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# Abstract

This document contains the draft text for changes to the Advanced Video Coding (AVC) standard (Rec. ITU-T H.264 | ISO/IEC 14496-10) to specify additional supplemental enhancement information (SEI) messages for content light level information, equirectangular projection, cubemap projection, sphere rotation, region-wise packing, omnidirectional viewport, SEI manifest, and SEI prefix, along with some corrections to the existing specification text.

Note that the drafted changes are based on Rec. ITU-T H.264 | ISO/IEC 14496-10 version 25, which was approved by ITU-T on 13 April 2017 and published on 2 August 2017, and which includes the colour remapping information SEI message that, for the WG 11 parent body, is specified in the PDAM1 proposed draft amendment in output document WG 11 N16675 (Geneva, January 2017).

**Changes to the specification text:**

*Throughout the document, search "ITU T " and replace all the found instances of "ITU T " with "ITU-T " (note the space in the end of the string).*

*Throughout the document, search "a MVC" and replace all the found instances of "a MVC" with "an MVC".*

*In clause 3, add the following term definitions (in alphabetical order within the current list):*

**3.X** **azimuth circle**: circle on a sphere connecting all points with the same azimuth value.

NOTE 1 to Entry – An azimuth circle is always a *great circle* like a longitude line on the earth.

**3.X** **constituent picture**: part of a spatially frame-packed stereoscopic video picture that corresponds to one view, or a picture itself when frame packing is not in use or the temporal interleaving frame packing arrangement is in use.

**3.X** **elevation circle**: circle on a sphere connecting all points with the same elevation value.

NOTE 1 to Entry – An elevation circle is similar to a lattitude line on the earth. Except when the elevation value is zero, an elevation circle is not a *great circle* like a longitude circle on the earth.

**3.X** **global coordinate axes**: coordinate axes associated with *omnidirectional video* that are associated with an externally referenceable position and orientation.

NOTE 1 to Entry – The global coordinate axes may correspond to the position and orientation of a device or rig used for omnidirectional audio/video acquisition as well as the position of an observer's head in the three-dimensional space of the *omnidirectional video* rendering environment.

**3.X** **great circle**: intersection of a sphere and a plane that passes through the centre point of the sphere.

NOTE 1 to Entry – A great circle is also known as an orthodrome or Riemannian circle.

**3.X** **local coordinate axes**: coordinate axes having a specified rotation relationship relative to the *global coordinate axes*.

**3.X** **omnidirectional video**: video content in a format that enables rendering according to the user's viewing orientation, e.g., if viewed using a head-mounted device, or according to a user's desired *viewport*, reflecting a potentially rotated viewing position.

**3.X** **packed region**: region in a *region-wise packed picture* that is mapped to a *projected region* according to a *region-wise packing*.

**3.X** **projected picture**: picture that uses a *projection* format for *omnidirectional video*.

**3.X** **projected region**: region in a *projected picture* that is mapped to a *packed region* according to a *region-wise packing*.

**3.X** **projection**: specified correspondence between the colour samples of a *projected picture* and azimuth and elevation positions on a sphere.

**3.X** **region-wise packed picture**: decoded picture that contains one or more *packed regions*.

NOTE 1 to Entry – A packed picture may contain a *region-wise packing* of a *projected picture*.

**3.X** **region-wise packing**: transformation, resizing, and relocation of *packed regions* of a *region-wise packed picture* to remap the *packed regions* to *projected region*s of a *projected picture*.

**3.X** **sphere coordinates**: azimuth and elevation angles identifying a location of a point on a sphere.

**3.X** **sphere region**: region on a sphere, specified either by four *great circles* or by two *azimuth circles* and two *elevation circles*, or such a region on a rotated sphere after applying yaw, pitch, and roll rotations.

**3.X** **tilt angle**: angle indicating the amount of tilt of a *sphere region*, measured as the amount of rotation of a *sphere region* along the axis originating from the sphere origin passing through the centre point of the *sphere region*, where the angle value increases clockwise when looking from the origin towards the positive end of the axis.

**3.X** **viewport**: region of *omnidirectional video* content suitable for display and viewing by the user.

*In 5.7, add the following function definitions:*

Asin( x ) the trigonometric inverse sine function, operating on an argument x that is  
in the range of −1.0 to 1.0, inclusive, with an output value in the range of  
−π÷2 to π÷2, inclusive, in units of radians (5‑2)

Atan( x ) the trigonometric inverse tangent function, operating on an argument x, with  
an output value in the range of −π÷2 to π÷2, inclusive, in units of radians (5‑3)

Atan2( y, x ) =  (5‑4)

*Renumber the prior formulae 5-2 through 5-16 as 5-5 to 5-19 to account for the added formulae.*

*In 5.7, add the following function definitions:*

Sin( x ) the trigonometric sine function operating on an argument x in units of radians (5‑19)

*Renumber the prior formula 5-19 as 5-20 to account for the added formula.*

*In 5.7, add the following function definition:*

Tan( x ) the trigonometric tangent function operating on an argument x in units of radians (5‑21)

*Replace D.1.1 with the following:*

**D.1.1 General SEI message syntax**

|  |  |  |
| --- | --- | --- |
| sei\_payload( payloadType, payloadSize ) { | **C** | **Descriptor** |
| if( payloadType = = 0 ) |  |  |
| buffering\_period( payloadSize ) | 5 |  |
| else if( payloadType = = 1 ) |  |  |
| pic\_timing( payloadSize ) | 5 |  |
| else if( payloadType = = 2 ) |  |  |
| pan\_scan\_rect( payloadSize ) | 5 |  |
| else if( payloadType = = 3 ) |  |  |
| filler\_payload( payloadSize ) | 5 |  |
| else if( payloadType = = 4 ) |  |  |
| user\_data\_registered\_itu\_t\_t35( payloadSize ) | 5 |  |
| else if( payloadType = = 5 ) |  |  |
| user\_data\_unregistered( payloadSize ) | 5 |  |
| else if( payloadType = = 6 ) |  |  |
| recovery\_point( payloadSize ) | 5 |  |
| else if( payloadType = = 7 ) |  |  |
| dec\_ref\_pic\_marking\_repetition( payloadSize ) | 5 |  |
| else if( payloadType = = 8 ) |  |  |
| spare\_pic( payloadSize ) | 5 |  |
| else if( payloadType = = 9 ) |  |  |
| scene\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 10 ) |  |  |
| sub\_seq\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 11 ) |  |  |
| sub\_seq\_layer\_characteristics( payloadSize ) | 5 |  |
| else if( payloadType = = 12 ) |  |  |
| sub\_seq\_characteristics( payloadSize ) | 5 |  |
| else if( payloadType = = 13 ) |  |  |
| full\_frame\_freeze( payloadSize ) | 5 |  |
| else if( payloadType = = 14 ) |  |  |
| full\_frame\_freeze\_release( payloadSize ) | 5 |  |
| else if( payloadType = = 15 ) |  |  |
| full\_frame\_snapshot( payloadSize ) | 5 |  |
| else if( payloadType = = 16 ) |  |  |
| progressive\_refinement\_segment\_start( payloadSize ) | 5 |  |
| else if( payloadType = = 17 ) |  |  |
| progressive\_refinement\_segment\_end( payloadSize ) | 5 |  |
| else if( payloadType = = 18 ) |  |  |
| motion\_constrained\_slice\_group\_set( payloadSize ) | 5 |  |
| else if( payloadType = = 19 ) |  |  |
| film\_grain\_characteristics( payloadSize ) | 5 |  |
| else if( payloadType = = 20 ) |  |  |
| deblocking\_filter\_display\_preference( payloadSize ) | 5 |  |
| else if( payloadType = = 21 ) |  |  |
| stereo\_video\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 22 ) |  |  |
| post\_filter\_hint( payloadSize ) | 5 |  |
| else if( payloadType = = 23 ) |  |  |
| tone\_mapping\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 24 ) |  |  |
| scalability\_info( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 25 ) |  |  |
| sub\_pic\_scalable\_layer( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 26 ) |  |  |
| non\_required\_layer\_rep( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 27 ) |  |  |
| priority\_layer\_info( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 28 ) |  |  |
| layers\_not\_present( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 29 ) |  |  |
| layer\_dependency\_change( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 30 ) |  |  |
| scalable\_nesting( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 31 ) |  |  |
| base\_layer\_temporal\_hrd( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 32 ) |  |  |
| quality\_layer\_integrity\_check( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 33 ) |  |  |
| redundant\_pic\_property( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 34 ) |  |  |
| tl0\_dep\_rep\_index( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 35 ) |  |  |
| tl\_switching\_point( payloadSize ) /\* specified in Annex ‎G \*/ | 5 |  |
| else if( payloadType = = 36 ) |  |  |
| parallel\_decoding\_info( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 37 ) |  |  |
| mvc\_scalable\_nesting( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 38 ) |  |  |
| view\_scalability\_info( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 39 ) |  |  |
| multiview\_scene\_info( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 40 ) |  |  |
| multiview\_acquisition\_info( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 41 ) |  |  |
| non\_required\_view\_component( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 42 ) |  |  |
| view\_dependency\_change( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 43 ) |  |  |
| operation\_points\_not\_present( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 44 ) |  |  |
| base\_view\_temporal\_hrd( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 45 ) |  |  |
| frame\_packing\_arrangement( payloadSize ) | 5 |  |
| else if( payloadType = = 46 ) |  |  |
| multiview\_view\_position( payloadSize ) /\* specified in Annex ‎H \*/ | 5 |  |
| else if( payloadType = = 47 ) |  |  |
| display\_orientation( payloadSize ) | 5 |  |
| else if( payloadType = = 48 ) |  |  |
| mvcd\_scalable\_nesting( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 49 ) |  |  |
| mvcd\_view\_scalability\_info( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 50 ) |  |  |
| depth\_representation\_info( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 51 ) |  |  |
| three\_dimensional\_reference\_displays\_info( payloadSize )  /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 52 ) |  |  |
| depth\_timing( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 53 ) |  |  |
| depth\_sampling\_info( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 54 ) |  |  |
| constrained\_depth\_parameter\_set\_identifier( payloadSize )   /\* specified in Annex ‎J \*/ | 5 |  |
| else if( payloadType = = 56 ) |  |  |
| green\_metadata( payloadSize ) /\* specified in ISO/IEC 23001-11 \*/ | 5 |  |
| else if( payloadType = = 137 ) |  |  |
| mastering\_display\_colour\_volume( payloadSize ) | 5 |  |
| else if( payloadType = = 142 ) |  |  |
| colour\_remapping\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 144 ) |  |  |
| content\_light\_level\_info( payloadSize ) | 5 |  |
| else if( payloadType = = 147 ) |  |  |
| alternative\_transfer\_characteristics( payloadSize ) | 5 |  |
| else if( payloadType = = 150 ) |  |  |
| equirectangular\_projection( payloadSize ) |  |  |
| else if( payloadType = = 151 ) |  |  |
| cubemap\_projection( payloadSize ) |  |  |
| else if( payloadType = = 154 ) |  |  |
| sphere\_rotation( payloadSize ) |  |  |
| else if( payloadType = = 155 ) |  |  |
| regionwise\_packing( payloadSize ) |  |  |
| else if( payloadType = = 156 ) |  |  |
| omni\_viewport( payloadSize ) |  |  |
| else if( payloadType = = 181 ) |  |  |
| alternative\_depth\_info( payloadSize ) /\* specified in Annex ‎I \*/ | 5 |  |
| else if( payloadType = = 200 ) |  |  |
| sei\_manifest( payloadSize ) |  |  |
| else if( payloadType = = 201 ) |  |  |
| sei\_prefix\_indication( payloadSize ) |  |  |
| else |  |  |
| reserved\_sei\_message( payloadSize ) | 5 |  |
| if( !byte\_aligned( ) ) { |  |  |
| **bit\_equal\_to\_one** /\* equal to 1 \*/ | 5 | f(1) |
| while( !byte\_aligned( ) ) |  |  |
| **bit\_equal\_to\_zero** /\* equal to 0 \*/ | 5 | f(1) |
| } |  |  |
| } |  |  |

