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HEVC Video Constraints for Cable Television
Part 1- Coding

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1.0 SCOPE

This document defines the coding constraints on ITU-T Rec. H.265 | ISO/IEC 23008-2 [5] video compression (hereafter called "HEVC") for Cable Television. In particular, this document describes the coding of a single HEVC coded video elementary stream carried in MPEG-2 transport (ISO/IEC 13818-1) [4] for linear delivery systems supporting ad insertion services [3]. Beyond linear delivery with DPI, signaling is provided for segmentation of content for xDVR applications.

1.1 Background (Informative)

This document specifies the creation of an HEVC coded video elementary stream and is intended for cable video services applications such as broadcast, time-shifting (e.g., PVR/DVR service), Video-on-Demand services, and splicing (e.g., Ad-insertion) that could employ the specifications in this document. However, constraints specific to those applications are outside of the scope of this document at this time.

2.0 NORMATIVE REFERENCES

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1 SCTE References

[1] ANSI/SCTE 54 2015, Digital Video Service Multiplex and Transport System Standard for Cable Television.

[2] ANSI/SCTE 128-1 2013, AVC Video Constraints for Cable Television: Part 1 – Coding

[3] ANSI/SCTE 35 2017, Digital Program Insertion Cueing Message for Cable

2.2 Standards from other Organizations

[4] ISO/IEC 13818-1:2018, “Information Technology – Generic coding of moving pictures and associated audio – Part 1: Systems.

[5] ITU-T Rec. H.265 | ISO/IEC 23008-2:2017 – MPEG-H Part 2: High Efficiency Video Coding.

[6] CTA-608-E 2008, Line 21 Data Services.

[7] ANSI/CTA-708-E 2013, Digital Television (DTV) Closed Captioning.

[8] ATSC A/53 Part 4:2009, Digital Television Standard, MPEG-2 Video System Characteristics.

[9] SMPTE ST 2016-1-2009: Standard for Television – Format for Active Format Description and Bar Data.

[10] ISO/IEC 13818-2:2013, Information Technology – Generic coding of moving pictures and associated audio - Part 2: Video

[11] ITU-R BT.2100-1:2017 Image parameter values for high dynamic range television for use in production and international programme exchange.

[12] CTA-861-G “A DTV Profile for Uncompressed High Speed Digital Interfaces”

3.0 INFORMATIVE REFERENCES

The following documents *may* provide valuable information to the reader but are not required when complying with this standard.

3.1 SCTE References

[13] ANSI/SCTE 215-2, HEVC Video Constraints for Cable Television Part 2- Transport.

[14] ANSI/SCTE 43, Digital Video Systems Characteristics Standard for Cable Television.

[15] ANSI/SCTE 07, Digital Transmission Standard for Cable Television.

[16] ANSI/SCTE 172, Constraints on AVC and HEVC Structured Video Coding for Digital Program Insertion.

[17] ANSI/SCTE 128-2, AVC Transport Constraints for Cable Television Part 2: Transport

[18] ANSI/SCTE 54, Digital Video Service Multiplex and Transport System Standard for Cable Television.

[19] ANSI/SCTE 187-2, Stereoscopic 3D PSI Signaling.

[20] ANSI/SCTE 67, Recommended Practice for SCTE 35 Digital Program Insertion Cueing Message for Cable

3.2 Standards from other Organizations

[21] ETSI TS 101 154 V2.4.1 Digital Video Broadcasting (DVB): Specification for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream.

[22] SMPTE ST 170, Television – Composite Analog Video Signal – NTSC for Studio Applications.

[23] SMPTE ST 274, Standard for television, 1920 x 1080 Scanning and Interface.

[24] SMPTE ST 296, Standard for television, 1280 x 720 Scanning, Analog and Digital Representation, and Analog Interface.

[25] ITU-R BT.601-6, Encoding parameters of digital television for studios.

[26] ITU-R BT.709-6, Parameter values for the HDTV standards for production and international programme exchange.

[27] ITU-R BT.2020-2, Parameter values for ultra-high definition television systems for production and international programme exchange.

[28] ITU-T J.83 Digital Video Transmission Standard for Cable Television.

[29] CEA-CEB16: Active Format Description (AFD) & Bar Data Recommended Practice.

[30] SMPTE ST 125, Standard for television, Component Video Signal 4:2:2, Bit Parallel Digital Interface.

[31] SMPTE ST 293, Standard for television, 720x483 Active Line at 59.95 Hz Progressive Scan Production, Digital Representation.

[32] SMPTE ST 267, Standard for television, Bit Parallel Digital Interface- Component Video Signal 4:2:2 16x9 Aspect Ratios.

[33] ITU-T Rec. T.35, “Procedure for the allocation of ITU-T defined codes for non-standard facilities.”

[34] ATSC A/53, Part 3, “Service Multiplex and Transport Subsystem Characteristics”

[35] SMPTE ST 2036-1, Ultra High Definition Television- Image Parameter Values for Program Production.

[36] SMPTE ST 2046-1, Specifications for Safe Action and Safe Title Areas for Television.

[37] ITU: Report ITU-R BT.2390, “High dynamic range television for production and international programme exchange,” International Telecommunications Union, Geneva.

