EUROVISION MEDIA SERVICES

UHD 4K Transmissions on the EBU Network

Technical and Operational Notice

EBU/Eurovision
Eurovision Media Services
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INTRODUCTION

This document describes the signal acquisition at the source, HEVC encoding, NS3/NS4 modulation and satellite parameters for the UHD-4K signal.

High Efficiency Video Coding (HEVC), also known as H.265, is a single standard that is approved by two standards bodies:

- ITU-T Study Group 16 – Video Coding Experts Group (VCEG) – published the H.265 standard as **ITU-T H.265**, and
- ISO/IEC JTC 1/SC 29/WG 11 Motion Picture Experts Group (MPEG) – published the HEVC standard as **ISO/IEC 23008-2**.

HEVC Encoding

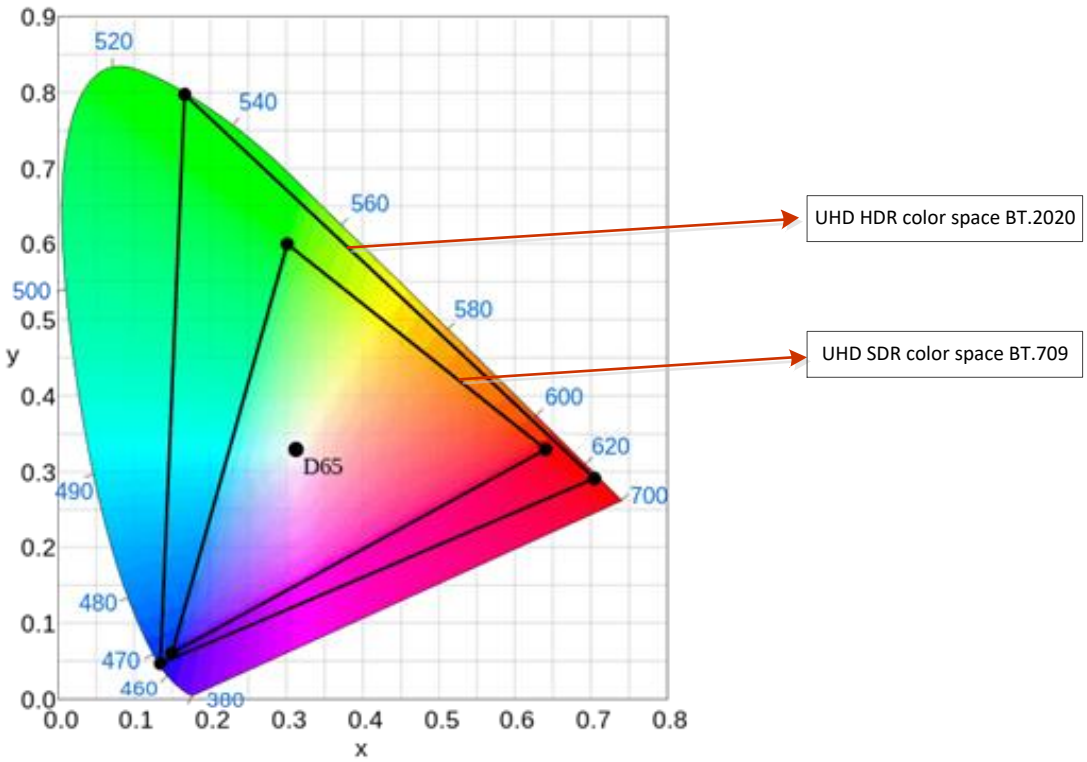
HEVC provides superior coding efficiency when compared to its predecessors; in particular it can achieve equivalent H.264/MPEG-4 AVC subjective quality using approximately 50% less bit rate on average.
The power of HEVC encoding is related to several improvements over the H.264 compression standard:

- Where H.264/AVC defines macroblocks up to 16×16 pixels, HEVC can describe a much larger range of block sizes, up to 64 x 64 pixels.
- HEVC allows predicted blocks to be coded in different block sizes than the residual error. Each top level coding unit (or CTU) is first coded as a prediction quad-tree, where at each depth the encoder decides whether to encode with merge/skip, inter, or intra coding. The residual from those predictions is then coded with a second quad-tree which can optionally have greater depth than the prediction quad-tree. For instance, this allows the residual error from a 32×32 inter coded coding unit (CU) to be represented by a mixture of 16×16, 8×8, and 4×4 transforms.
- HEVC can encode motion vectors with much greater precision, giving a better predicted block with less residual error. There are 35 intra-picture directions, compared with only 9 for H.264/AVC.
- HEVC includes Adaptive Motion Vector Prediction, a new method to improve inter-prediction.

UHD HDR, UHD SDR

ITU-R BT.2100

- Recommendation **ITU-R BT.2100** is the international standard for high dynamic range program production and exchange. It defines two formats for HDR video, **PQ (Perceptual Quantization)** also given in **SMPTE ST 2084** and termed `display-referred` - and **HLG (Hybrid Log-Gamma)** also given in **ARIB STD-B67** and termed `scene-referred.`
- Scene-referred signals are the conventional approach to video where the signal represents the light detected by the camera while display-referred signals represent the light displayed on the production or “grading” monitor.
- ITU-R BT.2100 as ITU-R BT.709 and ITU-R BT.2020 also provides the image spatial and temporal characteristics, the system colorimetry ITU-R BT.2020, and the reference viewing environment for critical viewing of HDR programme material.



BT.2100 should be read in conjunction with Report ITU-R BT.2390 which provides additional background information and Report ITU-R BT.2408-0 (2017) that summarises the operational practices to produce HDR using the PQ and HLG methods.

Recommendation ITU-R BT.2100 defines two formats for HDR video, **PQ** and **HLG**.

HLG is a relative, scene-referred, signal while **PQ** is an absolute, display-referred, signal.
Relative video signals represent the intensity of the light relative to the peak output of the camera sensor while an absolute video signal represents the absolute brightness of a pixel. Absolute brightness is usually denoted as candelas per square meter (also known as “nits”).
PQ covers signal range with brightness lower than 10 000 cd/m2. HLG is not aimed at any particular screen brightness and has natural correction for different brightness displays (up to 4000 cd/m2): the formula is part of the ITU-R BT.2100 standard and is applied by the display manufacturer as appropriate. It was designed to provide backwards compatibility to BT.2020 UHD displays.

HLG, as a scene-referred approach, does not need any content dependent metadata while the PQ signal need them when the signal is displayed in an environment or on a display that is different from the mastering set-up.

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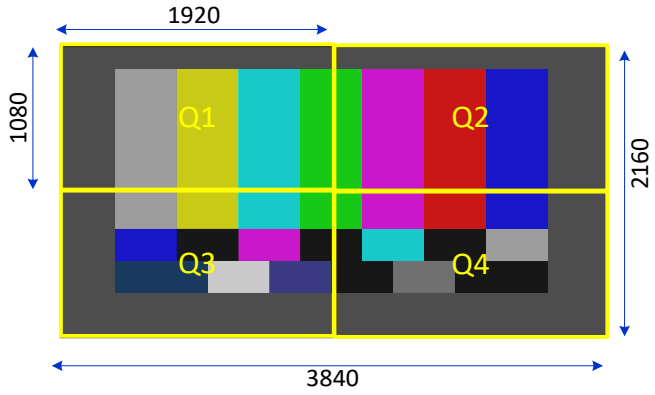
SOURCE SIGNAL DESCRIPTION

Acquisition

The signals will be available from a 4K production OB van in Quad Full High Definition (QFHD) 4K, which actually consists of four (4) synchronous 1920 x 1080 resolution quadrants **1080p 50 fps** (Q1, Q2, Q3 & Q4). These four video streams combined provide a 3840 x 2160 resolution signal at 50 fps.



Each quadrant is delivered over an independent **3G-SDI, SMPTE ST 425-5** link to the HEVC encoder. Each quadrant will be encoded by using standard parameters described in this document; the Dolby-E will be injected in Q1.