*Renumber clauses D.1.31 (Alternative transfer characteristics SEI message semantics) and D.1.32 (Reserved SEI message semantics) as clauses D.1.32 and D.1.36, respectively.*

*Add clauses D.1.31, D.1.33, D.1.34, and D.1.35 as follows*:

**D.1.31 Content light level information SEI message syntax**

|  |  |  |
| --- | --- | --- |
| content\_light\_level\_info ( payloadSize ) { | **C** | **Descriptor** |
| **max\_content\_light\_level** | 5 | u(16) |
| **max\_picture\_average\_light\_level** | 5 | u(16) |
| } |  |  |

**D.1.33** **Syntax of omnidirectional video specific SEI messages**

**D.1.33.1 Equirectangular projection SEI message syntax**

|  |  |  |
| --- | --- | --- |
| equirectangular\_projection( payloadSize ) { | **C** | **Descriptor** |
| **erp\_cancel\_flag** | 5 | u(1) |
| if( !erp\_cancel\_flag ) |  |  |
| **erp\_persistence\_flag** | 5 | u(1) |
| **erp\_padding\_flag** | 5 | u(1) |
| **erp**\_**reserved\_zero\_2bits** | 5 | u(2) |
| if( erp\_padding\_flag  = =  1 ) { |  |  |
| **gp\_erp\_type** | 5 | u(3) |
| **left\_gb\_erp\_width** | 5 | u(8) |
| **right\_gb\_erp\_width** | 5 | u(8) |
| } |  |  |
| } |  |  |
| } |  |  |

**D.1.33.2 Cubemap projection SEI message syntax**

|  |  |  |
| --- | --- | --- |
| cubemap\_projection( payloadSize ) { | **C** | **Descriptor** |
| **cmp\_cancel\_flag** | 5 | u(1) |
| if( !cmp\_cancel\_flag ) |  |  |
| **cmp\_persistence\_flag** | 5 | u(1) |
| } |  |  |

**D.1.33.3 Sphere rotation SEI message syntax**

|  |  |  |
| --- | --- | --- |
| sphere\_rotation( payloadSize ) { | **C** | **Descriptor** |
| **sphere\_rotation\_cancel\_flag** | 5 | u(1) |
| if( !sphere\_rotation\_cancel\_flag ) { |  |  |
| **sphere\_rotation\_persistence\_flag** | 5 | u(1) |
| **sphere\_rotation\_reserved\_zero\_6bits** | 5 | u(6) |
| **yaw\_rotation** | 5 | i(32) |
| **pitch\_rotation** | 5 | i(32) |
| **roll\_rotation** | 5 | i(32) |
| } |  |  |
| } |  |  |

**D.1.33.4 Region-wise packing SEI message syntax**

|  |  |  |
| --- | --- | --- |
| regionwise\_packing( payloadSize ) { | **C** | **Descriptor** |
| **rwp\_cancel\_flag** | 5 | u(1) |
| if( !rwp\_cancel\_flag ) { |  |  |
| **rwp\_persistence\_flag** | 5 | u(1) |
| **constituent\_picture\_matching\_flag** | 5 | u(1) |
| **rwp\_reserved\_zero\_5bits** | 5 | u(5) |
| **num\_packed\_regions** | 5 | u(8) |
| **proj\_picture\_width** | 5 | u(32) |
| **proj\_picture\_height** | 5 | u(32) |
| **packed\_picture\_width** | 5 | u(16) |
| **packed\_picture\_height** | 5 | u(16) |
| for( i = 0; i < num\_packed\_regions; i++ ) { |  |  |
| **rwp\_reserved\_zero\_4bits**[ i ] | 5 | u(4) |
| **transform\_type**[ i ] | 5 | u(3) |
| **guard\_band\_flag**[ i ] | 5 | u(1) |
| **proj\_region\_width**[ i ] | 5 | u(32) |
| **proj\_region\_height**[ i ] | 5 | u(32) |
| **proj\_region\_top**[ i ] | 5 | u(32) |
| **proj\_region\_left**[ i ] | 5 | u(32) |
| **packed\_region\_width**[ i ] | 5 | u(16) |
| **packed\_region\_height**[ i ] | 5 | u(16) |
| **packed\_region\_top**[ i ] | 5 | u(16) |
| **packed\_region\_left**[ i ] | 5 | u(16) |
| if( guard\_band\_flag[ i ] ) { |  |  |
| **left\_gb\_width**[ i ] | 5 | u(8) |
| **right\_gb\_width**[ i ] | 5 | u(8) |
| **top\_gb\_height**[ i ] | 5 | u(8) |
| **bottom\_gb\_height**[ i ] | 5 | u(8) |
| **gb\_not\_used\_for\_pred\_flag**[ i ] | 5 | u(1) |
| for( j = 0; j < 4; j++ ) |  |  |
| **gb\_type**[ i ][ j ] | 5 | u(3) |
| **rwp\_gb\_reserved\_zero\_3bits**[ i ] | 5 | u(3) |
| } |  |  |
| } |  |  |
| } |  |  |
| } |  |  |

**D.1.33.5 Omnidirectional viewport SEI message syntax**

|  |  |  |
| --- | --- | --- |
| omni\_viewport( payloadSize ) { | **C** | **Descriptor** |
| **omni\_viewport\_id** | 5 | u(10) |
| **omni\_viewport\_cancel\_flag** | 5 | u(1) |
| if( !omni\_viewport\_cancel\_flag ) { |  |  |
| **omni\_viewport\_persistence\_flag** | 5 | u(1) |
| **omni\_viewport\_cnt\_minus1** | 5 | u(4) |
| for( i = 0; i  <=  omni\_viewport\_cnt\_minus1; i++ ) { |  |  |
| **omni\_viewport\_azimuth\_centre**[ i ] | 5 | i(32) |
| **omni\_viewport\_elevation\_centre**[ i ] | 5 | i(32) |
| **omni\_viewport\_tilt\_centre**[ i ] | 5 | i(32) |
| **omni\_viewport\_hor\_range**[ i ] | 5 | u(32) |
| **omni\_viewport\_ver\_range**[ i ] | 5 | u(32) |
| } |  |  |
| } |  |  |
| } |  |  |

**D.1.34 SEI manifest SEI message syntax**

[Ed. (YK): The syntax will be aligned with the syntax of the corresponding SEI message for HEVC, currently specified in clause D.2.45 of JCTVC-AD1005. The intent is to include the syntax herein after the HEVC amendment becomes more mature.]

**D.1.35 SEI prefix indication SEI message syntax**

[Ed. (YK): The syntax will be aligned with the syntax of the corresponding SEI message for HEVC, currently specified in clause D.2.46 of JCTVC-AD1005. The intent is to include the syntax herein after the HEVC amendment becomes more mature.]

*In the end of D.2.1, add the following paragraph:*

The values of some SEI message syntax elements, including pan\_scan\_rect\_id, scene\_id, second\_scene\_id, snapshot\_id, progressive\_refinement\_id, tone\_map\_id, frame\_packing\_arrangement\_id, and colour\_remap\_id, are split into two sets of value ranges, where the first set is specified as "may be used as determined by the application", and the second set is specified as "reserved for future use by ITU-T | ISO/IEC". Applications should be cautious of potential “collisions” of the interpretation for values of these syntax elements belonging to the first set of value ranges. Since different applications might use these IDs having values in the first set of value ranges for different purposes, particular care should be exercised in the design of encoders that generate SEI messages with these IDs having values in the first set of value ranges, and in the design of decoders that interpret SEI messages with these IDs. This Specification does not define any management for these values. These IDs having values in the first set of value ranges might only be suitable for use in contexts in which "collisions" of usage (i.e., different definitions of the syntax and semantics of an SEI message with one of these IDs having the same value in the first set of value ranges) are unimportant, or not possible, or are managed – e.g., defined or managed in the controlling application or transport specification, or by controlling the environment in which bitstreams are distributed.

*In D.2.4 (Pan-scan rectangle SEI message semantics), replace the following:*

Values of pan\_scan\_rect\_id from 0 to 255 and from 512 to 231 − 1 may be used as determined by the application. Values of pan\_scan\_rect\_id from 256 to 511 and from 231 to 232 − 2 are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of pan\_scan\_rect\_id in the range of 256 to 511 or in the range of 231 to 232 − 2 shall ignore (remove from the bitstream and discard) it.

*with the following:*

Values of pan\_scan\_rect\_id from 0 to 255, inclusive, and from 512 to 231 − 1, inclusive, may be used as determined by the application. Values of pan\_scan\_rect\_id from 256 to 511, inclusive, and from 231 to 232 − 2, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of pan\_scan\_rect\_id in the range of 256 to 511, inclusive, or in the range of 231 to 232 − 2, inclusive, shall ignore it.

*In D.2.25 (Tone mapping information SEI message semantics), replace the following paragraph:*

Values of tone\_map\_id from 0 to 255 and from 512 to 231 − 1 may be used as determined by the application. Values of tone\_map\_id from 256 to 511 and from 231 to 232 − 2 are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore (remove from the bitstream and discard) all tone mapping information SEI messages containing a value of tone\_map\_id in the range of 256 to 511 or in the range of 231 to 232 − 2, and bitstreams shall not contain such values.