4.0 COMPLIANCE NOTATION

Throughout this document, there are words that are used to define the significance of particular requirements. These words are:

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this specification.
shall not	This phrase means that the item is an absolute prohibition of this specification.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of the standard. Implementations should avoid use of deprecated features.

This document contains symbolic references to syntactic elements used in the video and transport coding subsystems. These references are typographically distinguished by the use of a different font (e.g., reserved), *may* contain the underscore character (e.g., constraint_set0_flag) and *may* consist of character strings that are not English words (e.g., pic_width_in_mbs_minus1).

5.0 DEFINITIONS AND ACRONYMS

5.1 Acronyms

The following definitions and acronyms are used in this document:

AFD Active Format Description

ATSC Advanced Television Systems Committee

AU Access Unit

AVC Advanced Video Coding

BLA Broken Link Access

CPB Coded Picture Buffer

CRA Clean Random Access

CVS Coded Video Sequence

DPB Decoded Picture Buffer

DPI Digital Program Insertion

DTS	Decoding Time Stamp
DTV	Digital Television
DVB	Digital Video Broadcasting
DVS	Digital Video Subcommittee
ETSI	European Telecommunications Standards Institute
FPP	Forward Predicted Picture
FPS	Frames Per Second
HDR	High Dynamic Range
HDTV	High Definition Television
HRD	Hypothetical Reference Decoder
IDR	Instantaneous Decoding Refresh
IEC	International Electrotechnical Commission
IRAP	Intra Random Access Point [see definitions in 5.2]
ISO	International Organization for Standardization
MPEG	Moving Picture Experts Group
NAL	Network Abstraction Layer
NCG	Narrow Color Gamut
nPVR	Network based Personal Video Recorder
PES	Packetized Elementary Stream
POC	Picture Order Count
PPS	Picture Parameter Set
PTS	Presentation Time Stamp
PVR	Personal Video Recorder
RADL	Random Access Decodable Leading (Picture)
RASL	Random Access Skipped Leading (Picture)
SDR	Standard Dynamic Range
SDTV	Standard Definition Television
SEI	Supplemental Enhancement Information
SGOP	SCTE Group of Pictures [see definitions in 5.2]
SHRAP	SCTE HEVC Random Access Point [see definitions in 5.2]
SPS	Sequence Parameter Set
SRAP	SCTE (AVC) Random Access Point
T-STD	Transport Stream System Target Decoder
VCL	Video Coding Layer
VOD	Video on Demand
VPS	Video Parameter Set
VUI	Video Usability Information

WCG Wide Color Gamut

xDVR Generic Digital Video Recorder [see definitions in 5.2]

5.2 Definitions

FPP A predicted picture that does not use any later-displayed picture as a reference.

HEVC ITU-T Rec. H. 265 | ISO/IEC 23008-2:2014 High Efficiency Video Coding [5]

HEVC Receiver The term "HEVC Receiver" in this standard for coding means a receiver having at least the attributes (in no particular order) listed below:

1. Able to parse and decode the normative elements from HEVC [5] that are specified with constraints in this standard;
2. Not adversely affected by the presence or absence of optional and informative elements from HEVC [5];
3. Not adversely affected by the presence or absence of optional and informative elements in this standard;
4. Able to parse and process all elements from HEVC [5] Annex D (SEI messages) and Annex E (VUI syntax elements) that are normatively specified and/or constrained by this standard and conveyed in-band;

   NOTE 1: These are optional elements in the HEVC specification.

5. Supports the processing of end_of_bitstream_rbsp() syntax element (NAL unit type =37, EOB_NUT) required by applications where another bitstream follows the end_of_bitstream NAL unit. The bitstream that follows will start with an IDR picture (NAL unit type = 20, IDR_N_LP) and *may* be accompanied by a time base discontinuity. The “no_output_of_prior_pics_flag” ***shall*** be read and not inferred.

   NOTE 2: Management of DPB frame buffers in accordance with the HEVC Specification [5] supports graceful output transitions between fields and frames at an SHRAP containing an IDR or BLA picture.

6. Supports the processing of elementary streams in Low Delay Mode and Still Pictures.

   NOTE 3: The additional information from items 5 and 6 is optionally provided for the benefit of HEVC receivers that include support for applications such as PVR, DPI and VOD.

   NOTE 4: Transport related attributes for an HEVC Receiver definition can be found in SCTE 215-2 (Transport) [13]

IRAP IRAP as specified in HEVC [5].

SGOP A SCTE Group of Pictures (SGOP) is the group of pictures spanning two consecutive SHRAPs, starting with a SHRAP AU but not including the subsequent SRAP AU.

SHRAP Picture An IRAP picture that is part of an SHRAP AU or an intra-coded field picture with NAL unit type = TRAIL_R that is part of an SHRAP AU.

xDVR Generic DVR implementation. This could be ‘Cloud DVR (cDVR)’, ‘Network DVR (nDVR), local DVR or any other generic DVR.