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FRAME RATE AND SATELLITE DISTRIBUTION

The UHD 4K signal will be distributed in **2160p 50fps** over EBU/Eurovision satellite fleet depending coverage, availability and format.

Europe and MENA

The European distribution will be on

- Eutelsat 10A@10°East
- Eutelsat 7B@7°East
- ABS3A@3°East

Asia

The Asian distribution will be on

- Asiasat-9@122° East
- Asiasat-5@ 100.5° East
- Apstar-7 @ 76.5°East

Americas

The Americas distribution will be on

- NS806@47.5° West
- IS34@ 55.5° West

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TRANSMISSION PARAMETERS AND SYSTEMS SETUP

Satellites and Modulation parameters

The UHD 4K signal will be distributed using the EBU satellite capacity with coverage of Europe and MENA, Asia and the Americas; the EBU synopsis for the transmission will contain the parameters and the satellite details for each region.

The satellite transponder will be modulated with the set of parameters detailed in the table below. The exact frequency and polarization will be communicated by Eurovision Operations for each individual transmission. The NS3 Modulation system will be used for the transmission, therefore **a Novelsat NS2000 demodulator is required for the NS3 demodulation.**

NS3 modulation				
	Info bit-rate (188) [Mb/s]		41.808	58.8483
	Modulation		16APSK	16APSK
	FEC (LDPC)		19/30	2/3
	Pilot		ON	ON
	Frame		Normal	Normal
	Roll-off factor [%]		5%	5%
	Symbol rate [Ms/s]		**17.112**	**22.8571**

Figure 1: Modulation parameters

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AUDIO VIDEO ENCODING PARAMETERS

Each of the four HD signals will be encoded at the venue using HEVC compression for video. The audio will be encoded in MPEG-1 layer II (international sound and commentaries) and Dolby E for surround sound.

		UHD SDR	UHD HDR
	Profile Title	**42 UHD HEVC**	**58 UHD HEVC**
Video			
	CBR	enabled	enabled
	Profile	Main 4:2:2 10	Main 4:2:2 10
	Entropy Coding	CABAC	CABAC
	Colour Sampling	422	422
	Bit depth	10	10
	Hierarchical B frames	enabled	enabled
	EOTF	BT.709	BT.2100 HLG
	Colour Space	BT.709	BT.2020
Standard Delay Mode	**GOP Structure (no of b-frames)**	2	2
	GOP length	24	24
	Closed GOP	enabled	enabled
	Adaptive GOP	*disabled*	*disabled*
	HRD	enabled	enabled
	IDR Pictures	enabled	enabled
	Video Bit-rate in kbps	38500	54649.3
Audio			
	Number of channels pairs available	4	4
	Phase Aligned Audio (Mandatory)	enabled	enabled
	MPEG I - Layer 2 (kbps) (stereo pair)	384	384
	Dolby E	2304	2304
Total TS Rate		**41808**	**58848.3**

HEVC Main10 Profile bitstream elements		Application value		
		PQ10	HLG10 (HLG in VUI)	HLG10 (SDR in VUI)
VUI	**colour_primaries**	9 (BT.2020 [3] space)		
	transfer_characteristics	16 (PQ)	18 (HLG)	14 (SDR)
	matrix_coeffs	9 (Y $'C_BC_R$ Non-constant luminance)		
SEI	alternative_transfer_characteristics() **preferred_transfer_characteristics**	(Not present in bitstream)		18
	mastering_display_color_volume() **(display primaries, white point)** [note: this is ST 2086 [9] data]	(Optional)	N/A	
	content_light level _info() **(MaxCLL, MaxFALL)**			

Figure 2: Encoding parameters

In particular for UHD HDR based on HLG, SEI alternative_transfer_characteristics=18 and VUI transfer_characteristics=14. European receivers are not capable of interpreting non-backwards compatible signalling with only the VUI transfer_characteristics set to 18.

