ETSI TS 103 433-3 V1.2.1 (2021-08)

TECHNICAL SPECIFICATION

High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 3: Enhancements for Hybrid Log Gamma (HLG) transfer function based High Dynamic Range (HDR) Systems (SL-HDR3)

EBU

Reference

RTS/JTC-059-3

Keywords

broadcasting, content, digital, distribution, HDR, HDTV, UHDTV, video

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Sous-Préfecture de Grasse (06) N° w061004871

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Foreword

This Technical Specification (TS) has been produced by Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECtrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI).

The present document is part 3 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Motivation

Today Ultra HD services have been launched or are being launched by broadcasters and network operators in many regions of the world. Besides higher resolution, wider colour gamut and higher frame rate, High Dynamic Range is a highly demanded feature.

The goal of ETSI TS 103 433-1 [1], SL-HDR1, is to standardize a single layer HDR system addressing direct SDR backwards compatibility i.e. a system leveraging SDR distribution networks and services already in place and that enables high quality HDR rendering on HDR-enabled CE devices including high quality SDR rendering on SDR CE devices.

The goal of ETSI TS 103 433-2 [2], SL-HDR2, is to specify enhancements for single layer Perceptual Quantization (PQ) transfer function based HDR systems, enabled by signal processing blocks that are similar/the same to those in SL-HDR1.

The goal of the present document is to specify enhancements for single layer Hybrid Log Gamma (HLG) transfer function based HDR systems, enabled by signal processing blocks that are similar/the same to those in SL-HDR1 and SL-HDR2. Similar to SL-HDR1 and SL-HDR2, these enhancements are enabled by use of dynamic metadata and a post processor in the Consumer Electronics device.

Pre-processing

At the distribution stage, an incoming HDR signal is analysed and content-dependent dynamic metadata is produced. This dynamic metadata can be produced in an automatic process or in a manual process where the image quality resulting of the metadata that has been set manually is judged on an SDR grading monitor and/or on a distribution channel grading monitor. This dynamic metadata can be used to create an optimal picture for a display that has different characteristics, most noticeably a different maximum luminance, than the display used when grading the HDR content. The HDR signal is encoded with any distribution codec (e.g. HEVC as specified in part 1 [1], Annex A) and carried throughout an HDR distribution network with accompanying metadata conveyed on a specific channel or embedded in an HDR bitstream. The dynamic metadata can for instance be carried in an SEI message when used in conjunction with an HEVC or VVC codec. The pre-processor that produces dynamic metadata is not a normative requirement of the present document. Nonetheless, the pre-processor is expected to produce a dynamic metadata stream matching the syntax specified in Annex A, Annex K, Annex L or Annex M.

Post-processing

The post-processing stage occurs just after HDR bitstream decoding. The post-processing takes as input an HLG video frame and associated dynamic metadata and the characteristic of the attached rendering device in order to optimize the HDR picture for the rendering device as specified in clause 7.

Structure of the present document

The present document is structured as follows. Clause 1 provides the scope of the present document. Clause 2 provides references used in the present document. Clause 3 gives essential definition of terms, symbols, abbreviations and conventions used in the present document. Clause 4 provides information on the end to end system. Clause 5 details the architecture of the HDR system. Clause 6 specifies the format of the content-based dynamic metadata common to systems based on ETSI TS 103 433 multi-part documents [i.2]. Specifically to the present document, the metadata are produced during the HDR-to-SDR decomposition stage and they enable reconstruction of the SDR signal from the decoded HDR signal using those metadata. Clause 7 specifies the reconstruction process of the SDR signal and an HDR signal that is adapted to the maximum luminance of the presentation display. The dynamic metadata format specified in clause 6 is normatively mapped from SEI messages representative of the SL-HDR system that are specified for HEVC and AVC respectively in Annex A and Annex B. Informative Annex C and Annex D provide information on an HDR-to-SDR decomposition process, and a gamut mapping process. Informative Annex E describes a way to transfer dynamic metadata by embedding it in the video transferred over a CE digital video interface. Informative Annex F proposes a recovery procedure when dynamic metadata are detected as missing by the post-processor during the HDR signal reconstruction. The recovery procedure may also be applied in case it is desirable to replace the original metadata by a fixed tone mapping function, e.g. when graphics overlays are inserted on the decoded video by a mid-device (e.g. STB) which transmits SL-HDR reconstruction metadata as well as the mixed video to an SL-HDR capable TV. Informative Annex G gives reference to a standard mechanism to carry SL-HDR reconstruction metadata through interfaces and Annex H provides a recommendation on the maximum presentation display luminance that display adaptation can be used with. Annex I provides information on SL-HDR metadata indication for CMAF based applications, and informative Annex J provides information on the use of SL-HDR in DVB Services. Annex K, Annex L and Annex M specify the SL-HDR reconstruction metadata to be used with VVC, a WebM container or AV1 respectively.

