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| **Joint Collaborative Team on 3D Video Coding Extensions**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  6th Meeting: Geneva, CH, 25 Oct. – 1 Nov. 2013 | Document: JCT3V-F0025 |

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| --- | --- | --- | --- |
| *Title:* | **CE5 Summary Report: Depth Intra Modes** | | |
| *Status:* | Input Document | | |
| *Purpose:* | Summary Report | | |
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# Abstract

This document summarizes the proposals and cross check results of CE5, including tools under test according to JCT3V-E1106 as well as related input contributions.

# Introduction

In this document a summary of proposals and cross check results for CE5 is reported. The goal of this Core Experiment (CE) is to investigate intra coding tools specifically designed for coding of depth maps for an HEVC-based 3D extension. The proposed tools are evaluated in terms of coding efficiency and computational complexity. The objective of tools under test in CE5 was simplification, harmonization and improvement of existing depth intra modes.

Participants in CE5 are as follows:

|  |  |  |  |  |
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# Recommendation for an Editorial Change

The CE coordinator recommends to rename *Simplified Depth Coding (SDC)* to *Segmental DC Coding (SDC)* to better describe the idea and meaning of the corresponding coding method.

# List of Input Documents

## Tools under Test (3)

|  |  |  |  |
| --- | --- | --- | --- |
| **Participants** | **Doc No.** | **Title** | **Type** |
| Samsung | [JCT3V-F0148](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1486) | Simplified depth coding based on most probable mode | Proposal |
| RWTH Aachen University | [JCT3V-F0154](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1492) | Cross Check of Simplified depth coding based on most probable mode | Cross Check |
| Hisilicon, Tsinghua University | [JCT3V-F0153](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1491) | Test result on simplification of DMM pattern generation and signaling | Proposal |
| Qualcomm | [JCT3V-F0236](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1578) | Crosscheck on simplification of DMM pattern generation and signaling | Cross Check |
| LG Electronics | [JCT3V-F0159](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1497) | Fast depth lookup table application method to intra modes for depth data | Proposal |
| Samsung | [JCT3V-F0207](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1545) | Cross check of fast depth lookup table application method to intra modes for depth data | Cross Check |

