDR.

There are many other measurements that are not directly related to HDR, such as viewing angle, response time, latency, and flicker. Though no new test methods are required, existing test patterns might need to be adapted to consider HDR coding levels.

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[4] SMPTE ST-2084:2014 – High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays

[5] SMPTE ST-2086:2014 – Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images

[6] SMPTE ST 2036-1:2013 Ultra High Definition Television — Image Parameter Values for Program Production

[7] Consumer Electronics Association (CEA) - CEA-861.3 – HDR Static Metadata Extensions

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