*with the following:*

Values of tone\_map\_id from 0 to 255, inclusive, and from 512 to 231 − 1, inclusive, may be used as determined by the application. Values of tone\_map\_id from 256 to 511, inclusive, and from 231 to 232 − 2, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of tone\_map\_id in the range of 256 to 511, inclusive, or in the range of 231 to 232 − 2, inclusive, shall ignore it.

*In D.2.26 (Frame packing arrangement SEI message semantics), replace the following sentence:*

This SEI message informs the decoder that the output cropped decoded picture contains samples of multiple distinct spatially packed constituent frames that are packed into one frame using an indicated frame packing arrangement scheme.

*with the following:*

This SEI message informs the decoder that the output cropped decoded picture contains samples of multiple distinct spatially packed constituent frames that are packed into one frame, or that the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames, using an indicated frame packing arrangement scheme.

*In D.2.26 (Frame packing arrangement SEI message semantics), replace the following paragraph:*

Values of frame\_packing\_arrangement\_id from 0 to 255 and from 512 to 231 − 1 may be used as determined by the application. Values of frame\_packing\_arrangement\_id from 256 to 511 and from 231 to 232 − 2 are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore (remove from the bitstream and discard) all frame packing arrangement SEI messages containing a value of frame\_packing\_arrangement\_id in the range of 256 to 511 or in the range of 231 to 232 − 2, and bitstreams shall not contain such values.

*with the following:*

Values of frame\_packing\_arrangement\_id from 0 to 255, inclusive, and from 512 to 231 − 1, inclusive, may be used as determined by the application. Values of frame\_packing\_arrangement\_id from 256 to 511, inclusive, and from 231 to 232 − 2, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of frame\_packing\_arrangement\_id in the range of 256 to 511, inclusive, or in the range of 231 to 232 − 2, inclusive, shall ignore it.

*In D.2.26 (Frame packing arrangement SEI message semantics), replace Table D.9 with the following:*

|  |  |
| --- | --- |
| **Value** | **Interpretation** |
| 0 | Each component plane of the output cropped decoded picture contains a "checkerboard" based interleaving of corresponding planes of two constituent frames as illustrated in Figure D‑1. |
| 1 | Each component plane of the output cropped decoded picture contains a column based interleaving of corresponding planes of two constituent frames as illustrated in Figure D‑2 and Figure D‑3. |
| 2 | Each component plane of the output cropped decoded picture contains a row based interleaving of corresponding planes of two constituent frames as illustrated in Figure D‑4 and Figure D‑5. |
| 3 | Each component plane of the output cropped decoded picture contains a side-by-side packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D‑6, Figure D‑7, and Figure D‑10. |
| 4 | Each component plane of the output cropped decoded picture contains a top-bottom packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D‑8 and Figure D‑9. |
| 5 | The component planes of the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames as illustrated in Figure D‑11. |
| 6 | The output cropped decoded picture constitutes a complete 2D frame without any frame packing (see NOTE 6). |
| 7 | Each component plane of the output cropped decoded picture contains a tile format packing arrangement of corresponding planes of two constituent frames as illustrated in Figure D‑12. |

*In D.2.29 (Mastering display colour volume SEI message semantics), replace the following:*

The following constraints apply for the presence of mastering display colour volume SEI messages in IDR access units:

– When a mastering display colour volume SEI message is present in any access unit of a coded video sequence and the mastering display colour volume SEI message is not contained within any other SEI message, a mastering display colour volume SEI message that is not contained within any other SEI message shall be present in the IDR access unit that is the first access unit of the coded video sequence.

– When a mastering display colour volume SEI message is present in any access unit of a coded video sequence and the mastering display colour volume SEI message is contained in a scalable nesting SEI message applying to dependency\_id dId, quality\_id qId, and temporal\_id tId, a mastering display colour volume SEI message that is contained in a scalable nesting SEI message applying to dependency\_id equal to dId, quality\_id equal to qId, and temporal\_id equal to tId shall be present in the IDR access unit that is the first access unit of the coded video sequence.

– When a mastering display colour volume SEI message is present in any access unit of a coded video sequence and the mastering display colour volume SEI message is contained in an MVC scalable nesting SEI message applying to view\_id vId and temporal\_id tId, a mastering display colour volume SEI message that is contained in an MVC scalable nesting SEI message applying to view\_id equal to vId and temporal\_id equal to tId shall be present in the IDR access unit that is the first access unit of the coded video sequence.

– When a mastering display colour volume SEI message is present in any access unit of a coded video sequence and the mastering display colour volume SEI message is contained in an MVCD scalable nesting SEI message applying to texture views with view\_id vId and temporal\_id tId, a mastering display colour volume SEI message that is contained in an MVCD scalable nesting SEI message applying to texture views with view\_id equal to vId and temporal\_id equal to tId shall be present in the IDR access unit that is the first access unit of the coded video sequence.

The mastering display colour volume SEI message persists in decoding order from the current access unit until the end of the coded video sequence.

When a mastering display colour volume SEI message is not contained within any other SEI message, it pertains only to VCL NAL units with nal\_unit\_type in the range of 1 to 5, inclusive.

NOTE – When the bitstream is a scalable video bitstream according to Annex ‎G, a mastering display colour volume SEI message that is not contained within any other SEI message applies only to the base layer bitstream. When the bitstream is a multiview video bitstream according to Annex ‎H, a mastering display colour volume SEI message that is not contained within any other SEI message applies only to the base layer bitstream. When the bitstream is a multiview video bitstream with depth according to Annex ‎I or Annex ‎J, a mastering display colour volume SEI message that is not contained within any other SEI message applies only to the base texture view.

The following constraints apply for the content of mastering display colour volume SEI messages:

– All mastering display colour volume SEI messages that apply to the same coded video sequence and are not contained within any other SEI message shall have the same content.

– All mastering display colour volume SEI messages that apply to the same coded video sequence and are contained in a scalable nesting SEI message applying to particular values of dependency\_id, quality\_id, and temporal\_id shall have the same content.

– All mastering display colour volume SEI messages that apply to the same coded video sequence and are contained in an MVC scalable nesting SEI message applying to particular values of view\_id and temporal\_id shall have the same content.

– All mastering display colour volume SEI messages that apply to the same coded video sequence and are contained in an MVCD scalable nesting SEI message applying to texture views with particular values of view\_id and temporal\_id shall have the same content.

*with the following:*

When a mastering display colour volume SEI message is present in any access unit of a coded video sequence, a mastering display colour volume SEI message shall be present in the IDR access unit that is the first access unit of the coded video sequence. All mastering display colour volume SEI messages that apply to the same coded video sequence shall have the same content.

The mastering display colour volume SEI message persists in decoding order from the current access unit until the end of the coded video sequence.

*In D.2.30 (Colour remapping information SEI message semantics), replace the following paragraph:*

Values of colour\_remap\_id from 0 to 255 and from 512 to 231 − 1 may be used as determined by the application. Values of colour\_remap\_id from 256 to 511, inclusive, and from 231 to 232 − 2, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore all colour remapping information SEI messages containing a value of colour\_remap\_id in the range of 256 to 511, inclusive, or in the range of 231 to 232 − 2, inclusive, and bitstreams shall not contain such values.

*with the following:*

Values of colour\_remap\_id from 0 to 255, inclusive, and from 512 to 231 − 1, inclusive, may be used as determined by the application. Values of colour\_remap\_id from 256 to 511, inclusive, and from 231 to 232 − 2, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of colour\_remap\_id in the range of 256 to 511, inclusive, or in the range of 231 to 232 − 2, inclusive, shall ignore it.

*Renumber clause D.2.31 (Alternative transfer characteristics SEI message semantics) and D.2.32 (Reserved SEI message semantics) as D.2.32 and D.2.34, respectively.*

*Add clauses D.2.31 and D.2.33 as follows:*

**D.2.31 Content light level information SEI message semantics**

This SEI message identifies upper bounds for the nominal target brightness light level of the pictures of the coded video sequence.

The information conveyed in this SEI message is intended to be adequate for purposes corresponding to the use of the Consumer Electronics Association 861.3 specification.

The semantics of the content light level information SEI message are defined in relation to the values of samples in a 4:4:4 representation of red, green, and blue colour primary intensities in the linear light domain for the pictures of the coded video sequence, in units of candelas per square metre. However, this SEI message does not, by itself, identify a conversion process for converting the sample values of a decoded picture to the samples in a 4:4:4 representation of red, green, and blue colour primary intensities in the linear light domain for the picture.

NOTE 1 – Other syntax elements, such as colour\_primaries, transfer\_characteristics, matrix\_coeffs, and the chroma resampling filter hint SEI message, when present, may assist in the identification of such a conversion process.

Given the red, green, and blue colour primary intensities in the linear light domain for the location of a luma sample in a corresponding 4:4:4 representation, denoted as ER, EG, and EB, the maximum component intensity is defined as EMax = Max( ER, Max( EG, EB ) ). The light level corresponding to the stimulus is then defined as the CIE 1931 luminance corresponding to equal amplitudes of EMax for all three colour primary intensities for red, green, and blue (with appropriate scaling to reflect the nominal luminance level associated with peak white – e.g., ordinarily scaling to associate peak white with 10 000 candelas per square metre when transfer\_characteristics is equal to 16).

NOTE 2 – Since the maximum value EMax is used in this definition at each sample location, rather than a direct conversion from ER, EG, and EB to the corresponding CIE 1931 luminance, the CIE 1931 luminance at a location may in some cases be less than the indicated light level. This situation would occur, for example, when ER and EG are very small and EB is large, in which case the indicated light level would be much larger than the true CIE 1931 luminance associated with the ( ER, EG, EB ) triplet.

When a content light level information SEI message is present in any access unit of a coded video sequence, a content light level information SEI message shall be present in the IDR access unit that is the first access unit of the coded video sequence. All content light level information SEI messages that apply to the same coded video sequence shall have the same content.

The content light level information SEI message persists in decoding order from the current access unit until the end of the coded video sequence.

**max\_content\_light\_level**, when not equal to 0, indicates an upper bound on the maximum light level among all individual samples in a 4:4:4 representation of red, green, and blue colour primary intensities (in the linear light domain) for the pictures of the coded video sequence, in units of candelas per square metre. When equal to 0, no such upper bound is indicated by max\_content\_light\_level.

**max\_pic\_average\_light\_level**, when not equal to 0, indicates an upper bound on the maximum average light level among the samples in a 4:4:4 representation of red, green, and blue colour primary intensities (in the linear light domain) for any individual picture of the coded video sequence, in units of candelas per square metre. When equal to 0, no such upper bound is indicated by max\_pic\_average\_light\_level.

NOTE 3 – When the visually relevant region does not correspond to the entire cropped decoded picture, such as for "letterbox" encoding of video content with a wide picture aspect ratio within a taller cropped decoded picture, the indicated average should be performed only within the visually relevant region.