## Related Contributions (14)

|  |  |  |  |
| --- | --- | --- | --- |
| **Participants** | **Doc No.** | **Title** | **Type** |
| MediaTek | [JCT3V-F0113](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1450) | Bin reduction for SDC residual coding | Proposal |
| Sharp | [JCT3V-F0210](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1548) | Cross-check of Bin reduction for SDC residual coding | Cross Check |
| MediaTek | [JCT3V-F0117](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1454) | Improvement on SDC | Proposal |
| NTT | [JCT3V-F0251](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1602) | Crosscheck on Improvement on SDC | Cross Check |
| Qualcomm | [JCT3V-F0126](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1463) | Generic SDC for all Intra modes in 3D-HEVC | Proposal |
| HHI | [JCT3V-F0222](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1561) | Cross check of generic SDC for all Intra modes | Cross Check |
| Qualcomm | [JCT3V-F0132](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1469) | Unification of delta DC coding for depth intra modes | Proposal |
| ETRI | [JCT3V-F0235](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1577) | Crosscheck on Unification of delta DC coding for depth intra modes | Cross Check |
| Qualcomm | [JCT3V-F0133](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1470) | Simplification of Wedgelet pattern generation in half-pel accuracy | Proposal |
| Huawei | [JCT3V-F0239](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1583) | Crosscheck of Qualcomm's simplification of Wedgelet pattern generation in half-pel accuracy | Cross Check |
| Qualcomm | [JCT3V-F0134](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1471) | Wedgelet pattern extension from 4x4 block | Proposal |
| HHI | [JCT3V-F0223](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1562) | Cross check of Wedgelet pattern extension from 4x4 block | Cross Check |
| Samsung | [JCT3V-F0147](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1485) | DMM simplification and signalling | Proposal |
| MediaTek | [JCT3V-F0241](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1586) | Cross-check on DMM simplification and signalling | Cross Check |
| Samsung | [JCT3V-F0149](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1487) | Simplified depth inter mode coding | Proposal |
| RWTH Aachen University | [JCT3V-F0155](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1493) | Cross Check of Simplified depth inter mode coding | Cross Check |
| Hisilicon, SCU | [JCT3V-F0157](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1495) | Simplified DC predictor improvement for depth intra modes | Proposal |
| HHI | [JCT3V-F0224](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1563) | Cross check of simplified DC predictor improvement for depth intra modes | Cross Check |
| LG Electronics | [JCT3V-F0158](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1496) | Software bug-fix on all zero residual method in intra-picture | Bug Fix |
| Samsung | [JCT3V-F0226](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1566) | Cross check of Software bug-fix on all zero residual method in intra-picture | Cross Check |
| Zhejiang University | [JCT3V-F0167](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1505) | Results on Using DLT in Intra Modes of Depth Map | Proposal |
| ZTE | [JCT3V-F0254](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1609) | Crosscheck results on using DLT in intra modes of depth map | Cross Check |
| Hisilicon | [JCT3V-F0170](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1508) | Simplification on SDC planar coding | Proposal |
| MediaTek | [JCT3V-F0232](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1574) | Crosscheck for Hisilicon's F0170 on simplification on SDC planar | Cross Check |
| HHI | [JCT3V-F0171](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1509) | Fix for DMM/RBC reference sample filtering | Proposal |
| Qualcomm | [JCT3V-F0204](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1542) | Crosscheck on Fix for DMM/RBC reference sample filtering | Cross Check |
| Hisilicon | [JCT3V-F0201](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1539) | Bug-fix for DLT coding in 3D-HEVC | Bug Fix |
| Zhejiang University | [JCT3V-F0255](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1610) | Cross check of bug-fix for DLT coding in 3D-HEVC | Cross Check |

# Summary of Proposals

## Tools under Test

[**JCT3V-F0148**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1486) **Simplified depth coding based on most probable mode**

The proposed method uses the most probable modes as SDC modes to improve the coding performance, instead of Planar and DMM1 modes.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | -0.1% | -0.2% | 100% | 99% |
| All-Intra | 0.0% | -0.2% | -0.2% | 101% | 100% |

Related Proposals: [**JCT3V-F0117**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1454)and [**JCT3V-F0126**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1463)

[**JCT3V-F0153**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1491) **Simplification of DMM pattern generation and signaling**

The proposed method can simplify the pattern generation process and reduce both, number of patterns and required signaling bits.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | -0.1% | 0.0% | 98% | 97% |
| All-Intra | 0.0% | -0.1% | 0.1% | 96% | 98% |
| CTC  (w/o DMM3) | 0.0% | -0.1% | 0.0% | 95% | 99% |
| All-Intra  (w/o DMM3) | 0.0% | -0.1% | 0.1% | 92% | 96% |

Related Proposals: [**JCT3V-F0133**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1470)and [**JCT3V-F0134**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1471)

[**JCT3V-F0159**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1497) **Fast depth lookup table application method to intra modes for depth data**

This contribution proposes a fast depth lookup table application method in an alternative residual generation method.

Method 1: Applying depth lookup table to 2Nx2N block size  
Method 2: Method 1 + reduction of the number of candidate modes  
Method 3: Applying depth lookup table to particular modes: DMM, RBC, DC, vertical, horizontal

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC (1) | 0.0% | -0.1% | -0.1% | 102% | 100% |
| All-Intra (1) | 0.0% | -0.3% | -0.3% | 110% | 100% |
| CTC (2) | 0.0% | -0.1% | -0.1% | 101% | 100% |
| All-Intra (2) | 0.0% | -0.2% | -0.2% | 107% | 100% |
| CTC (3) | 0.0% | -0.1% | -0.1% | 100% | 100% |
| All-Intra (3) | 0.0% | -0.3% | -0.2% | 100% | 100% |