The structure of the present document is summarized in Table 1.

Table 1: Structure of the present document

Clause/Annex #	Description	Normative/Informative (in the present document)
Clause 1	Scope of the document	Informative
Clause 2	References used in the present document	Normative/Informative
Clause 3	Definition of terms, symbols, abbreviations and conventions	Informative
Clause 4	End-to-end system	Informative
Clause 5	Architecture of the HDR system	Informative
Clause 6	Metadata format abstraction layer (agnostic to the distribution format)	Normative
Clause 7	HDR-to-HDR/SDR reconstruction process	Normative
Annex A	SL-HDR reconstruction metadata using HEVC	Normative
Annex B	SL-HDR reconstruction metadata using AVC	Informative
Annex C	HDR-to-SDR decomposition principles and considerations	Informative
Annex D	Gamut mapping	Informative
Annex E	Embedded data on CE digital video interfaces	Informative
Annex F	Error-concealment and recovery procedure	Informative
Annex G	ETSI TS 103 433 [i.2] signalling in CTA-861-H	Informative
Annex H	Minimum and maximum value of L_{pdisp} for display adaptation	Informative
Annex I	SL-HDR metadata indication for CMAF based applications	Informative
Annex J	Use of SL-HDR in DVB Services	Informative
Annex K	SL-HDR reconstruction metadata using VVC	Normative
Annex L	SL-HDR reconstruction metadata using a WebM container	Informative
Annex M	SL-HDR reconstruction metadata using AV1	Informative
Annex N	Change History	Informative

1 Scope

The present document specifies the HDR-to-HDR/SDR content-based dynamic metadata and the post-decoding process. The post-decoding process takes the specified metadata and an HLG HDR signal as input, and enables the reconstruction of an SDR signal (typically 100 cd/m^2) or an HDR signal with a maximum luminance ranging from 100 cd/m^2 to a maximum luminance that is greater than that of the original HDR signal. This reconstruction process is typically invoked in a Consumer Electronics device such as a TV set, a smartphone, a tablet or a Set Top Box. Besides, it provides information and recommendations on the usage of the described HDR system.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 433-1: "High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 1: Directly Standard Dynamic Range (SDR) Compatible HDR System (SL-HDR1)".

[2] ETSI TS 103 433-2: "High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 2: Enhancements for Perceptual Quantization (PQ) transfer function based High Dynamic Range (HDR) Systems (SL-HDR2)".

[3] Recommendation ITU-R BT.709-6 (06-2015): "Parameter values for HDTV standards for production and international programme exchange".

[4] Recommendation ITU-R BT.2020-2 (10-2015): "Parameter values for ultra-high definition television systems for production and international programme exchange".

[5] Recommendation ITU-R BT.2100-2 (07/2018): "Image parameter values for high dynamic range television for use in production and international programme exchange".

[6] Recommendation ITU-R BT.2390-6 (04/2019): "High dynamic range television for production and international programme exchange".

[7] Recommendation ITU-T H.264 (04-2017): "Advanced video coding for generic audiovisual services".

[8] Recommendation ITU-T H 265 (12-2016): "High efficiency video coding".

[9] SMPTE ST 2086:2014: "Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images".

[10] Recommendation ITU-T H.266 (08-2020): "Versatile video coding".

[11] Recommendation ITU-T H.274 (08-2020): "Versatile supplemental enhancement information messages for coded video bitstreams".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CTA Standard CTA-861-H (December 2020): "A DTV Profile for Uncompressed High Speed Digital Interfaces".

[i.2] ETSI TS 103 433 (all parts): "High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices".

[i.3] Recommendation ITU-R BT.2035: "A reference environment for evaluation of HDTV program material or completed programmes".

[i.4] SMPTE Engineering Guideline EG 28-1993: "Annotated Glossary of Essential Terms for Electronic Production".

[i.5] SMPTE ST 2094-20:2016: "Dynamic Metadata for Color Volume Transform - Application #2".

[i.6] SMPTE ST 2094-30:2016: "Dynamic Metadata for Color Volume Transform - Application #3".