**D.2.33 Semantics of omnidirectional video specific SEI messages**

**D.2.33.1 Equirectangular projection SEI message semantics**

The equirectangular projection SEI message provides information to enable remapping (through an equirectangular projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

When an equirectangular projection SEI message is present for any picture of a coded video sequence (CVS), an equirectangular projection SEI message shall be present for the first picture of the CVS and no SEI message indicating a different type of projection shall be present for any picture of the CVS.

When aspect\_ratio\_idc is present and greater than 1 in the active sequence parameter set, there should be no equirectangular projection SEI messages applicable for any picture of the CVS.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

– The value of frame\_packing\_arrangement\_cancel\_flag is equal to 0.

– The value of frame\_packing\_arrangement\_type is equal to 3, 4, or 5.

– The value of quincunx\_sampling\_flag is equal to 0.

– The value of spatial\_flipping\_flag is equal to 0.

– The value of field\_views\_flag is equal to 0.

– The value of frame0\_grid\_position\_x is equal to 0.

– The value of frame0\_grid\_position\_y is equal to 0.

– The value of frame1\_grid\_position\_x is equal to 0.

– The value of frame1\_grid\_position\_y is equal to 0.

When an effectively applicable frame packing arrangement SEI message that applies to the picture is not present, an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore equirectangular projection SEI messages when an effectively applicable frame packing arrangement SEI message that applies to the picture is not present.

**erp\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous equirectangular projection SEI message in output order. erp\_cancel\_flag equal to 0 indicates that equirectangular projection information follows.

**erp\_persistence\_flag** specifies the persistence of the equirectangular projection SEI message.

erp\_persistence\_flag equal to 0 specifies that the equirectangular projection SEI message applies to the current decoded picture only.

Let picA be the current picture. erp\_persistence\_flag equal to 1 specifies that the equirectangular projection SEI message persists in output order until one or more of the following conditions are true:

– A new CVS begins.

– The bitstream ends.

– A picture picB in an access unit containing an equirectangular projection SEI message is output having PicOrderCnt( picB ) greater than PicOrderCnt( picA ).

**erp\_padding\_flag** equal to 1 indicates that the constituent picture contains padded areas for which the sizes are specified by the syntax elements left\_gb\_erp\_width and right\_gb\_erp\_width. erp\_padding\_flag equal to 0 indicates that the constituent picture does not contains padded areas for which the sizes are specified by the syntax elements left\_gb\_erp\_width and right\_gb\_erp\_width.

**erp**\_**reserved\_zero\_2bits** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for erp\_reserved\_zero\_2bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of erp\_reserved\_zero\_2bits.

**gb\_erp\_type** specifies the type of the guard bands as follows:

– gb\_erp\_type equal to 0 specifies that the content of the guard band in relation to the content of the constituent picture is unspecified.

– gb\_erp\_type equal to 1 specifies that the content of the guard band suffices for interpolation of sample values at sub-pel sample fractional locations within the constituent picture.

NOTE – gb\_erp\_type equal to 1 could be used when the boundary samples of a constituent picture have been copied horizontally to the guard band.

– gb\_erp\_type equal to 2 specifies that the content of the guard band represents actual picture content at quality that gradually changes from the picture quality of the constituent picture.

– gb\_erp\_type equal to 3 specifies that the content of the guard bands represents actual picture content at a similar level of quality as the constituent picture.

– gb\_erp\_type values greater than 3 are reserved. Decoders shall ignore the value of gb\_erp\_type when the value is greater than 3.

**left\_gb\_erp\_width** specifies the width of the guard band on the left side of the constituent picture in units of luma samples. When erp\_padding\_flag is equal to 0, the value of left\_gb\_erp\_width is inferred to be equal to 0. When the decoded picture has 4:2:0 or 4:2:2 chroma format, left\_gb\_erp\_width shall be an even number.

**right\_gb\_erp\_width** specifies the width of the guard band on the right side of the constituent picture in units of luma samples. When erp\_padding\_flag is equal to 0, the value of right\_gb\_erp\_width is inferred to be equal to 0. When the decoded picture has 4:2:0 or 4:2:2 chroma format, right\_gb\_erp\_width shall be an even number.

**D.2.33.2 Cubemap projection SEI message semantics**

The cubemap projection SEI message provides information to enable remapping (through a cubemap projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

When a cubemap projection SEI message is present for any picture of a coded video sequence (CVS), a cubemap projection SEI message shall be present for the first picture of the CVS and no SEI message indicating a different type of projection shall be present for any picture.

When aspect\_ratio\_idc is present and greater than 1 in the active sequence parameter set, there should be no cubemap projection SEI messages applicable for any picture of the CVS.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

– The value of frame\_packing\_arrangement\_cancel\_flag is equal to 0.

– The value of frame\_packing\_arrangement\_type is equal to 3, 4, or 5.

– The value of quincunx\_sampling\_flag is equal to 0.

– The value of spatial\_flipping\_flag is equal to 0.

– The value of field\_views\_flag is equal to 0.

– The value of frame0\_grid\_position\_x is equal to 0.

– The value of frame0\_grid\_position\_y is equal to 0.

– The value of frame1\_grid\_position\_x is equal to 0.

– The value of frame1\_grid\_position\_y is equal to 0.

When an effectively applicable frame packing arrangement SEI message that applies to the picture is not present, a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore cubemap projection SEI messages when an effectively applicable frame packing arrangement SEI message that applies to the picture is not present.

**cmp\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous cubemap projection SEI message in output order. cmp\_cancel\_flag equal to 0 indicates that cubemap projection information follows.

**cmp\_persistence\_flag** specifies the persistence of the cubemap projection SEI message.

cmp\_persistence\_flag equal to 0 specifies that the cubemap projection SEI message applies to the current decoded picture only.

Let picA be the current picture. cmp\_persistence\_flag equal to 1 specifies that the cubemap projection SEI message persists in output order until one or more of the following conditions are true:

– A new CVS begins.

– The bitstream ends.

– A picture picB in an access unit containing a cubemap projection SEI message is output having PicOrderCnt( picB ) greater than PicOrderCnt( picA ).

**D.2.33.3 Sphere rotation SEI message semantics**

The sphere rotation SEI message provides information on rotation angles yaw (α), pitch (β), and roll (γ) that are used for conversion between the global coordinate axes and the local coordinate axes.

Relative to an (x, y, z) Cartesian coordinate system, yaw expresses a rotation around the z (vertical, up) axis, pitch rotates around the y (lateral, side-to-side) axis, and roll rotates around the x (back-to-front) axis. Rotations are extrinsic, i.e., around x, y, and z fixed reference axes. The angles increase clockwise when looking from the origin towards the positive end of an axis.

**sphere\_rotation\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous sphere rotation SEI message in output order. sphere\_rotation\_cancel\_flag equal to 0 indicates that sphere rotation information follows.

**sphere\_rotation\_persistence\_flag** specifies the persistence of the sphere rotation SEI message.

sphere\_rotation\_persistence\_flag equal to 0 specifies that the sphere rotation SEI message applies to the current decoded picture only.

Let picA be the current picture. sphere\_rotation\_persistence\_flag equal to 1 specifies that the sphere rotation SEI message persists in output order until one or more of the following conditions are true:

– A new coded video sequence (CVS) begins.

– The bitstream ends.

– A picture picB in an access unit containing a sphere rotation SEI message is output having PicOrderCnt( picB ) greater than PicOrderCnt( picA ).

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 is not present in the CVS that applies to the current picture and precedes the sphere rotation SEI message in decoding order, a sphere rotation SEI message with sphere\_rotation\_cancel\_flag equal to 0 shall not be present in the CVS that applies to the current picture. Decoders shall ignore sphere rotation SEI messages with sphere\_rotation\_cancel\_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 in the CVS that applies to the current picture.

**sphere\_rotation\_reserved\_zero\_6bits** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for sphere\_rotation\_reserved\_zero\_6bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of sphere\_rotation\_reserved\_zero\_6bits.

**yaw\_rotation** specifies the value of the yaw rotation angle, in units of 2−16 degrees. The value of yaw\_rotation shall be in the range of −180 \* 216 (i.e., −11 796 480) to 180 \* 216 − 1 (i.e., 11 796 479), inclusive. When not present, the value of yaw\_rotation is inferred to be equal to 0.

**pitch\_rotation** specifies the value of the pitch rotation angle, in units of 2−16 degrees. The value of pitch\_rotation shall be in the range of −90 \* 216 (i.e., −5 898 240) to 90 \* 216 (i.e., 5 898 240), inclusive. When not present, the value of pitch\_rotation is inferred to be equal to 0.

**roll\_rotation** specifies the value of the roll rotation angle, in units of 2−16 degrees. The value of roll\_rotation shall be in the range of −180 \* 216 (i.e., −11 796 480) to 180 \* 216 − 1 (i.e., 11 796 479), inclusive. When not present, the value of roll\_rotation is inferred to be equal to 0.

**D.2.33.4 Region-wise packing SEI message semantics**

The region-wise packing SEI message provides information to enable remapping of the colour samples of the cropped decoded pictures onto projected pictures as well as information on the location and size of the guard bands, if any.

**rwp\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous region-wise packing SEI message in output order. rwp\_cancel\_flag equal to 0 indicates that region-wise packing information follows.

**rwp\_persistence\_flag** specifies the persistence of the region-wise packing SEI message.

rwp\_persistence\_flag equal to 0 specifies that the region-wise packing SEI message applies to the current decoded picture only.

Let picA be the current picture. rwp\_persistence\_flag equal to 1 specifies that the region-wise packing SEI message persists in output order until one or more of the following conditions are true:

– A new coded video sequence (CVS) begins.

– The bitstream ends.

– A picture picB in an access unit containing a region-wise packing SEI message is output having PicOrderCnt( picB ) greater than PicOrderCnt( picA ).

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 and erp\_padding\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 is not present in the CVS that applies to the current picture and precedes the region-wise packing SEI message in decoding order, a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 shall not be present in the CVS that applies to the current picture. Decoders shall ignore region-wise packing SEI messages with rwp\_cancel\_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 in the CVS that applies to the current picture.

For the frame packing arrangement scheme indicated by a frame packing arrangement SEI message that applies to the current picture, if a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 is present that applies to the current picture, the frame packing arrangement scheme applies to the projected picture, otherwise, the frame packing arrangement scheme applies to the cropped decoded picture.

