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# Abstract

This document presents a test report on verification of the coding performance of the HEVC screen content coding (SCC) extensions. The coding performance of HEVC reference software with the SCC extensions (SCM) is compared with that of HEVC reference software without the SCC extensions (SCM-w/o-SCC) as well as with the AVC reference software (JM) in both lossy and mathematical lossless compression modes using All-Intra (AI), Random Access (RA), and Low-delay B (LB) encoding structures and using similar encoding rate-distortion optimization techniques. Six test sequences are used in the test, which have been classified into two categories, namely “text and graphics with motion” (TGM)’ and “mixed content” (M)”. The test bitstreams were generated in RGB, YUV 4:4:4, and YUV 4:2:0 color sampling formats with bit-depth equal to 8 for each color component. For the lossless mode, the coding performance of JM, SCM, and SCM-w/o-SCC is evaluated in relative bit-rate savings. For the lossy compression mode, subjective testing has been conducted at 4 different quality levels for every coding case, and the test results are presented through MOS curves. Furthermore, the relative coding performance has also been evaluated in terms of BD-rate savings by using all 648 subjective test points. The test results have shown significant improvements in coding efficiency from the coding tools specified in the screen content coding extensions.

# Test conditions description

## General description

The coding performance of HEVC with screen content coding extensions, HEVC without screen content coding extensions, and AVC was compared by encoding selected video test sequences that contained rendered text and graphics content (instead of, or in addition to, camera-captured video content) at selected bit rates using reference software representing well-understood and similarly configured encoding methods for these video coding standards. Since the relevant video coding standards specify only bitstream syntax and decoding process, without prescribing how to perform encoding, it is not possible in general to directly compare the capabilities of such standards. Instead, some particular encoding method must be selected as a proxy to represent the coding capabilities of a standard, as encoding techniques and encoded video quality may vary widely from implementation to implementation. For purposes of this test, reference software codebases developed during the standardization process were used to represent each standard – i.e., the HEVC SCC Model (SCM) in the case of HEVC with and without SCC extensions and the Joint Model (JM) in the case of AVC. These two software codebases were developed for similar purposes, use similar encoding techniques such as rate-distortion optimization decision-making processing, and were configured in a very similar way for these tests, i.e., in terms of hierarchical picture referencing structures, random-access refresh periods, quantization control settings, etc.

## Test material

Table 1 below lists the video test sequences used in the verification testing. These test sequences are classified into two categories, namely “text and graphics with motion” (TGM)’ and “mixed content” (M)”. Both 4:4:4 and 4:2:0 sampling formats were tested. For the 4:4:4 colour sampling format, the tests were conducted in both RGB and YUV colour spaces.

These test sequences have been available to members (at <ftp://hevc@ftp.tnt.uni-hannover.de/testsequences/FrExt-candidate-sequences/upload/screen_content/ScExt-TestSequences>, accessible using a password available to accredited members). Their md5 checksums are given in Annex A of this report.

**Table 1 - Test sequences**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Resolution** | **Sequence name** | **Category** | **fps** | **Frames to be encoded** |
| 1920x1080 | CircuitLayoutPresentation  ClearTypeSpreadsheet  EnglishDocumentEditing  ChineseDocumentEditing  BigBuckBunnyStudio  KristenAndSaraScreen | TGM  TGM  TGM  TGM  M  M | 30  30  30  30  50\*  60 | 0-239  0-239  0-239  0-239  0-399  0-479 |
| \* Note that this sequence was captured at 60 fps, but it is tested at 50 fps to provide adequate visual duration.  TGM: Text and graphics with motion; M: mixed content; | | | | |

## Encoder software

The bitstreams were generated by using the following reference software:

* SCM-8.1: available at <https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/tags/HM-16.10+SCM-8.1>). This software was used to generate both the HEVC and HEVC-SCC bitstreams. When generating HEVC non-SCC bitstreams, all the new coding tools adopted in the specifications of HEVC SCC extensions were disabled.
* JM-19.0: available at http://iphome.hhi.de/suehring/tml/download/

## Coding configurations and bit rates

Both lossy and mathematically lossless encodings are tested using three commonly used encoding configurations, which are All-Intra (AI), Random Access (RA), and Low-delay B (LB).

For the random access configuration, the period for intra random access frames for each test sequence is configured in the SCM by the following parameter:

* IntraPeriod: Specifies the intra refresh period in the random access configuration. The intra refresh period is dependent on the frame rate of the test sequence. A value 32 is used for test sequences at 30 fps, 48 for those at 50 fps, and 64 for those at 60 fps.

The same intra refresh structure is also used in JM-19.0.