[i.7] VP9 Video Codec.

NOTE: Available at https://www.webmproject.org/vp9/.

[i.8] AV1 Bitstream & Decoding Process Specification.

NOTE: Available at http://aomedia.org/av1/specification/.

[i.9] WebM Container Guidelines.

NOTE: Available at https://www.webmproject.org/docs/container/.

3 Definition of terms, symbols, abbreviations and conventions

3.1 Terms

For the purposes of the present document, the following terms apply:

colour correction: adjustment of the luma and chroma components of a signal derived from the HDR signal in order to avoid hue shift and preserve the colour look of the HDR signal in the SDR signal

display adaptation: adaptation of a video signal to the characteristics of the targeted Consumer Electronics display (e.g. maximum luminance of the CE display)

dynamic metadata: metadata that can be different for different portions of the video and can change at each associated picture

gamut: complete subset of colours which can be represented within a given colour space or by a certain output device

NOTE: Also known as colour gamut.

gamut mapping: mapping of the colour space coordinates of the elements of a source image to colour space coordinates of the elements of a reproduction

NOTE: Gamut mapping intent is not to change the dynamic range of the source but to compensate for differences in the source and output medium colour gamut capability.

High Dynamic Range (HDR) system: system specified and designed for capturing, processing, and reproducing a scene, conveying the full range of perceptible shadow and highlight detail, with sufficient precision and acceptable artefacts, including sufficient separation of diffuse white and specular highlights

luma: linear combination of non-linear-light (gamma-corrected) primary colour signals

luminance: objective measure of the visible radiant flux weighted for colour by the CIE Photopic Spectral Luminous Efficiency Function [i.4]

luminance mapping: adjustment of the luminance representative of a source signal to the luminance of a targeted system

post-production: part of the process of filmmaking and video production gathering many different processes such as video editing, adding visual special effects, transfer of colour motion picture film to video

presentation display: display that the IRD outputs to

reconstructed picture: output picture of SL-HDR post-processing stage

Single Layer High Dynamic Range (SL-HDR) system: system implementing at least one of the parts of the ETSI TS 103 433 multi-part document [i.2]

source picture: input picture of SL-HDR pre-processing stage

NOTE: Typically an HDR picture coming from post-production facilities.

Standard Dynamic Range (SDR) system: system having a reference reproduction using a luminance range constrained by Recommendation ITU-R BT.2035 [i.3], section 3.2

NOTE: Typically no more than 10 stops.

Supplemental Enhancement Information (SEI) message: carriage mechanism defined in Recommendation ITU-T H.264 [7] and Recommendation ITU-T H 265 [8] that is intended to assist in processes related to decoding, display or other purposes

3.2 Symbols

3.2.1 Arithmetic operators

Void.

3.2.2 Mathematical functions

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AOMedia	Alliance for Open Media
AV1	AOMedia Video 1
AVC	Advanced Video Coding
CE	Consumer Electronics
CIE	Commission Internationale de l'Eclairage
HDMI	High-Definition Multimedia Interface

HDR	High Dynamic Range
HEVC	High Efficiency Video Coding
HLG	Hybrid Log-Gamma
IRD	Integrated Receiver Decoder
MDCV	Mastering Display Colour Volume
OBU	Open Bitstream Unit
PQ	Perceptual Quantization
SDR	Standard Dynamic Range
SEI	Supplemental Enhancement Information
NOTE:	As in AVC, HEVC and VVC.
SL-HDR	Single Layer High Dynamic Range
SL-HDRI	Single Layer High Dynamic Range Information
SMPTE	Society of Motion Picture and Television Engineers
STB	Set Top Box
VP9	Video Predictor 9
VVC	Versatile Video Coding

3.4 Conventions

Unless otherwise stated, the following convention regarding the notation is used:

- Variables specified in the present document are indicated by bold Arial font 9 points lower camel case style e.g. **camelCase**. All those variables are described in clause 6.
- Internal variables of the present document are indicated by italic Cambria math font 10 points style e.g. *variable*.
- Structures of syntactic elements or structures of variables are indicated by Arial font 9 points C-style with parentheses e.g. structure_of_variables( ). Those structures are defined in clause 6 of part 1 [1], Annex A of part 1 [1], Annex B of part 1 [1], Annex K of part 1 [1], Annex L of part 1 [1] and in Annex E of SL-HDR2 part 2 [2].
- Bitstream syntactic elements are indicated by bold Arial font 9 points C-style e.g. **syntactic_element**. All those variables are defined in Annex A of part 1 [1] Annex B of part 1 [1], Annex K of part 1 [1], Annex L of part 1 [1] and in Annex E of part 2 [2].
- Functions are indicated as *func*(*x*).
- Tables are indicated as *table[idx]*.