If a frame packing arrangement SEI message with frame\_packing\_arrangement\_cancel\_flag equal to 0, frame\_packing\_arrangement\_type equal to 3, 4, or 5, and quincunx\_sampling\_flag equal to 0 is not present that applies to the current picture, the variables StereoFlag, TopBottomFlag, SideBySideFlag, and TempInterleavingFlag are all set equal to 0, the variables HorDiv1 and VerDiv1 are both set equal to 1. Otherwise the following applies:

– StereoFlag is equal to 1.

– When the frame\_packing\_arrangement\_type is equal to 3, SideBySideFlag is set equal to 1, TopBottomFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

– When the frame\_packing\_arrangement\_type is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 1 and VerDiv1 is set equal to 2.

– When the frame\_packing\_arrangement\_type is equal to 5, TempInterleavingFlag is set equal to 1, TopBottomFlag and SideBySideFlag are both set equal to 0, HorDiv1 and VerDiv1 are both set equal to 1.

**constituent\_picture\_matching\_flag** equal to 1 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply individually to each constituent picture and that the packed picture and the projected picture have the same stereoscopic frame packing format indicated by the frame packing arrangement SEI message. constituent\_picture\_matching\_flag equal to 0 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply to the projected picture.

When either of the following two conditions is true, the value of constituent\_picture\_matching\_flag shall be equal to 0:

– StereoFlag is equal to 0.

– StereoFlag is equal to 1 and frame\_packing\_arrangement\_type is equal to 5.

**rwp\_reserved\_zero\_5bits** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp\_reserved\_zero\_56bits[ i ] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp\_reserved\_zero\_5bits[ i ].

**num\_packed\_regions** specifies the number of packed regions when constituent\_picture\_matching\_flag is equal to 0. The value of num\_packed\_regions shall be greater than 0. When constituent\_picture\_matching\_flag is equal to 1, the total number of packed regions is equal to num\_packed\_regions \* 2, and the information in each entry of the loop of num\_packed\_regions entries applies to each constituent picture of the projected picture and the packed picture.

**proj\_picture\_width** and **proj\_picture\_height** specify the width and height, respectively, of the projected picture, in relative projected picture sample units.

The values of proj\_picture\_width and proj\_picture\_height shall both be greater than 0.

**packed\_picture\_width** and **packed\_picture\_height** specify the width and height, respectively, of the packed picture, in relative packed picture sample units.

The values of packed\_picture\_width and packed\_picture\_height shall both be greater than 0.

It is a requirement of bitstream conformance that packed\_picture\_width and packed\_picture\_height shall have such values that packed\_picture\_width is an integer multiple of cropPicWidth and packed\_picture\_height is an integer multiple of cropPicHeight, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture.

**rwp\_reserved\_zero\_4bits**[ i ] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp\_reserved\_zero\_4bits[ i ] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp\_reserved\_zero\_4bits[ i ].

**transform\_type**[ i ] specifies the rotation and mirroring to be applied to the i-th packed region to remap to the i-th projected region. When transform\_type[ i ] specifies both rotation and mirroring, rotation applies before mirroring. The values of transform\_type[ i ] are specified in Table D.X:

Table D.X – transform\_type[ i ] values

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0 | no transform |
| 1 | mirroring horizontally |
| 2 | rotation by 180 degrees (anticlockwise) |
| 3 | rotation by 180 degrees (anticlockwise) before mirroring horizontally |
| 4 | rotation by 90 degrees (anticlockwise) before mirroring horizontally |
| 5 | rotation by 90 degrees (anticlockwise) |
| 6 | rotation by 270 degrees (anticlockwise) before mirroring horizontally |
| 7 | rotation by 270 degrees (anticlockwise) |

**guard\_band\_flag**[ i ] equal to 0 specifies that the i-th packed region does not have a guard band. guard\_band\_flag[ i ] equal to 1 specifies that the i-th packed region has a guard band.

**proj\_region\_width**[ i ], **proj\_region\_height**[ i ], **proj\_region\_top**[ i ] and **proj\_region\_left**[ i ] specify the width, height, top sample row, and the left-most sample column, respectively, of the i-th projected region, either within the projected picture (when constituent\_picture\_matching\_flag is equal to 0) or within the constituent picture of the projected picture (when constituent\_picture\_matching\_flag is equal to 1).

proj\_region\_width[ i ], proj\_region\_height[ i ], proj\_region\_top[ i ], and proj\_region\_left[ i ] are indicated in relative projected picture sample units.

NOTE 1 – Two projected regions may partially or entirely overlap with each other.

**packed\_region\_width**[ i ], **packed\_region\_height**[ i ], **packed\_region\_top**[ i ], and **packed\_region\_left**[ i ] specify the width, height, the top luma sample row, and the left-most luma sample column, respectively, of the packed region, either within the region-wise packed picture (when constituent\_picture\_matching\_flag is equal to 0) or within each constituent picture of the region-wise packed picture (when constituent\_picture\_matching\_flag is equal to 1).

packed\_region\_width[ i ], packed\_region\_height[ i ], packed\_region\_top[ i ], and packed\_region\_left[ i ] are indicated in relative region-wise packed picture sample units. packed\_region\_width[ i ], packed\_region\_height[ i ], packed\_region\_top[ i ], and packed\_region\_left[ i ] shall represent integer horizontal and vertical coordinates of luma sample units within the cropped decoded pictures.

NOTE 2 – Two packed regions may partially or entirely overlap with each other.

**left\_gb\_width**[ i ] specifies the width of the guard band on the left side of the i-th packed region in relative region-wise packed picture sample units. When the decoded picture has 4:2:0 or 4:2:2 chroma format, left\_gb\_width[ i ] shall correspond to an even number of luma samples within the cropped decoded picture.

**right\_gb\_width**[ i ] specifies the width of the guard band on the right side of the i-th packed region in relative region-wise packed picture sample units. When the decoded picture has 4:2:0 or 4:2:2 chroma format, right\_gb\_width[ i ] shall correspond to an even number of luma samples within the cropped decoded picture.

**top\_gb\_height**[ i ] specifies the height of the guard band above the i-th packed region in relative region-wise packed picture sample units. When the decoded picture has 4:2:0 chroma format, top\_gb\_height[ i ] shall correspond to an even number of luma samples within the cropped decoded picture.

**bottom\_gb\_height**[ i ] specifies the height of the guard band below the i-th packed region in relative region-wise packed picture sample units. When the decoded picture has 4:2:0 chroma format, bottom\_gb\_height[ i ] shall correspond to an even number of luma samples within the cropped decoded picture.

When guard\_band\_flag[ i ] is equal to 1, left\_gb\_width[ i ], right\_gb\_width[ i ], top\_gb\_height[ i ], or bottom\_gb\_height[ i ] shall be greater than 0.

The i-th packed region as specified by this SEI message shall not overlap with any other packed region specified by the same SEI message or any guard band specified by the same SEI message.

The guard bands associated with the i-th packed region, if any, as specified by this SEI message shall not overlap with any packed region specified by the same SEI message or any other guard bands specified by the same SEI message.

**gb\_not\_used\_for\_pred\_flag**[ i ] equal to 0 specifies that the guard bands may or may not be used in the inter prediction process. gb\_not\_used\_for\_pred\_flag[ i ] equal to 1 specifies that the sample values of the guard bands are not used in the inter prediction process.

NOTE 3 – When gb\_not\_used\_for\_pred\_flag[ i ] is equal to 1, the sample values within guard bands in cropped decoded pictures can be rewritten even if the cropped decoded pictures were used as references for inter prediction of subsequent pictures to be decoded. For example, the content of a packed region can be seamlessly expanded to its guard band with decoded and re-projected samples of another packed region.

**gb\_type**[ i ][ j ] specifies the type of the guard bands for the i-th packed region as follows, with j equal to 0, 1, 2, or 3 indicating that the semantics below apply to the left, right, top, or bottom edge, respectively, of the packed region:

– gb\_type[ i ][ j ] equal to 0 specifies that the content of the guard bands in relation to the content of the packed regions is unspecified. When gb\_not\_used\_for\_pred\_flag[ i ] is equal to 0, gb\_type[ i ][ j ] shall not be equal to 0.

– gb\_type[ i ][ j ] equal to 1 specifies that the content of the guard bands suffices for interpolation of sample values at sub-pel sample fractional locations within the packed region and less than sample outside of the boundary of the packed region.

NOTE 4 – gb\_type[ i ][ j ] equal to 1 can be used when the boundary samples of a packed region have been copied horizontally or vertically to the guard band.

– gb\_type[ i ][ j ] equal to 2 specifies that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at quality that gradually changes from the picture quality of the packed region to that of the spherically adjacent packed region.

– gb\_type[ i ][ j ] equal to 3 specifies that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at the picture quality of the packed region.

– gb\_type[ i ][ j ] values greater than 3 are reserved. Decoders shall ignore the value of gb\_type[ i ][ j ] when the value is greater than 3.

**rwp\_gb\_reserved\_zero\_3bits**[ i ] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp\_gb\_reserved\_zero\_3bits[ i ] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp\_gb\_reserved\_zero\_3bits[ i ].

The variables NumPackedRegions, PackedRegionLeft[ n ], PackedRegionTop[ n ], PackedRegionWidth[ n ], PackedRegionHeight[ n ], ProjRegionLeft[ n ], ProjRegionTop[ n ], ProjRegionWidth[ n ], ProjRegionHeight[ n ], and TrasnformType[ n ] are derived as follows:

* For n in the range of 0 to num\_packed\_regions − 1, inclusive, the following applies:
  + PackedRegionLeft[ n ] is set equal to packed\_region\_left[ n ].
  + PackedRegionTop[ n ] is set equal to packed\_region\_top[ n ].
  + PackedRegionWidth[ n ] is set equal to packed\_region\_width[ n ].
  + PackedRegionHeight[ n ] is set equal to packed\_region\_height[ n ].
  + ProjRegionLeft[ n ] is set equal to proj\_region\_left[ n ].
  + ProjRegionTop[ n ] is set equal to proj\_region\_top[ n ].
  + ProjRegionWidth[ n ] is set equal to proj\_region\_width[ n ].
  + ProjRegionHeight[ n ] is set equal to proj\_region\_height[ n ].
  + TransformType[ n ] is set equal to transform\_type[ n ].
* If constituent\_picture\_matching\_flag is equal to 0, the following applies:
  + NumPackedRegions is set equal to num\_packed\_regions.
* Otherwise (constituent\_picture\_matching\_flag is equal to 1), the following applies:
  + NumPackedRegions is set equal to 2 \* num\_packed\_regions.
  + When TopBottomFlag is equal to 1, the following applies:
  + projLeftOffset and packedLeftOffset are both set equal to 0.
  + projTopOffset is set equal to proj\_picture\_height / 2 and packedTopOffset is set equal to packed\_picture\_height / 2.
  + When SideBySideFlag is equal to 1, the following applies:
  + projLeftOffset is set equal to proj\_picture\_width / 2 and packedLeftOffset is set equal to packed\_picture\_width / 2.
  + projTopOffset and packedTopOffset are both set equal to 0.
  + For n in the range of NumPackedRegions / 2 to NumPackedRegions − 1, inclusive, the following applies:
    - nIdx is set equal to n – NumPackedRegions / 2.
    - PackedRegionLeft[ n ] is set equal to packed\_region\_left[ nIdx ] + packedLeftOffset.
    - PackedRegionTop[ n ] is set equal to packed\_region\_top[ nIdx ] + packedTopOffset.
    - PackedRegionWidth[ n ] is set equal to packed\_region\_width[ nIdx ].
    - PackedRegionHeight[ n ] is set equal to packed\_region\_height[ nIdx ].
    - ProjRegionLeft[ n ] is set equal to proj\_region\_left[ nIdx ] + projLeftOffset.
    - ProjRegionTop[ n ] is set equal to proj\_region\_top[ nIdx ] + projTopOffset.
    - ProjRegionWidth[ n ] is set equal to proj\_region\_width[ nIdx ].
    - ProjRegionHeight[ n ] is set equal to proj\_region\_height[ nIdx ].
    - TransformType[ n ] is set equal to transform\_type[ nIdx ].