Numerical formats are defined in the following Table 1:

Table 1- Numerical Format Definitions

Example Values	Description
12345	Example of a decimal value format
0x2A	Example of a hexadecimal value format
'10010100'	Example of a string of binary digits

6.0 POSSIBLE VIDEO INPUTS

The television production standards shown in Table 2 correspond to the video production formats specified in Table 13.

Table 2- Standardized Video Input Formats

Video Standard	Active Lines	Active Samples/ Line	Name
SMPTE ST 2036-1 [35]	2160	3840	UHDTV1
SMPTE ST 274 [23]	1080	1920	HDTV
SMPTE ST 296 [24]	720	1280	HDTV
SMPTE ST 125 [30]	576	720	SDTV
SMPTE ST 2046-1 [36]	480	720	SDTV

The compression formats *may* be derived from one or more appropriate video input formats.

Production standards supported by this standard may include formats with frame rates of 24/1.001 (23.976), 24, 25, 30/1.001 (29.97), 30, 50, 60/1.001 (59.94), 60, 100, 120 and 120/1.001 Hz.

Video streams can be in the form of standard dynamic range (SDR) which are identified by video streams using a transfer characteristic for BT.709 assuming a display characteristic corresponding to BT.1886. Video streams can also be in the form of high dynamic range (HDR) which consists of streams of dynamic range types as identified in HDR subpart documents.

NOTE 5: Resolution of video can be considered orthogonal to the dynamic range properties of video. For example, HDR streams may be either HDTV or UHDTV1 resolution.

7.0 CONSTRAINTS ON HEVC CODING

7.1 Syntactical Constraints on Parameter Sets

HEVC bitstreams ***shall*** conform to the HEVC Specification [5] and ***shall*** also satisfy the normative constraints described in this document. Unless specified otherwise in this document, the allowable parameters ***shall*** be bounded

by the upper limits specified in the HEVC Specification [5]. Parameters pertaining to Profile, Level, and Tier ***shall*** be constrained as shown in Table 3 and Table 4 of Section 7.1.1.

Profiles and levels for respective production formats ***shall*** be constrained as shown in Table 13.

HEVC bitstreams ***shall*** include the SEI and the VUI syntactic elements as normatively specified and/or constrained in this document. SEI and the VUI syntactic elements are defined in HEVC [5] Annexes D and E, respectively. Some VUI and SEI messages are optional and *may* be ignored by the HEVC Receiver as specified herein. Unless otherwise constrained by this standard, HEVC Receivers should be able parse and decode and not be adversely affected by any legal structure permitted by HEVC [5], including the presence of syntax elements with values, specified as reserved or unspecified at the time of publication of this document.

7.1.1 Profiles, Levels, and Tiers constraints

HEVC ***shall*** operate with the coding constraints described below:

Table 3- General HEVC Coding Constraints

Allowed HEVC coding constraints	**Value**
Profiles	Main, Main 10
Levels	Up to Level 5.1 (2160p60)
Tier	Main

In addition, if the bitstream contains multiple sub-layers, (for which sps_max_sub_layers_minus1 is greater than 0), then the values of the following flags ***shall*** be:

sub_layer_profile_present_flag[i] = 0

sub_layer_level_present_flag[i] = 0.

The tables in the following sections list the allowed values for each of the HEVC syntax elements that are restricted beyond the limits imposed for the above specified profiles, levels, and tiers in the HEVC Specification.

Table 4- Profile, Tiers, Levels Constraints

profile_tier_level constraints	**Allowed Value**
general_profile_space	0
general_tier_flag	0- Main Tier
general_profile_idc	1- Main, 2-Main10
general_level_idc	Up to Level 5.1 for UHDTV1 (2160p60) see Table 2 and Table 13
sub_layer_profile_present_flag	0 if present
sub_layer_level_present_flag	0 if present

All HEVC receivers are defined to support a specified Level and be capable of processing HEVC Bitstreams with the video formats and constraints specified in Table 13 up to that Level.

HDR streams ***shall*** have general_profile_idc set to 2 which is the Main 10 profile.

The time interval between consecutive changes in general_profile_idc and/or general_level_idc ***shall*** be greater than or equal to one second.

NOTE 6: Profile and level changes should be avoided as they may result in disruption of the decoder's video output.

NOTE 7: It is envisioned that there may be services that include both Main bitstreams (general_profile_idc = 1) and Main 10 bitstreams (general_profile_idc = 2). Main-10 capable receivers are expected to handle the transitions in general_profile_idc values for such services.

7.1.2 Constraints Restrictions with respect to nal_unit_type

This section provides constraints to the values of nal_unit_type in a nal_unit_header.

The parameter nuh_layer_id ***shall*** be equal to 0.

The following Table 5 lists the constraints and guidance on the values of nal_unit_type.