Note: UHD HDR signals according to BT.2100 require the same bit-rate of UHD SDR unless dual layers technologies are used (e.g., Dolby Vision). HDR and SDR total rates, reported in the table above are different as they refer to the available network capacities.

RECEPTION OPTIONS

Broadcasters can purchase and use their own HEVC decoders.

The below decoders have passed EBU compatibility tests:

1. NTT HC11000D-4K HEVC/UHD decoder (Hardware decoding)
2. Harmonics RD9000 HD/UHD decoder (Software decoding)
3. Ericsson MFCP platform (Software defined hardware, hardware accelerated)

GLOSSARY

HDR10 is a set of parameter values announced in 2015 by the US Consumer Technology Association (CTA). It includes the wide-gamut ITU-R Rec. 2020 colour space, a sample bit depth of 10-bits, and the SMPTE ST 2084 (PQ) transfer function. It also includes SMPTE ST 2086 "Mastering Display Colour Volume" static metadata, to send colour calibration data of the mastering display, as well as MaxFALL (Maximum Frame Average Light Level) and MaxCLL (Maximum Content Light Level) static values.

PQ Perceptual Quantization is a transfer function used for HDR. It achieves a range of brightness levels for a given bit depth using a non-linear transfer function that matches the sensitivity curve of the human visual system. It is one of the two HDR specifications given in ITU-R BT.2100. PQ is also described in SMPTE ST 2084.

PQ10 is a profile of parameter values defined by the US Ultra HD Forum definition. It includes the PQ transfer function, ITU-R BT.2020 colour gamut, and a 10-bit sample depth. PQ10 is also one of the HDR systems included in the DVB Phase 2 UHD delivery specification.

HLG Hybrid Log Gamma is a transfer function used for HDR. It achieves a range of brightness levels for a given bit depth, and was designed to be a reverse compatible HDR system. Developed by the BBC and NHK, it is one of the two HDR specifications described in IITU-R BT.2100. HLG is also described in ARIB B67.

HLG10 is a profile of parameter values defined by the US Ultra HD Forum definition. It includes the HLG OETF, ITU-R BT.2020 colour gamut, 10-bit depth. HLG10 is one of the HDR systems included in the DVB Phase 2 UHD delivery specification.

HDR10+ is a profile of parameter values announced in 2017 by Samsung and Amazon Video. It is an extension of HDR10 adding dynamic metadata. The dynamic metadata is the Samsung system given in SMPTE ST 2094-40. The dynamic metadata is additional data that can be used to more accurately adjust brightness levels on a scene-by-scene or frame-by-frame basis.

Dolby Vision is an HDR format from Dolby Laboratories that is optionally supported by Ultra HD Blu-ray discs and some streaming video services. Dolby Vision includes the PQ (SMPTE ST 2084) electro-optical transfer function, up to 4K resolution, and a wide-gamut colour space (ITU-R Rec. 2020). A main difference from HDR10 is that Dolby Vision has a 12-bit colour depth and dynamic metadata. The colour depth allows up to 10,000-nits maximum screen brightness (mastered to 4,000-nits in practice). It can encode mastering display colorimetry information using static metadata (SMPTE ST 2086) but also provide dynamic metadata (SMPTE ST 2094-10, Dolby format) for each scene. Dolby Vision signals can be delivered using a single HEVC Main- 10 stream or as two AVC-8 or HEVC-8 or HEVC-10 streams.

SL-HDR1 was jointly developed by STMicroelectronics, Philips International B.V., CableLabs, and Technicolor R&D France. It was standardised as ETSI TS 103 433 in 2016. SL-HDR1 provides direct backwards compatibility by using static and dynamic metadata (using SMPTE ST 2094-20 Philips and 2094-30 Technicolor formats) to reconstruct a HDR signal from a SDR video stream which can be delivered using SDR distribution networks and services already in place. SL-HDR1 allows for HDR rendering on HDR devices and SDR rendering on SDR devices using a single layer video stream. The HDR reconstruction metadata can be added either to HEVC or AVC using a supplemental enhancement information (SEI) message. The HDR content source can be either PQ or HLG.