## Related Proposals

### Category A: Fixes (3)

[**JCT3V-F0158**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1496) **- Software bug-fix on all zero residual method in intra-picture**

All zero residual method [1] proposed to perform rate distortion optimization (RDO) selection between non-zero residual and all-zero residual in intra mode coding, and it is only applied to inter-picture of depth. However all zero residual method is only applied to intra-picture of depth in the current 3D-HEVC reference software version 8.1 as well as 8.0.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.1% | 0.0% | 98% | 93% |
| All-Intra | 0.0% | 0.4% | 0.3% | 76% | 98% |

[**JCT3V-F0171**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1509) **Fix for DMM/RBC reference sample filtering**

This contribution proposes aligning the 3D-HEVC specification and fixing the 3D-HTM software in terms of using the unfiltered reference samples for segment DC value prediction of DMM and RBC.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.0% | 0.0% | 100% | 102% |
| All-Intra | 0.0% | 0.0% | 0.0% | 99% | 101% |

[**JCT3V-F0201**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1539) **Bug-fix for DLT coding in 3D-HEVC**

DLT is currently not used when SDC and DMM are turned off. It is proposed to disable construction and coding of the mapping list table when SDC and DMM are turned off.

Results are non-CTC.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.0% | 0.0% | 99% | 100% |
| All-Intra | 0.0% | 0.0% | 0.0% | 100% | 97% |

### Category B: Simplifications (8)

[**JCT3V-F0113**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1450) **Bin reduction for SDC residual coding**

This contribution proposes to constrain the residual magnitude of intra SDC within a predefined range so that the bin number for coding the syntax element associated with the SDC residual could be significantly reduced.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC (N=5) | 0.0% | 0.0% | 0.0% | 100% | 99% |
| All-Intra | 0.0% | 0.0% | 0.0% | 100% | 101% |
| CTC (N=1) | 0.0% | 0.0% | 0.0% | 100% | 99% |
| All-Intra | 0.0% | 0.1% | 0.1% | 99% | 99% |
| CTC (N=0) | 0.0% | 0.1% | 0.2% | 100% | 99% |
| All-Intra | 0.0% | 0.2% | 0.4% | 100% | 99% |

[**JCT3V-F0132**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1469) **Unification of delta DC coding for depth intra modes**

The enhanced depth intra modes partition a depth PU into one or two segments, and each segment is coded together with an optional delta DC value (or residual). To simplify the delta DC coding, in this contribution, a unification scheme is proposed to code the delta DC values.

Test 1: Reference sample filtering is always applied  
Test 2: Reference sample filtering is never applied

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC (1) | 0.0% | 0.0% | -0.1% | 105% | 102% |
| All-Intra (1) | 0.0% | 0.0% | -0.1% | 98% | 95% |
| CTC (2) | 0.0% | 0.0% | -0.1% | 100% | 99% |
| All-Intra (2) | 0.0% | 0.0% | -0.1% | 103% | 105% |

[**JCT3V-F0133**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1470) **Simplification of wedgelet pattern generation in half-pel accuracy**

In this contribution, it is proposed to remove the dependency of the downsampling method from the pattern orientation and use one fixed downsampling method for all patterns in DMM.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.0% | 0.0% | 94% | 96% |
| All-Intra | 0.0% | 0.0% | 0.1% | 101% | 102% |

[**JCT3V-F0134**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1471) **Wedgelet pattern extension from 4x4 block**

In this contribution, a wedgelet pattern extension mechanism is proposed so that only the pattern list for the smallest size (4x4) needs to be maintained while any wedgelet pattern for a larger PU size can be extended from a 4x4 block within the PU.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.0% | 0.0% | 100% | 97% |
| All-Intra | 0.0% | 0.0% | 0.1% | 121% | 108% |

[**JCT3V-F0147**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1485) **DMM simplification and signaling**

It is observed that DMM3 and RBC have a negative impact on the coding performance. Hence, the proposal removes these two modes from the set of depth intra modes.