Table 5- Constraints and Guidance on NAL Unit Types

nal_unit_type	Category of nal_unit_type	Constraints	Guidance	Note
0	Coded slice segment of a non-TSA, non-STSA trailing picture: TRAIL_N		Use for trailing sub layer non-reference pictures	
1	Coded slice for TRAIL_R picture		Use for trailing reference pictures, or for SHRAP picture when field_seq_flag = 1	
2-5	TSAs, STSAs	Prohibited from use		Due to constraint that sps_temporal_id_nesting_flag = 0 per Table 6
6-9	Coded Slice of RADL and RASL pictures slice_segment_layer_rbsp (): RADL_N, RADL_R, RASL_N, RASL_R		Use for RADL and RASL pictures	
10-15	RSVs		Ignore: nal_unit_type reserved in HEVC specification [5]	
16-21	Coded slice of IRAP picture: BLA_W_LP, BLA_W_RADL, BLA_N_LP, IDR_W_RADL, IDR_N_LP, CRA_NUT		Use for SHRAP picture when field_seq_flag = 0 or 1	
22-31	RSVs		Ignore: nal_unit_type reserved in HEVC specification [5]	

nal_unit_type	Category of nal_unit_type	Constraints	Guidance	Note
32 33 34	VPS_NUT SPS_NUT PPS_NUT	see 7.1.2.1 For SHRAP Picture		
35	Access unit delimiter: AUD_NUT	Each access unit ***shall*** start with an AUD_NUT		
36	End of sequence: EOS_NUT	The next AU after an AU containing an EOS_NUT ***shall*** be an IDR AU, BLA AU, or CRA AU		The next AU after an AU containing an EOS NUT is prohibited from being a TRAIL_R AU
37	End of bitstream: EOB_NUT	The next AU after an AU containing an EOB_NUT ***shall*** be a SHRAP that is an IDR AU		
38	FD_NUT		As per [5] FD NUT needs to come after the first VCL of the AU	
39 40	PREFIX_SEI SUFFIX_SEI	See 7.1.2.1 & 7.1.7 See 7.1.7		
41-47	Reserved		Ignore: nal_unit_type reserved in HEVC specification [5]	
48-63	Unspecified			

7.1.2.1 Constraints for nal_unit_types associated with an SHRAP

A SHRAP access unit is an HEVC access unit shown pictorially in Figure 1. A SHRAP access unit ***shall*** include exactly one access unit delimiter (AUD), exactly one VPS, exactly one Sequence Parameter Set (SPS) (that is active) with VUI, and at least one Picture Parameter Set (PPS) that is required for decoding the associated picture. The SPS and any PPS ***shall*** precede any SEI NAL units that *may* be present in an SHRAP access unit.

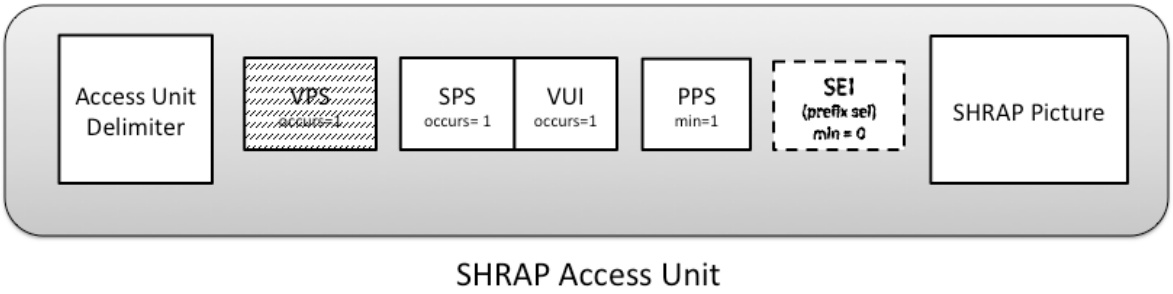

Figure 1: NAL Unit Order for a Typical SHRAP Access Unit

The value of nuh_temporal_id_plus1 ***shall*** be equal to 1 for all NAL units in an SHRAP AU.

The constraints for Video Usability Information (VUI) parameters are specified in Section 7.1.5 of this document. If the value of field_seq_flag in the VUI parameters is equal to 0, the SHRAP picture ***shall*** have a nal_unit_type value in the range of 16 to 21, inclusive. This range of nal_unit_type values corresponds to an IRAP picture in accordance with the HEVC Specification [5].

When the value of field_seq_flag in the VUI parameters is equal to 1, the SHRAP picture ***shall*** correspond to an intra-coded field picture with a NAL_unit_type value that is either:

in the range of 16 to 21, inclusive, or equal to 1.

A NAL_unit_type value equal to 1 corresponds to TRAIL_R. The value of field_seq_flag in the VUI parameters ***shall*** be equal to 1 if the NAL unit type of an SHRAP is equal to 1. A recovery point SEI ***shall*** be present in the AU of a SHRAP with a NAL unit type equal to 1.

The first access unit after an access unit that contains an end of sequence NAL unit ***shall*** be the access unit of an SHRAP containing an IDR, BLA, or CRA picture. An SHRAP picture with NAL unit type corresponding to TRAIL_R ***shall*** not follow an access unit containing an end of sequence NAL unit.

The first access unit after an access unit that contains an end of bitstream NAL unit ***shall*** be an IDR access unit corresponding to an SHRAP.

7.1.3 Video Parameter Set (VPS) constraints

For each SHRAP, there ***shall*** be one active Video Parameter Set (VPS) present in the bitstream. As per Note 1 in HEVC [5] section 7.4.3.1, the information in the VPS ***shall*** be ignored by decoders conforming to the Main and Main 10 profiles.