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of ProjRegionWidth[ n ], ProjRegionHeight[ n ], ProjRegionTop[ n ], and ProjRegionLeft[ n ] are constrained as follows:

* ProjRegionWidth[ n ] shall be in the range of 1 to proj\_picture\_width, inclusive.
* ProjRegionHeight[ n ] shall be in the range of 1 to proj\_picture\_height, inclusive.
* ProjRegionLeft[ n ] shall be in the range of 0 to proj\_picture\_width − 1, inclusive.
* ProjRegionTop[ n ] shall be in the range of 0 to proj\_picture\_height − 1, inclusive.
* If ProjRegionTop[ n ] is less than proj\_picture\_height / VerDiv1, the sum of ProjRegionTop[ n ] and ProjRegionHeight[ n ] shall be less than or equal to proj\_picture\_height / VerDiv1. Otherwise, the sum of ProjRegionTop[ n ] and ProjRegionHeight[ n ] shall be less than or equal to proj\_picture\_height / VerDiv1 \* 2.

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of PackedRegionWidth[ n ], PackedRegionHeight[ n ], PackedRegionTop[ n ], and PackedRegionLeft[ n ] are constrained as follows:

* PackedRegionWidth[ n ] shall be in the range of 1 to packed\_picture\_width, inclusive.
* ProjRegionHeight[ n ] shall be in the range of 1 to packed\_picture\_height, inclusive.
* PackedRegionLeft[ n ] shall be in the range of 0 to packed\_picture\_width − 1, inclusive.
* PackedRegionTop[ n ] shall be in the range of 0 to packed\_picture\_height − 1, inclusive.
* If PackedRegionLeft[ n ] is less than packed\_picture\_width / HorDiv1, the sum of PackedRegionLeft[ n ] and PackedRegionWidth[ n ] shall be less than or equal to packed\_picture\_width / HorDiv1. Otherwise, the sum of PackedRegionLeft[ n ] and PackedRegionWidth[ n ] shall be less than or equal to packed\_picture\_width / HorDiv1 \* 2.
* If PackedRegionTop[ n ] is less than packed\_picture\_height / VerDiv1, the sum of PackedRegionTop[ n ] and PackedRegionHeight[ n ] shall be less than or equal to packed\_picture\_height / VerDiv1. Otherwise, the sum of PackedRegionTop[ n ] and PackedRegionHeight[ n ] shall be less than or equal to packed\_picture\_height / VerDiv1 \* 2.
* When the decoded picture has 4:2:0 or 4:2:2 chroma format, PackedRegionLeft[ n ] shall correspond to an even horizontal coordinate value of luma sample units, and PackedRegionWidth[ n ] shall correspond to an even number of luma samples, both within the decoded picture.
* When the decoded picture has 4:2:0 chroma format, PackedRegionTop[ n ] shall correspond to an even vertical coordinate value of luma sample units, and ProjRegionHeight[ n ] shall correspond to an even number of luma samples, both within the decoded picture.

**D.2.33.5** **Omnidirectional viewport SEI message semantics**

The omnidirectional viewport SEI message specifies the coordinates of one or more regions of spherical-coordinate geometry, bounded by four great circles, corresponding to viewports recommended for display when the user does not have control of the viewing orientation or has released control of the viewing orientation.

When an effectively applicable frame packing arrangement SEI message, as specified in clause D.2.33.1 or D.2.33.2, that applies to the picture is present, the information indicated by the omnidirectional viewport SEI message applies to both views.

**omni\_viewport\_id** contains an identifying number that may be used to identify the purpose of the one or more recommended viewport regions.

omni\_viewport\_id equal to 0 indicates that the recommended viewports are per "director’s cut", i.e., a viewport suggested according to the creative intent of the content author or content provider. omni\_viewport\_id equal to 1 indicates that the recommended viewports are selected based on measurements of viewing statistics.

Values of omni\_viewport\_id from 2 to 511, inclusive, may be used as determined by the application. Values of omni\_viewport\_id from 512 to 1023 are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of omni\_viewport\_id in the range of 512 to 1023, inclusive, shall ignore it.

**omni\_viewport\_cancel\_flag** equal to 1 indicates that the SEI message cancels the persistence of any previous omnidirectional viewport SEI message in output order. omni\_viewport\_cancel\_flag equal to 0 indicates that omnidirectional viewport information follows.

**omni\_viewport\_persistence\_flag** specifies the persistence of the omnidirectional viewport SEI message.

omni\_viewport\_persistence\_flag equal to 0 specifies that the omnidirectional viewport SEI message applies to the current decoded picture only.

Let picA be the current picture. omni\_viewport\_persistence\_flag equal to 1 specifies that the omnidirectional viewport SEI message persists in output order until one or more of the following conditions are true:

– A new coded video sequence (CVS) begins.

– The bitstream ends.

– A picture picB in an access unit containing an omnidirectional viewport SEI message is output having PicOrderCnt( picB ) greater than PicOrderCnt( picA ).

When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 is not present in the CVS that applies to the current picture and precedes the omnidirectional viewport SEI message in decoding order, an omnidirectional viewport SEI message with omni\_viewport\_cancel\_flag equal to 0 shall not be present in the CVS that applies to the current picture. Decoders shall ignore omnidirectional viewport SEI messages with omni\_viewport\_cancel\_flag equal to 0 that do not follow, in decoding order, an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 or a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 in the CVS that applies to the current picture.

**omni\_viewport\_cnt\_minus1** plus 1 specifies the number of recommended viewport regions that are indicated by the SEI message.

When omni\_viewport\_cnt\_minus1 is greater than 0 and there is no information provided by external means not specified in this Specification on which recommended viewport is suggested to be displayed, the following applies:

* When omni\_viewport\_id is equal to 0 or 1, the 0-th recommended viewport is suggested to be displayed when the user does not have control of the viewing orientation or has released control of the viewing orientation.
* When omni\_viewport\_id is equal to 0, between any two recommended viewports per director's cut, the i-th recommended viewport has higher priority than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th recommended viewport per director's cut has the highest priority.
* When omni\_viewport\_id is equal to 1, between any two recommended viewports, the i-th recommended viewport has higher popularity, among some selection of candidate viewports, than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th most-viewed recommended viewport has the highest popularity. The selection of the candidate viewports is outside the scope of this Specification.

**omni\_viewport\_azimuth\_centre**[ i ] and **omni\_viewport\_elevation\_centre**[ i ] indicate the centre of the i-th recommended viewport region, in units of 2−16 degrees relative to the global coordinate axes. The value of omni\_viewport\_azimuth\_centre[ i ] shall be in the range of −180 \* 216 (i.e., −11 796 480) to 180 \* 216 − 1 (i.e., 11 796 479), inclusive. The value of omni\_viewport\_elevation\_centre[ i ] shall be in the range of −90 \* 216 (i.e., −5 898 240) to 90 \* 216 (i.e., 5 898 240), inclusive.

**omni\_viewport\_tilt\_centre**[ i ] indicates the tilt angle of the i-th recommended viewport region, in units of 2−16 degrees. The value of omni\_viewport\_tilt\_centre[ i ] shall be in the range of −180 \* 216 (i.e., −11 796 480) to  216 − 1 (i.e., 11 796 479), inclusive.

**omni\_viewport\_hor\_range**[ i ] indicates the azimuth range of the i-th recommended viewport region, in units of 2−16 degrees. The value of omni\_viewport\_hor\_range[ i ] shall be in the range of 1 to 360 \* 216 (i.e., 23 592 960), inclusive.

**omni\_viewport\_ver\_range**[ i ] indicates the elevation range of the i-th recommended viewport region, in units of 2−16 degrees. The value of omni\_viewport\_ver\_range[ i ] shall be in the range of 1 to 180 \* 216 (i.e., 11 796 480), inclusive.

**D.2.33.6 Sample location remapping process**

***D.2.33.6.1 General***

To remap colour sample locations of a region-wise packed picture to a unit sphere, the following ordered steps are applied:

– A region-wise packed picture is obtained as the cropped decoded picture by decoding a coded picture. For purposes of interpretation of chroma samples, the input to the indicated remapping process is the set of decoded sample values after applying an (unspecified) upsampling conversion process to the 4:4:4 colour sampling format as necessary when chroma\_format\_idc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format). This (unspecified) upsampling process should account for the relative positioning relationship between the luma and chroma samples as indicated by chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field, when present.

– If region-wise packing is indicated, the sample locations of the region-wise packed picture are converted to sample locations of the respective projected picture as specified in clause D.2.33.6.4. Otherwise, the projected picture is identical to the region-wise packed picture.

– If frame packing is indicated, the sample locations of the projected picture are converted to sample locations of the respective constituent picture of the projected picture, as specified in clause D.2.33.6.6. Otherwise, the constituent picture of the projected picture is identical to the projected picture.

– The sample locations of a constituent picture of the projected picture are converted to sphere coordinates relative to the local coordinate axes, as specified in clause D.2.33.6.2.

– If rotation is indicated, the sphere coordinates relative to the local coordinate axes are converted to sphere coordinates relative to the global coordinate axes, as specified in clause D.2.33.6.3. Otherwise, the global coordinate axes are identical to the local coordinate axes.

The overall process for mapping of luma sample locations within a region-wise packed picture to sphere coordinates relative to the global coordinate axes is normatively specified in clause D.2.33.6.5.

