



**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)**

EBU

Reference

RTS/JTC-051-2

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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 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

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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 the present document 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. Similar to SL-HDR1, these enhancements will be 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. 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 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 and Annex B.

Post-processing

The post-processing stage occurs just after HDR bitstream decoding. The post-processing takes as input an HDR video frame and associated dynamic metadata and the characteristic of the attached HDR compliant 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 and abbreviations 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. 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 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. Eventually, 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 describes a variation (called SL-HDR2+), where the distributed signal has a maximum luminance in between the maximum luminance of SDR and that of the original HDR signal. Decoders according to Annex I can reconstruct the original HDR signal, the SDR signal and an output signal with any maximum luminance in between that of SDR and the original HDR signal, where decoders according to clause 7 can reconstruct an output signal with any maximum luminance in between that of SDR and the distributed HDR signal. Finally, Annex J provides information on SL-HDR metadata indication for CMAF based applications, and informative Annex K provides information on the use of SL-HDR in DVB Services.

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 document	Normative/Informative
Clause 3	Definitions of terms, symbols and abbreviations	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 signalling in CTA-861-G	Informative
Annex H	Minimum and maximum value of L_{pdisp} for display adaptation	Informative
Annex I	SL-HDR2+ and adaptive presentation display adaptation	Informative
Annex J	SL-HDR metadata indication for CMAF based applications	Informative
Annex K	Use of SL-HDR in DVB Services	Informative
Annex L	Change History	Informative

1 Scope

The present document specifies the HDR-to-HDR/SDR content-based dynamic metadata and the post-decoding process enabling reconstruction from the specified metadata and an HDR signal of an SDR signal (100 cd/m² or less) or an HDR signal with a maximum luminance ranging from 100 cd/m² to a maximum luminance that is higher 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] Recommendation ITU-R BT.709-6 (06-2015): "Parameter values for HDTV standards for production and international programme exchange".
- [3] Recommendation ITU-R BT.2020-2 (10-2015): "Parameter values for ultra-high definition television systems for production and international programme exchange".
- [4] Recommendation ITU-T H.264 (06-2019): "Advanced video coding for generic audiovisual services".
- [5] Recommendation ITU-T H.265 (11-2019): "High efficiency video coding".
- [6] SMPTE ST 2084:2014: "High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays".
- [7] SMPTE ST 2086:2018: "Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images".

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.

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 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-G, November 2016: "A DTV Profile for Uncompressed High Speed Digital Interfaces".

- [i.2] Recommendation ITU-R BT.2035: "A reference environment for evaluation of HDTV program material or completed programmes".
- [i.3] Ross N. Williams: "A Painless Guide to CRC Error Detection Algorithms," Version 3, 19 August 1993.
- NOTE: Available at https://www.zlib.net/crc_v3.txt.
- [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] ETSI TS 103 433 (all parts): "High-Performance Single Layer Directly Standard Dynamic Range (SDR) Compatible High Dynamic Range (HDR) System for use in Consumer Electronics devices".

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

colour volume: solid in colorimetric space containing all possible colours a display can produce

decomposed picture: SDR picture derived from the HDR-to-SDR pre-processing stage

NOTE: Type of pre-processed picture.

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

original picture: output HDR picture of post-production, HDR picture input to the encoder

NOTE: The source picture is an original picture which characteristics may have been adjusted for distribution.

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

NOTE: The pre-processed picture is generated during the post-production stage at the encoding site.

pre-processed picture: output picture of SL-HDR pre-processing stage

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.7]

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

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

Standard Colour Gamut (SCG): chromaticity gamut equal to the chromaticity gamut defined by Recommendation ITU-R BT.709-6 [2]

Standard Dynamic Range (SDR) system: system having a reference reproduction using a luminance range constrained by Recommendation ITU-R BT.2035 [i.2], section 3.2

NOTE: Typically no more than 10 stops.