Test 1: Removal of DMM3  
Test 2: Removal of RBC  
Test 3: Removal of DMM3 and RBC

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC (1) | 0.0% | 0.0% | -0.1% | 97% | 99% |
| All-Intra (1) | 0.0% | 0.0% | 0.0% | 95% | 100% |
| CTC (2) | 0.0% | -0.1% | 0.0% | 97% | 99% |
| All-Intra (2) | 0.0% | 0.0% | 0.0% | 98% | 99% |
| CTC (3) | 0.0% | -0.1% | 0.0% | 94% | 99% |
| All-Intra (3) | 0.0% | -0.1% | 0.1% | 94% | 99% |

[**JCT3V-F0149**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1487) **Simplified depth inter mode coding**

The proposed method applies the simplified depth inter mode coding only to 2Nx2N partitions. In addition, to find more accurate residual values, the proposed method tests three candidates, which include DC, DC-1, and DC+1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.1% | -0.3% | 102% | 99% |

[**JCT3V-F0157**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1495) **Simplified DC predictor improvement for depth intra modes**

This contribution proposes an improvement of simplified DC prediction for depth intra coding methods including DMM, SDC\_DMM1 and Chain Coding.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | 0.0% | 0.0% | 99% | 97% |
| All-Intra | 0.0% | 0.0% | -0.1% | 99% | 95% |

[**JCT3V-F0170**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1508) **Simplification on SDC planar coding**

This contribution provides two simplification methods that can reduce the storage cost of prediction sample block in SDC planar coding.

Test 1: Sub-Sampling on 64x64 SDC Planar blocks only  
Test 2: Sub-Sampling on all SDC Planar blocks  
Test 3: Derivation of SDC planar prediction by first 32 samples at left-column or top-row of neighbouring samples.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC (1) | 0.0% | 0.0% | 0.0% | 95% | 101% |
| All-Intra (1) | 0.0% | 0.0% | 0.0% | 100% | 99% |
| CTC (2) | 0.0% | 0.0% | 0.0% | 95% | 101% |
| All-Intra (2) | 0.0% | 0.0% | 0.0% | 100% | 99% |
| CTC (3) | 0.0% | 0.0% | 0.0% | 95% | 100% |
| All-Intra (3) | 0.0% | 0.0% | 0.0% | 99% | 99% |

### Category C: Coding Efficiency (3)

[**JCT3V-F0117**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1454) **Improvement on SDC**

It is proposed to add two more options for generating the prediction samples in SDC. In addition to planar mode and DMM mode 1, horizontal mode and vertical mode are also allowed in SDC.

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| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | -0.1% | -0.1% | 100% | 96% |
| All-Intra | 0.0% | -0.1% | -0.1% | 101% | 96% |

[**JCT3V-F0126**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1463) **Generic SDC for all Intra modes in 3D-HEVC**

This contribution proposes an additional depth residual coding method for HEVC intra modes and region boundary chain coding (RBC) mode. Similar with simplified depth coding (SDC) in 3D-HEVC, only a DC residual is coded for each partition within a prediction unit, and transform and quantization are skipped.

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| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | -0.2% | -0.4% | 98% | 96% |
| All-Intra | 0.0% | -0.2% | -0.4% | 114% | 91% |

[**JCT3V-F0167**](http://phenix.it-sudparis.eu/jct3v/doc_end_user/current_document.php?id=1505) **Using DLT in Intra Modes of Depth Map**

This proposal applies the depth lookup table on the intra mode in depth map coding. In this proposal, a flag will be signaled in each slice header of the depth map to indicate whether the intra modes in this slice are performed in a conventional way or based on depth lookup table.

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| --- | --- | --- | --- | --- | --- |
|  | Video PSNR/ Video Bitrate | Video PSNR/ Total Bitrate | Synth PSNR/ Total Bitrate | Encoder Complexity | Decoder Complexity |
| CTC | 0.0% | -0.1% | -0.1% |  |  |
| All-Intra | 0.0% | -0.2% | 0.0% |  |  |

Complexity is missing