4 End-to-end system

Figure 1 shows an end-to-end workflow supporting content production and delivery to HDR and SDR displays and to displays with any maximum luminance level in-between SDR and HDR. The primary goal of this HDR workflow is to provide direct HLG backwards compatible services i.e. services which associated streams are directly compatible with HLG Consumer Electronics devices. This workflow is based on technologies and standards that facilitate an open approach.

It includes a single-layer HDR encoding-decoding, and uses static and dynamic metadata:

- Mastering Display Colour Volume (MDCV) standardized in HEVC [8], Recommendation ITU-T H.274 [11] and SMPTE ST 2086 [9] specifications, MasteringMetadata in WebM [i.9] specification and HDR MDCV Metadata in AV1 [i.8] specification; and
- SL-HDR Information (SL-HDRI) based on both SMPTE ST 2094-20 [i.5] and SMPTE ST 2094-30 [i.6] specifications.

Single-layer encoding/decoding requires only one encoder instance at HDR encoding side, and one decoder instance at player/display side. It supports the real-time workflow requirements of broadcast applications.

The elements specifically addressed in the present document are related to the HDR/SDR reconstruction process and the associated dynamic metadata format.

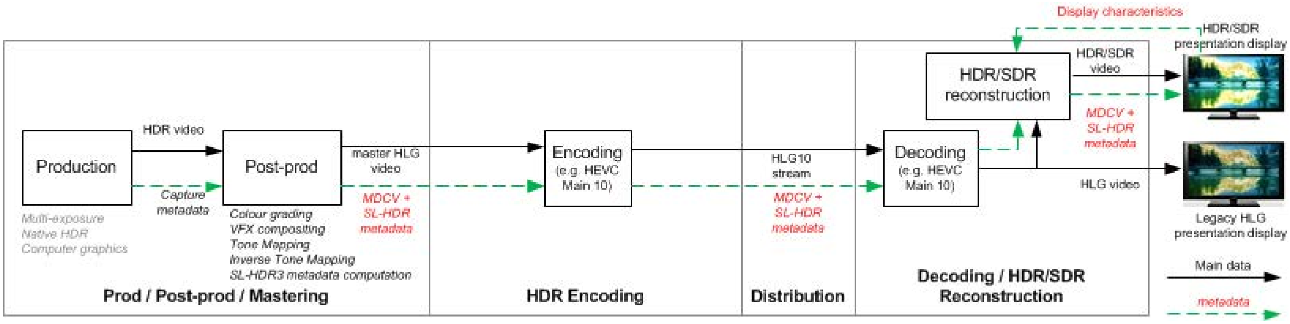


Figure 1: Example of an HDR end-to-end system

5 HDR system architecture

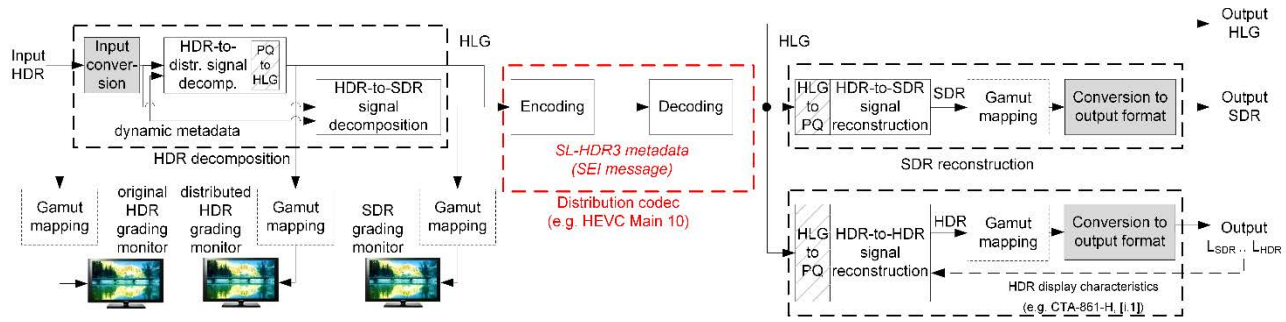
The block diagram in Figure 2 depicts in more detail the HDR decomposition and reconstruction processes of SL-HDR3. The SL-HDR3 system makes use of the SL-HDR2+ extension in SL-HDR2, see Annex I of [2], to which the diagonally shaded boxes are added. These boxes show "bridge point" conversions, see Recommendation ITU-R BT.2390-6 [6], section 7.2. The centre block included in dash-red box corresponds to the distribution encoding and decoding stages (e.g. based on HEVC video coding specifications). The left and right grey-coloured boxes respectively enable format adaptation to the input video signal of the HDR system and to the targeted system (e.g. a STB, a connected TV, etc.) connected with the HDR system. The black solid line boxes show the HDR specific processing. The additional HDR dynamic metadata are transmitted on distribution networks typically by way of the SEI messaging mechanism. The present document relates to both the HDR-to-HDR/SDR signal reconstruction process and the HDR metadata format. The core components of the HDR decomposition stage are the HDR-to-distributed signal decomposition that maps the input HDR with a maximum luminance larger than 1 000 cd/m^2 to 1 000 cd/m^2 for HLG distribution, see the "bridge point" conversion in Recommendation ITU-R BT.2390-6 [6], section 7.2, and the HDR-to-SDR decomposition that generates an SDR video from the HDR signal.