7.1.4 Sequence Parameter Set (SPS) constraints

The Sequence Parameter Set (SPS) ***shall*** comply with Table 6.

Table 6- Sequence Parameter Set Constraints

Parameter Set Syntactic Element	Allowed Value	
	SDR	HDR
sps_temporal_id_nesting_flag	0	0
chroma_format_idc	1 (4:2:0)	1
sps_sub_layer_ordering_info_present_flag	0	0

Parameter Set Syntactic Element	Allowed Value	
	SDR	HDR
long_term_ref_pics_present_flag	0	0
vui_parameters_present_flag	1	1
bit_depth_luma_minus8	0 (8 bit) or 2 (10 bit)	2
bit_depth_chroma_minus8	0 (8 bit) or 2 (10 bit)	2

The use of bitstreams using a BT.2100-1[11] colorspace ***shall*** require the use of Main 10 Profile.

7.1.5 VUI Constraints

The VUI parameters ***shall*** comply with Table 7.

Table 7- Video Usability Information Constraints

VUI Header Syntactic Element	Allowed Value
aspect_ratio_idc	See Appendix A
video_signal_type_present_flag	1 for Level 5 and 5.1 (UHDTV1) and for HDR
colour_description_present_flag	1 for Level 5 and 5.1 (UHDTV1) and for HDR
chroma_loc_info_present_flag	***Shall*** be 1 when field_seq_flag = 1
field_seq_flag	***Shall*** be 1 for a field-coded video sequence ***Shall*** be 0 otherwise
frame_field_info_present_flag	1
vui_timing_info_present_flag	***Shall*** be 1 for fixed frame rate *May* be either 0 or 1 for low delay
vui_num_units_in_tick	See Table 14
vui_time_scale	See Table 14
vui_poc _proportional_to_timing_flag	0
vui_hrd_parameters_present_flag	Preferred to be 0 for fixed frame rate ***Shall*** be 1 for low delay mode

It is recommended to send colorimetry information in the form of the following parameters in the VUI (colour_primaries, transfer_characteristics, and matrix_coefficients) as the implied values for these parameters results in unspecified values. It is noted that ITU-R BT.2100 [11] , ITU-R BT.709-6 [26] and SMPTE ST 170 [22] are the most likely parameters to be used in practice.

Additional VUI constraints sets for colorimetry information are listed below in Table 8:

Table 8- Video Usability Information Constraints

VUI Header Syntactic Element	Allowed Value
	SDR
colour_primaries	1 9 (for UHDTV1)
transfer_characteristics	1

VUI Header Syntactic Element	Allowed Value
	SDR
matrix_coefficients	1
VideoFullRangeFlag	0

It is required that the colorimetry information be sent for Level 5 and Level 5.1 (UHDTV1) bitstreams and for all HDR type bitstreams. For SDR streams with unspecified values for colorimetry information, a decoder *may* assume that the values are those listed in Table 8.

NOTE 8: matrix_coefficients are orthogonal to the dynamic range type of the stream and in the future could extend to additional values.

NOTE 9: Some Syntactical elements require that the corresponding preceding flag, "xxx_present_flag", if it exists, be equal to 1 (for example, the colour_description_present flag).

The value of field_seq_flag ***shall*** be equal to 1 only for field-coded video sequences.

In accordance with Annex E of the HEVC [5], HRD parameters *may* be conveyed to decoders by other means not specified. HRD parameters ***shall*** be constrained when present as shown in Table 9 and Table 10.

A fixed frame rate bitstream *may* or *may* not include HRD parameters. When **vui_hrd_parameters_present_flag** = 0, the bitstream ***shall*** comply to fixed picture rate and the parameter values shown in Table 9 ***shall*** be inferred.

A fixed frame rate bitstream with **vui_hrd_parameters_present_flag** = 1 ***shall*** be constrained with parameter values shown in Table 9.

NOTE 10: ***low_delay_hrd_flag*** *[maxNumSubLayersMinus1] = 0 when* ***fixed_pic_rate_general_flag[*** *maxNumSubLayersMinus1] = 1.*

Table 9 - HRD Parameter Constraints for fixed frame rate

HRD Syntactic Element	Allowed Value	
	i = maxNumSubLayersMinus1	**i** < maxNumSubLayersMinus1
nal_hrd_parameters_present_flag	0	0
vcl_hrd_parameters_present_flag	0	0
fixed_pic_rate_general_flag [i]	1	0
fixed_pic_rate_within_cvs_flag[i]	1	0
elemental_duration_in_tc_minus1[i]	0	0
low_delay_hrd_flag[i]	0	0

The value of vui_hrd_parameters_present_flag ***shall*** be equal to 1 for Low Delay mode. HRD parameters ***shall*** have the values shown in Table 10 for Low Delay Mode.