Supplemental Enhancement Information (SEI) message: carriage mechanism defined in Recommendation ITU-T H.264 [4] and Recommendation ITU-T H.265 [5] that is intended to assist in processes related to decoding, display or other purposes

target picture: picture graded on an SDR mastering display

Wide Colour Gamut (WCG): chromaticity gamut larger than the chromaticity gamut defined by Recommendation ITU-R BT.709-6 [2]

3.2 Symbols

3.2.1 Arithmetic operators

For the purposes of the present document, the following arithmetic operators apply:

+	Addition
−	Subtraction (as a two-argument operator) or negation (as a unary prefix operator)
×	Multiplication, including matrix multiplication
x^y	Exponentiation

NOTE: Specifies x to the power of y . In other contexts, such notation is used for superscripting not intended for interpretation as exponentiation.

/	Integer division with truncation of the result toward zero
---	--

NOTE: For example, $7/4$ and $-7/4$ are truncated to 1 and $-7/4$ and $7/-4$ are truncated to -1.

\div	Used to denote division in mathematical equations where no truncation or rounding is intended
$\frac{x}{y}$	Used to denote division in mathematical equations where no truncation or rounding is intended

3.2.2 Mathematical functions

For the purposes of the present document, the following mathematical functions apply:

$$\text{Abs}(x) \begin{cases} x & , \quad x \geq 0 \\ -x & , \quad x < 0 \end{cases}$$

$$\text{Clip3}(x; y; z) \begin{cases} x & , \quad z < x \\ y & , \quad z > y \\ z & , \quad \text{otherwise} \end{cases}$$

Floor(*x*) the largest integer less than or equal to *x*

ln(*x*) natural logarithm of *x*

log10(*x*) the base-10 logarithm of *x*

$$\text{Min}(x; y) \begin{cases} x & , \quad x \leq y \\ y & , \quad x > y \end{cases}$$

$$\text{Max}(x; y) \begin{cases} x & , \quad x \geq y \\ y & , \quad x < y \end{cases}$$

x = y..z *x* takes on integer values starting from *y* to *z*, inclusive, with *x*, *y*, and *z* being integer numbers and *z* being greater than *y*

3.3 Abbreviations

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

ATSC	Advanced Television Systems Committee
AVC	Advanced Video Coding
BT	Broadcasting service (television)
CE	Consumer Electronics
CID	Company ID
CIE	Commission Internationale de l'Eclairage
CLVS	coded layer-wise video sequence
CMAF	Common Media Application Format
CRC	Cyclic Redundancy Check
EDC	Error Detection Code
EDID	Extended Display Identification Data
EOTF	Electro-Optical Transfer Function
HDMI	High-Definition Multimedia Interface
HDR	High Dynamic Range
HDRB	HDR Blue component
HDRG	HDR Green component
HDRR	HDR Red component
HDRY	HDR Y component
HEVC	High Efficiency Video Coding
HGC	Highlight Gain Control
IRD	Integrated Receiver Decoder
LHDR	maximum luminance of the HDR mastering display
LSB	Least Significant Bit
LSDR	maximum luminance of the SDR mastering display
LUT	Look-Up Table
MDCV	Mastering Display Colour Volume
MSB	Most Significant Bit
PQ	Perceptual Quantization
RGB	Red Green Blue colour model
SCG	Standard Colour Gamut

SDR	Standard Dynamic Range
SDRLUT	Standard Dynamic Range Look-Up Table
SEI	Supplemental Enhancement Information

NOTE: As in AVC and HEVC.

SGC	Saturation Gain Control
SL-HDR	Single Layer High Dynamic Range
SL-HDRI	Single Layer High Dynamic Range Information
SMPTE	Society of Motion Picture and Television Engineers
ST	Standard
STB	Set Top Box
TMBLO	Tone Mapping Input Signal Black Level Offset
TMO	Tone Mapping Operator
TMWLO	Tone Mapping Input Signal White Level Offset
VSVDB	Vendor-Specific Video Data Block
WCG	Wide Colour Gamut

3.4 Conventions

Unless otherwise stated, the following conventions 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 ETSI TS 103 433-1 [1], Annex A of ETSI TS 103 433-1 [1], and Annex B of ETSI TS 103 433-1 [1].
- 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 ETSI TS 103 433-1 [1] and in Annex B of ETSI TS 103 433-1 [1].
- 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 HDR backwards compatible services i.e. services which associated streams are directly compatible with HDR 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 AVC [4], HEVC [5] and SMPTE ST 2086 [7] specifications; 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.