For each region-wise packed picture corresponding to a decoded picture, the following applies:

– When an equirectangular projection SEI message with erp\_cancel\_flag equal to 0 that applies to the picture is present, ErpFlag is set equal to 1, and CmpFlag is set equal to 0.

– When a cubemap projection SEI message with cmp\_cancel\_flag equal to 0 that applies to the picture is present, CmpFlag is set equal to 1, and ErpFlag is set equal to 0.

– If a sphere rotation SEI message with sphere\_rotation\_cancel\_flag equal to 0 that applies to the picture is present, RotationFlag is set equal to 1, and RotationYaw, RotationPitch, and RotationRoll are set equal to yaw\_rotation ÷ 216, pitch\_rotation ÷ 216, and roll\_rotation ÷ 216, respectively.

– Otherwise, RotationFlag is set equal to 0.

– If a frame packing arrangement SEI message with frame\_packing\_arrangement\_cancel\_flag equal to 0 that applies to the picture is not present, StereoFlag, TopBottomFlag, and SideBySideFlag are all set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– Otherwise, the following applies:

– StereoFlag is set equal to 1.

– If the value of frame\_packing\_arrangement\_type of the frame packing arrangement SEI message is equal to 3, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 1, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

– Otherwise, if the value of frame\_packing\_arrangement\_type of the frame packing arrangement SEI message is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 2.

– Otherwise, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– If a region-wise packing SEI message with rwp\_cancel\_flag equal to 0 that applies to the picture is not present, RegionWisePackingFlag is set equal to 0, and ConstituentPicWidth and ConstituentPicHeight are set to be equal to cropPicWidth / HorDiv1 and cropPicHeight / VerDiv1, respectively, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture.

– Otherwise, RegionWisePackingFlag is set equal to 1, and ConstituentPicWidth and ConstituentPicHeight are set equal to proj\_picture\_width / HorDiv1 and proj\_picture\_height / VerDiv1, respectively.

***D.2.33.6.2 Projection for a sample location***

Inputs to this clause are:

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units, and

– the centre point of a sample location (hPos, vPos) along the horizontal and vertical axes, respectively, in relative projected picture sample units, where hPos and vPos may have non-integer real values.

Outputs of this clause are:

– sphere coordinates (ϕ, θ) for the sample location in degrees relative to the coordinate axes specified in clause D.2.33.6.1.

The projection for a sample location is derived as follows:

– If ErpFlag is equal to 1, the following applies:

– If RegionWisePackingFlag is equal to 0 and erp\_padding\_flag is equal to 1, the following applies:

hPos′ = hPos − left\_gb\_erp\_width (D‑XX)  
pictureWidth = pictureWidth – left\_gb\_erp\_width – right\_gb\_erp\_width

– Otherwise, the following applies:

hPos′ = hPos (D‑XX)

– The following applies:

ϕ = 180 − hPos′ \* ( 360 ÷ pictureWidth ) (D‑XX)  
θ = 90 − vPos \* ( 180 ÷ pictureHeight )

– Otherwise (CmpFlag is equal to 1), it is a requirement of bitstream conformance that pictureWidth shall be a multiple of 3 and pictureHeight shall be a multiple of 2, and that pictureWidth / 3 shall be equal to pictureHeight / 2, and the following applies:

lw = pictureWidth / 3  
lh = pictureHeight / 2  
w = Floor( hPos ÷ lw )  
h = Floor( vPos ÷ lh )  
tmpHorVal = hPos − w \* lw  
tmpVerVal = vPos − h \* lh  
hPos′ = −( 2 \* tmpHorVal ÷ lw ) + 1  
vPos′ = −( 2 \* tmpVerVal ÷ lh ) + 1  
if( w = = 1 && h = = 0 ) { /\* positive x front face \*/  
 x = 1.0  
 y = hPos′  
 z = vPos′  
} else if( w = = 1 && h = = 1 ) { /\* negative x back face \*/  
 x = −1.0  
 y = −vPos′  
 z = −hPos′  
} else if( w = = 2 && h = = 1 ) { /\* positive z top face \*/ (D‑XX)  
 x = −hPos′  
 y = −vPos′  
 z = 1.0  
} else if( w = = 0 && h = = 1 ) { /\* negative z bottom face \*/  
 x = hPos′  
 y = −vPos′  
 z = −1.0  
} else if( w = = 0 && h = = 0 ) { /\* positive y left face \*/  
 x = −hPos′  
 y = 1.0  
 z = vPos′  
} else { /\* ( w = = 2 && h = = 0 ), negative y right face \*/  
 x = hPos′  
 y = −1.0  
 z = vPos′  
}  
ϕ = Atan2( y, x ) \* 180 ÷ π  
θ =

***D.2.33.6.3 Conversion from the local coordinate axes to the global coordinate axes***

Inputs to this clause are:

– rotation\_yaw (αd), rotation\_pitch (βd), rotation\_roll (γd), all in units of degrees, and

– sphere coordinates (ϕd, θd) relative to the local coordinate axes.

Outputs of this clause are:

– sphere coordinates (ϕ′, θ′) relative to the global coordinate axes.

The outputs are derived as follows:

ϕ = ϕd \* ÷ 180  
θ = θd \* ÷ 180  
α = αd \* ÷ 180  
β = βd \* ÷ 180  
γ = γd \* ÷ 180  
x1 = Cos( ϕ ) \* Cos( θ )  
y1 = Sin( ϕ ) \* Cos( θ )  
z1 = Sin( θ )  
x2 = Cos( β ) \* Cos ( γ ) \* x1 − Cos( β ) \* Sin( γ ) \* y1 + Sin( β ) \* z1 (D‑XX)  
y2 = ( Cos( α ) \* Sin( γ ) + Sin( α ) \* Sin( β ) \* Cos( γ ) ) \* x1 +  
 ( Cos( α ) \* Cos( γ ) − Sin( α ) \* Sin( β ) \* Sin( γ ) ) \* y1 −  
 Sin( α ) \* Cos( β ) \* z1  
z2 = ( Sin( α ) \* Sin( γ ) − Cos( α ) \* Sin( β ) \* Cos( γ ) ) \* x1 +  
 ( Sin( α ) \* Cos( γ ) + Cos( α ) \* Sin( β ) \* Sin( γ ) ) \* y1 +  
 Cos( α ) \* Cos( β ) \* z1  
ϕ′ = Atan2( y2, x2 ) \* 180 ÷ π  
θ′ = Asin( z2 ) \* 180 ÷ π

***D.2.33.6.4 Conversion of sample locations for rectangular region-wise packing***

Inputs to this clause are:

– sample location (x, y) within the packed region, where x and y are in relative packed picture sample units, while the sample location is at an integer sample location within the packed picture,

– the width and the height (projRegWidth, projRegHeight) of the projected region, in relative projected picture sample units,

– the width and the height (packedRegWidth, packedRegHeight) of the packed region, in relative packed picture sample units,

– transform type (transformType), and

– offset values for the sampling position (offsetX, offsetY) in the range of 0, inclusive, to 1, exclusive, in horizontal and vertical relative packed picture sample units, respectively.

NOTE: offsetX and offsetY both equal to 0.5 indicate a sampling position that is in the centre point of a sample in packed picture sample units.

Outputs of this clause are:

– the centre point of the sample location (hPos, vPos) within the projected region in relative projected picture sample units, where hPos and vPos may have non-integer real values.

The outputs are derived as follows:

if( transformType  = =  0  | |  transformType  = =  1  | |  transformType  = =  2  | |  transformType  = =  3 ) {  
 horRatio = projRegWidth ÷ packedRegWidth  
 verRatio = projRegHeight ÷ packedRegHeight  
} else if ( transformType  = =  4  | |  transformType  = =  5  | |  transformType  = =  6  | |  
 transformType  = =  7 ) {  
 horRatio = projRegWidth ÷ packedRegHeight  
 verRatio = projRegHeight ÷ packedRegWidth  
}  
if( transformType = = 0 ) {  
 hPos = horRatio \* ( x + offsetX )  
 vPos = verRatio \* ( y + offsetY )  
} else if ( transformType = = 1 ) {  
 hPos = horRatio \* ( packedRegWidth − x − offsetX )  
 vPos = verRatio \* ( y + offsetY )  
} else if ( transformType = = 2 ) {  
 hPos = horRatio \* ( packedRegWidth − x − offsetX )  
 vPos = verRatio \* ( packedRegHeight − y − offsetY ) (D‑XX)  
} else if ( transformType = = 3 ) {  
 hPos = horRatio \* ( x + offsetX )  
 vPos = verRatio \* ( packedRegHeight − y − offsetY )  
} else if ( transformType = = 4 ) {  
 hPos = horRatio \* ( y + offsetY )  
 vPos = verRatio \* ( x + offsetX )  
} else if ( transformType = = 5 ) {  
 hPos = horRatio \* ( y + offsetY )  
 vPos = verRatio \* ( packedRegWidth − x − offsetX )  
} else if ( transformType = = 6 ) {  
 hPos = horRatio \* ( packedRegHeight − y − offsetY )  
 vPos = verRatio \* ( packedRegWidth − x − offsetX )  
} else if ( transformType = = 7 ) {  
 hPos = horRatio \* ( packedRegHeight − y − offsetY )  
 vPos = verRatio \* ( x+ offsetX )  
}

***D.2.33.6.5 Mapping of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes***

This clause specifies the semantics of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes.

offsetX is set equal to 0.5 and offsetY is set equal to 0.5.

If RegionWisePackingFlag is equal to 1, the following applies for each packed region n in the range of 0 to NumPackedRegions − 1, inclusive:

– For each sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region, the following applies:

– The corresponding sample location (xProjPicture, yProjPicture) of the projected picture is derived as follows:

– x is set equal to xPackedPicture – PackedRegionLeft[ n ].

– y is set equal to yPackedPicture – PackedRegionTop[ n ].

– Clause D.2.33.6.4 is invoked with x, y, PackedRegionWidth[ n ], PackedRegionHeight[ n ], ProjRegionWidth[ n ], ProjRegionHeight[ n ], TransformType[ n ], offsetX and offsetY as inputs, and the output is assigned to sample location (hPos, vPos).

– xProjPicture is set equal to ProjRegionLeft[ n ] + hPos.

– When StereoFlag is equal to 0 or TopBottomFlag is equal to 1, and when xProjPicture is greater than or equal to proj\_picture\_width, xProjPicture is set equal to xProjPicture − proj\_picture\_width.

– When SideBySideFlag is equal to 1, the following applies:

– When ProjRegionLeft[ n ] is less than proj\_picture\_width / 2 and xProjPicture is greater than or equal to proj\_picture\_width / 2, xProjPicture is set equal to xProjPicture − proj\_picture\_width / 2.