Table 10 - HRD Parameter Constraints for Low Delay Mode

HRD Syntactic Element	Allowed Value	
	i = maxNumSubLayersMinus1	**i** < maxNumSubLayersMinus1
nal_hrd_parameters_present_flag	0	0
vcl_hrd_parameters_present_flag	0	0

HRD Syntactic Element	Allowed Value	
fixed_pic_rate_general_flag [i]	0	0
fixed_pic_rate_within_cvs_flag[i]	0	0
elemental_duration_in_tc_minus1[i]	0	0
low_delay_hrd_flag[i]	1	0

7.1.6 Picture Parameter Constraints and Level Limits

The Picture Parameter Set (PPS) ***shall*** comply with Table 11.

HEVC Bitstreams ***shall not*** include non-paired fields (as defined in HEVC).

NOTE 11: In the context of HEVC, paired fields are two fields that are in consecutive access units in decoding order as two coded fields of opposite parity of the same frame, regardless of their display order.

All pictures in HEVC Bitstreams shall be displayable pictures except when a RASL picture of an associated IRAP has unavailable reference pictures.

Between two SHRAPs, the content of a picture parameter set with a particular pps_pic_parameter_set_id ***shall not*** change. That is, if more than one picture parameter set is present in the bitstream and these picture parameter sets are different from each other, then each picture parameter set ***shall*** have a different pps_pic_parameter_set_id.

Table 11- Picture Parameter Set Constraints

PPS Header Syntactic Element	Allowed Value
output_flag_present_flag	0
num_extra_slice_header_bits	0
slice_segment_header_extension_present_flag	0

7.1.7 Supplemental Enhancement Information (SEI) Constraints

All prefix SEIs ***shall not*** occur after the first VCL NAL unit of the access unit. All suffix SEIs ***shall*** not occur before the last VCL NAL unit of the access unit.

NOTE 12: The constraint in the present clause forbids SEI messages from occurring between the first and the last VCL NAL units of an access unit. The HEVC specification [5] allows SEI messages (both prefix and suffix SEI) to occur between the first and the last VCL NAL units of an access unit.

Repeated SEI messages of the same type in the same access unit ***should not*** occur. The use of SEI messages with identical payload information for the same persistence scope, as defined in Table D.1 of [5], provide no additional information at the expense of increased bitrate and require increased decoder processing capabilities. The use of SEI messages with inconsistent payload information for the same persistence scope results in ambiguity about which payload is the proper one to utilize.

Cable usage constraints on types of SEI messages are listed in Table 12.

Table 12- Supplementary Enhancement Information Constraints

SEI Header Syntactic Element	Usage Constraints
Picture Timing SEI message	Present in each AU
Frame packing SEI message	Top/Bottom & Side by Side Configurations only permitted as per SCTE 187 [19]
Decoding Unit Information SEI message	Prohibited
Scalable nesting SEI message	Prohibited
User data registered by ITU-T Rec. T.35 SEI message	Sent in prefix SEI Only

There may be additional SEI messages needed for HDR content as identified in each HDR subpart document.

The pic_timing SEI ***shall*** be present in each AU and ***shall*** be constrained as follows:

pic_struct *shall not* be equal to 1 or 2.

The value of CpbDpbDelaysPresentFlag ***shall*** be inferred equal to 0.

A coded field video sequence containing an SHRAP corresponding to a TRAIL_R picture ***shall*** have an output recovery point not later than the output time of the SHRAP picture. When the SHRAP picture has a NAL unit type in the range from 16 to 21, the output recovery point is derived from the NAL unit type of the respective coded pictures in accordance with the HEVC Specification [5].

The recovery point SEI ***shall*** be present in the AU of an SHRAP picture with NAL unit type equal to 1 (TRAIL_R) and its use for other AUs is optional. The recovery point SEI *may* be used to signal a recovery point that precedes the output time of the SHRAP picture, such as when some pictures with output time earlier than the SHRAP picture are backward predicted from the SHRAP picture or the field paired with the SHRAP picture. When the recovery point SEI is present, the value of exact_match_flag ***shall*** be set to 1, and the value of broken_link_flag ***shall*** be set to 0.

NOTE 13: An HEVC receiver may ignore the recovery point SEI.

A field coded video sequence ***shall*** contain only paired fields. The pic_struct in the pic_timing SEI ***shall*** not be equal to 1 or 2.

The field paired with a field-coded SHRAP picture with a NAL unit type corresponding to TRAIL_R ***shall not*** reference a picture that precedes the SHRAP picture in the bitstream.

Pictures after the SHRAP picture in the bitstream that have output time prior to the SHRAP picture are leading pictures. The output time of a picture is equal to its PTS. The PTS of a picture *may* be used to identify leading pictures after the SHRAP picture. The PTS is not sufficient to distinguish between decodable and non-decodable leading pictures. Upon entering a bitstream at an SHRAP AU containing a field-coded picture with NAL unit type corresponding to TRAIL_R, except for the coded field paired with the SHRAP picture, the following derivations and inferences ***shall*** be made:

- All pictures with a PTS prior to the PTS of the SHRAP ***shall*** be leading pictures.
- If the recovery point SEI is present in the SHRAP AU:

  Any leading pictures with a PTS prior to the recovery point specified by the recovery point SEI ***shall*** be inferred as a RASL picture, and

Any leading pictures that are not inferred as a RASL picture ***shall*** be inferred as a RADL picture.