Using the additional HDR dynamic metadata, an SL-HDR3 decoder is able to:

- recreate the original HDR input at the production stage;
- recreate the SDR generated by the HDR-to-SDR decomposition at the production stage; and
- create outputs that are adapted to the maximum luminance of the attached display between 100 cd/m^2 (SDR) and values higher than that of the original HDR input at the production stage.

Optionally in the IRD, a block of gamut mapping may be used when the output HDR/SDR picture is represented in a colour space or colour gamut different from the one of the connected display. The parameters of the optional gamut mapping and their impact on the rendering may be controlled during the post-production stage.

Optionally in the IRD, a block of HDR-to-HDR signal reconstruction may be used as a display adaptation process. The dynamic range output of the display adaptation process may be less and may be more than the dynamic range of the HDR signal input to the HDR-to-SDR signal decomposition process.



NOTE: The three diagonally shaded blocks are additional to an SL-HDR3 system compared to an SL-HDR2+ system.

Figure 2: HDR system architecture overview

6 Dynamic metadata format for HDR-to-HDR/SDR adaptation

Clause 6 of ETSI TS 103 433-2 [2] specifies the dynamic metadata format for signal reconstruction by referring to clause 6 of ETSI TS 103 433-1 [1] and specifying exceptions. In the present document, the dynamic metadata allows conversion of the HDR signal to any maximum luminance between SDR (100 cd/m²) and a value higher than the original maximum luminance. A recommendation for the maximum luminance boundary can be found in Annex H.

Clause 6 of ETSI TS 103 433-2 [2], together with the SL-HDR2+ metadata extension specified in clause I.2 of ETSI TS 103 433-2 [2] shall apply to the present document.

7 HDR-to-HDR/SDR signal reconstruction process

7.1 Input streams

The input stream is composed of a decoded HLG HDR video stream, see Recommendation ITU-R BT.2100-2 [5], and associated dynamic metadata that are combined to reconstruct an HDR or an SDR video signal. The dynamic metadata shall be conveyed by a parameter-based mode (**payloadMode** 0). Concerning ITU-T or ISO/IEC based video codecs, the payload carriage mode is carried by the SL-HDR Information SEI message specified in ETSI TS 103 433-1 [1]. The HDR-to-HDR/SDR reconstruction process is specified in clause 7.2. This process employs variables specified in clause 6.2 of [1] and retrieved from parsed and mapped (see clause A.2.3 of ETSI TS 103 433-1 [1]) syntax elements of SL-HDR3 dynamic metadata streams. Semantics attached to the syntax elements is provided in clause 6.3 of ETSI TS 103 433-1 [1].

The reconstruction process makes use of the SL-HDR2+ extension in SL-HDR2, see Annex I of ETSI TS 103 433-2 [2]. Therefore, the associated metadata in an SL-HDR3 compatible input stream also contains L_{HDR_o}, the value of the maximum luminance of the original HDR input to the encoder, which value may be higher than 1 000 cd/m².

An SL-HDR2+ decoder is capable of adapting its output to the maximum luminance of the displaying monitor, with a minimum of 100 cd/m² to more than L_{HDR_o} the maximum luminance of the HDR input to the encoder, see Annex I of ETSI TS 103 433-2 [2].