– When ProjRegionLeft[ n ] is greater than or equal to proj\_picture\_width / 2 and xProjPicture is greater than or equal to proj\_picture\_width, xProjPicture is set equal to xProjPicture − proj\_picture\_width / 2.

– yProjPicture is set equal to ProjRegionTop[ n ] + vPos.

– Clause D.2.33.6.6 is invoked with xProjPicture, yProjPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the luma sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region in the decoded picture.

Otherwise (RegionWisePackingFlag is equal 0), the following applies for each sample location (x, y) that is not an equirectangular projection padded sample within the cropped decoded picture, where a sample location (x, y) is an equirectangular projection padded sample when and only when ErpFlag is equal to 1, x is in the range of 0 to left\_gb\_erp\_width − 1, inclusive, or ConstituentPicWidth − right\_gb\_erp\_width to ConstituentPicWidth − 1, inclusive, and y is in the range of 0 to ConstituentPicHeight − 1, inclusive:

– xProjPicture is set equal to x + offsetX.

– yProjPicture is set equal to y + offsetY.

– If ErpFlag is equal to 0, projPicWidth is set equal to ConstituentPicWidth. Otherwise (ErpFlag is equal to 1), projPicWidth is set equal to ConstituentPicWidth − ( left\_gb\_erp\_width + right\_gb\_erp\_width ).

– Clause D.2.33.6.6 is invoked with xProjPicture, yProjPicture, projPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the sample location (x, y) within the region-wise packed picture.

***D.2.33.6.6 Conversion from a sample location in a projected picture to sphere coordinates relative to the global coordinate axes***

Inputs to this clause are:

– the centre point of a sample location (xProjPicture, yProjPicture) within a projected picture, where xProjPicture and yProjPicture are in relative projected picture sample units and may have non-integer real values, and

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units.

Outputs of this clause are:

– sphere coordinates (azimuthGlobal, elevationGlobal), in units of degrees relative to the global coordinate axes, and

– when StereoFlag is equal to 1, the index of the constituent picture (constituentPicture) equal to 0 or 1.

The outputs are derived with the following ordered steps:

– If xProjPicture is greater than or equal to pictureWidth or yProjPicture is greater than or equal to pictureHeight, the following applies:

– constituentPicture is set equal to 1.

– If xProjPicture is greater than or equal to pictureWidth, xProjPicture is set to xProjPicture − pictureWidth.

– If yProjPicture is greater than or equal to pictureHeight, yProjPicture is set to yProjPicture − pictureHeight.

– Otherwise, constituentPicture is set equal to 0.

– Clause D.2.33.6.2 is invoked with pictureWidth, pictureHeight, xProjPicture, and yProjPicture as inputs, and the output is assigned to azimuthLocal, elevationLocal.

– If RotationFlag is equal to 1, clause D.2.33.6.3 is invoked with azimuthLocal, elevationLocal, RotationYaw, RotationPitch, and RotationRoll as inputs, and the output is assigned to azimuthGlobal and elevationGlobal.

– Otherwise, azimuthGlobal is set equal to azimuthLocal and elevationGlobal is set equal to elevationLocal.

**D.2.34 SEI manifest SEI message semantics**

[Ed. (YK): The semantics will be aligned with the semantics of the corresponding SEI message for HEVC, currently specified in clause D.3.45 of JCTVC-AD1005. The intent is to include the semantics herein after the HEVC amendment becomes more mature.]

**D.1.35 SEI prefix indication SEI message semantics**

[Ed. (YK): The semantics will be aligned with the semantics of the corresponding SEI message for HEVC, currently specified in clause D.3.46 of JCTVC-AD1005. The intent is to include the semantics herein after the HEVC amendment becomes more mature.]

*In G.13.2 (SEI payload semantics), replace the following:*

The semantics of the SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, are extended as follows:

*with the following:*

The semantics of the SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, which are specified in clause ‎D.2, are extended as follows:

*In G.13.2 (SEI payload semantics), replace the following:*

– Otherwise, if payloadType is equal to 2, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 23, 45, or 47, the following applies:

*with the following:*

– Otherwise, if payloadType is equal to 2, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 23, 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, the following applies:

*In G.13.2 (SEI payload semantics), add the following two paragraphs:*

When an SEI message having a particular value of payloadType equal to 137 or 144, contained in a scalable nesting SEI message, and applying to a particular combination of dependency\_id, quality\_id, and temporal\_id is present in an access unit, the SEI message with the particular value of payloadType applying to the particular combination of dependency\_id, quality\_id, and temporal\_id shall be present a scalable nesting SEI message in the IDR access unit that is the first access unit of the coded video sequence.

All SEI messages having a particular value of payloadType equal to 137 or 144, contained in scalable nesting SEI messages, and applying to a particular combination of dependency\_id, quality\_id, and temporal\_id present in a coded video sequence shall have the same content.

*immediately before the following paragraph:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, SVC sequence parameter set is substituted for sequence parameter set; the parameters of the picture parameter set RBSP and SVC sequence parameter set RBSP that are in effect are specified in clause ‎G.7.4.1.2.1.

*In G.13.2 (SEI payload semantics), replace the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, SVC sequence parameter set is substituted for sequence parameter set; the parameters of the picture parameter set RBSP and SVC sequence parameter set RBSP that are in effect are specified in clause ‎G.7.4.1.2.1.

*with the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, which are specified in clause ‎D.2, SVC sequence parameter set is substituted for sequence parameter set; the parameters of the picture parameter set RBSP and SVC sequence parameter set RBSP that are in effect are specified in clause ‎G.7.4.1.2.1.

*In G.13.2 (SEI payload semantics), replace the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 24 to 35, inclusive, which are specified in clause ‎G.13, it shall not contain any SEI message that has payloadType less than 24 or equal to 45 or 47 that is not included in a scalable nesting SEI message, and the first SEI message in the SEI NAL unit shall have payloadType in the range of 24 to 35, inclusive.

*with the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 24 to 35, inclusive, which are specified in clause ‎G.13, it shall not contain any SEI message that has payloadType less than 24 or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201 that is not included in a scalable nesting SEI message, and the first SEI message in the SEI NAL unit shall have payloadType in the range of 24 to 35, inclusive.

*In H.13.2 (SEI payload semantics), replace the following:*

– If payloadType is equal to 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 23, 45, or 47, the following applies:

*with the following:*

– If payloadType is equal to 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 23, 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, the following applies:

*In H.13.2 (SEI payload semantics), add the following two paragraphs:*

When an SEI message having a particular value of payloadType equal to 137 or 144, contained in an MVC scalable nesting SEI message, and applying to a particular combination of a list of view\_id and a temporal\_id is present in an access unit, the SEI message with the particular value of payloadType applying to the particular combination of a list of view\_id and a temporal\_id shall be present an MVC scalable nesting SEI message in the IDR access unit that is the first access unit of the coded video sequence.

All SEI messages having a particular value of payloadType equal to 137 or 144, contained in MVC scalable nesting SEI messages, and applying to a particular combination of a list of view\_id and a temporal\_id present in a coded video sequence shall have the same content.

*immediately before the following paragraph:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, MVC sequence parameter set is substituted for sequence parameter set; the parameters of MVC sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎H.7.4.2.1 and ‎H.7.4.2.2, respectively.

*In H.13.2 (SEI payload semantics), replace the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, MVC sequence parameter set is substituted for sequence parameter set; the parameters of MVC sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎H.7.4.2.1 and ‎H.7.4.2.2, respectively.

*with the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, which are specified in clause ‎D.2, MVC sequence parameter set is substituted for sequence parameter set; the parameters of MVC sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎H.7.4.2.1 and ‎H.7.4.2.2, respectively.

*In H.13.2 (SEI payload semantics), replace the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 36 to 44, inclusive, or equal to 46, which are specified in clause ‎H.13, it shall not contain any SEI messages with payloadType less than 36 or equal to 45 or 47, and the first SEI message in the SEI NAL unit shall have payloadType in the range of 36 to 44, inclusive, or equal to 46.

*with the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 36 to 44, inclusive, or equal to 46, which are specified in clause ‎H.13, it shall not contain any SEI messages with payloadType less than 36 or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, and the first SEI message in the SEI NAL unit shall have payloadType in the range of 36 to 44, inclusive, or equal to 46.

*In I.13.2 (SEI payload semantics), replace the following:*

– If payloadType is equal to 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 45 or 47, the following applies:

*with the following:*

– If payloadType is equal to 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, the following applies:

*In I.13.2 (SEI payload semantics), add the following two paragraphs:*

When an SEI message having a particular value of payloadType equal to 137 or 144, contained in an MVCD scalable nesting SEI message, and applying to a particular combination of a list of view\_id and a temporal\_id is present in an access unit, the SEI message with the particular value of payloadType applying to the particular combination of a list of view\_id and a temporal\_id shall be present an MVCD scalable nesting SEI message in the IDR access unit that is the first access unit of the coded video sequence.

All SEI messages having a particular value of payloadType equal to 137 or 144, contained in MVCD scalable nesting SEI messages, and applying to a particular combination of a list of view\_id and a temporal\_id present in a coded video sequence shall have the same content.

*immediately before the following paragraph:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, MVCD sequence parameter set is substituted for sequence parameter set; the parameters of MVCD sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎I.7.4.2.1 and ‎I.7.4.2.2, respectively.

*In I.13.2 (SEI payload semantics), replace the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45 or 47, which are specified in clause ‎D.2, MVCD sequence parameter set is substituted for sequence parameter set; the parameters of MVCD sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎I.7.4.2.1 and ‎I.7.4.2.2, respectively.

*with the following:*

For the semantics of SEI messages with payloadType in the range of 0 to 23, inclusive, or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, which are specified in clause ‎D.2, MVCD sequence parameter set is substituted for sequence parameter set; the parameters of MVCD sequence parameter set RBSP and picture parameter set RBSP that are in effect are specified in clauses ‎I.7.4.2.1 and ‎I.7.4.2.2, respectively.

*In I.13.2 (SEI payload semantics), replace the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 36 to 44, inclusive, or equal to 46, or in the range of 48 to 53, inclusive, it shall not contain any SEI messages with payloadType less than 36 and the first SEI message in the SEI NAL unit shall have payloadType in the range of 36 to 44, inclusive, or equal to 46, or in the range of  48 to 53, inclusive.

*with the following:*

When an SEI NAL unit contains an SEI message with payloadType in the range of 36 to 44, inclusive, or equal to 46, or in the range of 48 to 53, inclusive, it shall not contain any SEI messages with payloadType less than 36 or equal to 45, 47, 137, 142, 144, 147, 150, 151, 154, 155, 156, 200, or 201, and the first SEI message in the SEI NAL unit shall have payloadType in the range of 36 to 44, inclusive, or equal to 46, or in the range of 48 to 53, inclusive.

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