- If the recovery point SEI is not present in the SHRAP AU:

  All leading pictures ***shall*** be inferred as RASL pictures.

- The value of NoRaslOutputFlag ***shall*** be equal to 1 for each inferred RASL picture.

When supporting AFD, bar data, and closed captioning (see section 8.0 for more details), related SEI information ***shall*** comply with what is described in SCTE 128-1 [2] section 7.2.1.4 ("Supplemental Enhancement Information (SEI) Constraints").

7.2 Compression format, conformance points & format constraints

This section supports definition and constraints on compression formats with horizontal sizes and vertical sizes as well as frame rates. The aspect_ratio_idc *should* equal 1 (square samples) for most formats. The display aspect ratio is nominally 16:9 (for UHDTV1 and HDTV signals) or 4:3 (for SDTV signals).

All compression ***shall*** comply with the constraints and levels of the Main Tier. Therefore general_tier_flag ***shall*** equal 0.

Tables for format resolutions and codec constraints are listed in Appendix A specific to different applications used in cable systems.

Video formats with vertical sizes of 1080 lines can be coded as either 1080 lines or 1088 lines with a conformance cropping window of 1080 lines. If 1088 lines is used to code 1080 line pictures, the conformance cropping window ***shall*** be defined with conf_win_top_offset equal to 0 and conf_win_bottom_offset = 4.

*NOTE 14: The formula to determine the number of lines to crop from the bottom is SubHeightC * conf_win_bottom_offset and SubHeightC has a value of 2 when chroma_format_idc = 1 for 4:2:0 video.*

Table 13- Format Constraints Based on Production Format for HEVC Bitstreams

Production Format	Profile	general_ profile_ idc[1]	general_ level_idc (max permitted value)
UHDTV1	Main 10	2	153
HDTV (1080)	Main or Main 10 HDR is Main10	1 or 2	123 (<= 60 fps) / 150 (> 60fps)
HDTV (720)	Main or Main 10 HDR is Main 10	1 or 2	120 (<= 60fps) / 123 (> 60fps)
SDTV or Below	Main	1	90

The values for vui_num_units_in_tick, vui_time_scale, and fixed_pic_rate_general_flag[i] ***shall*** be explicitly indicated in the vui_parameters( ). Table 14 indicates the entire set of defined frame rates, and the values for vui_num_units_in_tick, vui_time_scale, and pic_struct that ***shall*** be used. In the Appendix section describing format constraints for each application, a numbered subset of frame rates will be defined.

Table 14- Complete Frame Rate VUI Parameter Constraints for HEVC

Interlaced or Progressive	Frame Rate	vui_time_scale	vui_num_units_in_tick	Allowed pic_struct
P	24/1.001 Hz	24,000	1001	0,7,8
P	24 Hz	24	1	0,7,8
P	25 Hz	25	1	0,7,8
I (encoded as frames)	25 Hz	50	1	3,4,5,6
I (encoded as fields)	25 Hz	50	1	9,10,11,12
P	30/1.001 Hz	30,000	1001	0,7,8
I (encoded as frames)	30/1.001 Hz	60,000	1001	3,4,5,6
I (encoded as fields)	30/1.001 Hz	60,000	1001	9,10,11,12
P	30 Hz	30	1	0,7,8
P	50 Hz	50	1	0,7,8
P	60/1.001 Hz	60,000	1001	0,7,8
P	60 Hz	60	1	0,7,8
P	100 Hz	100	1	0,7,8
P	120 Hz	120	1	0,7,8
P	120/1.001 Hz	120,000	1001	0,7,8

The Maximum Luma Picture Size, Max Video Bit Rate, and Max CPB (Coded Picture Buffer) for a particular Profile, Level, and Tier does not exceed the limitations set forth in Appendix A of the HEVC specification [5].

7.3 Constraints on alternative application modes

Most common cable applications are in fixed frame rate mode, however, there are alternative applications such as VOD trickplay speeds or music channels that *may* not require fixed frame rate operation and do not have associated

audio or require audio/video synchronization. This section describes some of the constraints on these alternative application modes.

7.3.1 Low Delay Mode

In Low Delay Mode, picture coding constraints are as follows:

1. All pictures ***shall*** be intra coded pictures or FPP pictures.

2. The output time of each picture ***shall*** be equal to or inferred equal to its decode time.

   NOTE 6:The decode time of a picture, or DTS in accordance with the HEVC Transport contraints [13], may or may not be present in the PES packet header.

3. The POC value, or PTS, in accordance with the HEVC Transport constraints [13], of each picture in the bitstream ***shall*** be greater than the POC value of the prior picture.

4. Each decoded picture ***shall*** be output repeatedly until the next decoded picture is available.

5. The CPB *may* underflow.

NOTE 15: An HEVC receiver may ignore the information in the pic_timing SEI in Low Delay Mode.

NOTE 16: Transport related low-delay constraints can be found in SCTE 215-2 (Transport) [13]

7.3.2 Program Splicing Constraint

System processes (such as digital ad insertion and program splicing) *may* require a resolution change in the HEVC stream within the same program that results in a seamless or near-seamless behavior in the HEVC receiver. The stream may also undergo colorimetry changes. When a user of this standard wishes to facilitate such a change, the HEVC elementary stream ***shall*** be encoded in accordance with these additional constraints (also see SCTE 172 [16]):

If such seamless or near-seamless behavior in the HEVC receiver is desired, it is highly recommended that parameters such as general_level_idc, the vertical picture size, and colorimetry information in the HEVC elementary stream *should* not change within the same program.

NOTE 17: Profile changes, display aspect ratio changes, frame rate changes, colorimetry changes and interlaced/progressive transitions (in either order) should be avoided as they may result in disruption of the decoder's video output.

NOTE 18: A disruption of the pixel clock rate MAY cause non-seamless output behavior receivers

A DPI operation that returns to the network feed at an SHRAP AU containing a field-coded picture with NAL unit type corresponding to TRAIL_R ***shall*** convert the SHRAP picture from TRAIL_R to BLA or IDR. Some or possibly all pictures after the SHRAP AU in the bitstream *may* need to be transcoded to satisfy picture dependencies and/or converted to different NAL unit types in accordance to the HEVC Specification [5]. If the NAL unit type of the SHRAP picture is changed to BLA and the pictures after the SHRAP AU are not transcoded, then except for the coded field paired with the SHRAP picture, the NAL unit type of each picture after the SHRAP picture in decode order that is determined to be a leading picture ***shall*** be changed to a NAL unit type corresponding to the RASL NUT.

7.3.3 Support of Still Picture Mode in HEVC

HEVC still pictures *may* be used in transport multiplex and when used ***shall*** comply with the following picture coding constraints. Transport constraints for HEVC still pictures are found in part 2 of HEVC video constraints for cable television.

- The still picture coding ***shall*** comply with Section 2.1.103 of 13818-1 [4]. In addition, still picture applications *should* conform to the video coding constraints (except frame rate) specified in Table 15 in Appendix A
- Low_delay_hrd_flag (as defined in HEVC [5]) *may* be either set to '0' or '1'. Still picture applications *should* follow the coding constraints specified in section 7.3.1 when set to low_delay.
- The time interval between successive still pictures ***shall*** be less than or equal to 60 seconds.
- The fixed_pic_rate_general_flag and fixed_pic_rate_within_cvs_flag are set to '0' in the HRD parameters.

8.0 CARRIAGE OF CAPTIONING, AFD, AND BAR DATA

The carriage of closed captions, AFD, and bar data when present ***shall*** be carried as per specified in SCTE 128-1[2] in section 8.0.

APPENDIX A- RESOLUTIONS, CONFORMANCE POINTS, FORMAT CONSTRAINTS & FRAME RATES

Broadcast applications are a well-known instance of a push delivery system carrying MPEG-2 Transport streams compliant to T-STD model for use in North American Cable Systems.

Table 15 lists the resolutions and their format constraints for compliance with this specification for broadcast applications.

Table 15- Resolution/Compression Format Constraints for HEVC Bitstreams

Vertical Size (lines)	Horizontal Size (pixels)	aspect_ ratio_idc	Display Aspect Ratio	Supported Frame Rates (P-progressive i-interlaced)	Production Format
2160	3840	1	16:9	**P-1,2,3,6,7,8**	UHDTV1
1080	1920	1	16:9	**P-1,2,3,6,7,8,9, 10** **I- 4,5**	HDTV
1080	1440	14	16:9	**P-1,2,3,6,7,8,9, 10** **I- 4,5**	HDTV
720	1280	1	16:9	**P-1,2,3,6,7,8,9, 10**	HDTV
480	720	3	4:3	**P-1,2,3,6** **I- 4,5**	SDTV
480	720	5	16:9	**P-1,2,3,6** **I- 4,5**	SDTV
480	704	3	4:3	**P-1,2,3,6** **I- 4,5**	SDTV
480	704	5	16:9	**P-1,2,3,6** **I- 4,5**	SDTV
480	640	1	4:3	**P-1,2,3,6** **I- 4,5**	SDTV

The frame rates associated with the integer values in the “Supported Frame Rates” column of Table 15 are defined in Table 16.

Table 16- Frame Rate VUI Parameter Constraints for HEVC

Frame Rate Number	Interlaced or Progressive	Frame Rate	vui_time_scale	vui_num_units_in_tick	Allowed pic_struct
1	P	24000/1001 Hz	24,000	1001	0,7,8
2	P	24 Hz	24	1	0,7,8

Frame Rate Number	Interlaced or Progressive	Frame Rate	vui_time_scale	vui_num_units_in_tick	Allowed pic_struct
3	P	30000/1001 Hz	30,000	1001	0,7,8
4	I (encoded as frames)	30000/1001 Hz	60,000	1001	3,4,5,6
5	I (encoded as fields)	30000/1001 Hz	60,000	1001	9,10,11,12
6	P	30 Hz	30	1	0,7,8
7	P	60000/1001 Hz	60,000	1001	0,7,8
8	P	60 Hz	60	1	0,7,8
9	P	120 Hz	120	1	0,7,8
10	P	120/1.001 Hz	120,000	1001	0,7,8