A list of the encoder configuration files used in the tests is shown in Table 2 and attached to this report.

**Table 2 – Configuration files for JM and SCM**

|  |  |  |
| --- | --- | --- |
| Coding configuration | JM configuration file | SCM configuration file |
| AI | encoder\_JM\_Intra\_RExt.cfg | encoder\_intra\_main\_scc.cfg |
| RA | encoder\_JM\_RA\_B\_RExt.cfg | encoder\_randomaccess\_main\_scc.cfg |
| LB | encoder\_JM\_LB\_RExt.cfg | encoder\_lowdelay\_main\_scc.cfg |

Beside these general encoder configuration files, a set of sequence specific configuration files have also been generated for JM to specify the width, height, frame rate, color format, etc. These configuration files are also attached with this report document.

For lossless compression, the following encoder settings have been applied to the encoders:

* JM:
* SCM: TransquantBypassEnableFlag=1, CUTransquantBypassFlagForce=1, CostMode=lossless, IntraReferenceSmoothing=0.

When using SCM to generate HEVC non-SCC bitstreams, the following encoder settings were applied to disable the SCC specific tools:

* IntraBlockCopyEnabled =0
* ColourTransform=0
* PaletteMode=0
* IntraBoundaryFilterDisabled=0
* TransquantBypassInferTUSplit=0

For each test case, a formal subjective evaluation has conducted by comparing bitstreams from the three encoders at 4 different quantization parameter (QP) values on all lossy coding conditions. The final QP values have been selected based on the actual encoding results.

# Evaluation methods

The test data from each coding configuration shown in Table 2 are collected into Excel files similar to the result-reporting templates in JCTVC-X1015 [1].

A formal subjective evaluation has been done on the Lossy coding conditions. Furthermore, the relative coding performance is also calculated and reported in BD-rates.

The Lossless coding conditions have been evaluated objectively through compression ratio and relative bit-rate saving.

The subjective testing was coordinated and supervised by the Test Chair person and conducted in Roma at the GBTech Laboratories.

The test method is the DCR (Degradation Category Rating) as specified in Recommendation ITU-T P.910 [2].

The DCR test method is commonly adopted when the material to be evaluated shows a range of visual quality that well distributes across all quality scales.

This method is used under the schema of evaluation of the impairment between the images to test and an un-impaired reference. The score is collected on paper scoring sheets.

The viewers selected as the test subjects have been carefully screened for visual acuity and colour blindness, and have been carefully trained on both the test protocol and the kind of impairments they have to detect.

A detailed explanation of the test experiment was given to each viewer before the beginning of the testing activities. A short practice (training) session was also conducted to allow the subjects to understand better the rules and to get practice with scoring process.

The training session included a representative set of whole quality range of the video test material to allow a better detection of any possible impairment and a proper ranking of the test cases.

A stabilization phase was also applied at the beginning of each SCC test sessions, to make more effective the evaluation process.

More details on the test method are given in Section 3.2.2 Test method.

# Test results

## Bitstreams

For the lossy conditions described above, bitstreams have been generated by using all integer QP values between 10 and 47. Additional bitstreams have also been generated by using QP values between 1 and 10 for AVC and HEVC and QP values between 47 and 51 for HEVC-SCC. Superior coding efficiency of HEVC-SCC over HEVC and AVC has been exhibited for every test case in PSNR objective terms. Figure 1and Figure 2 below below present two R/D comparison examples.

Figure EnglishDocumentEditing RGB sequence coded in AI configuration

Figure EnglishDocumentEditing RGB sequence coded in RA configuration

## Subjective testing

### Test plan and test content selection

The subjective testing was done in Rome at the GBTech laboratory, during the week before the Geneva 2017 JCT-VC meeting. Originally it was intended to complete the test by 5 January 2017, but an additional up-load of bitstreams was required to try to optimize the visual assessment. This led also to a very long analysis of many additional decoded bitstreams that required much more time than what originally estimated. Due to the above situation, the Test Chair (in agreement with the members of the AHG) modified the general schedule of the verification test in two steps:

* Step 1: a reduced set of test cases were evaluated according to Table 3; the subjective evaluation of these test cases were executed in the period between the Cheng-Du and the Geneva Meetings;
* Step 2: all the remaining test cases (see Table 4) were evaluated in the period between the Geneva and the Hobart Meetings

Table List of test cases in Step 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sequence**  **code** | **Sequence name** | **Test** | | |
| **RGB** | **YUV 4:2:0** | **YUV 4:4:4** |
| S01 | BigBuckBunnyStudio | **✓** |  |  |
| S02 | ChineseDocumentEditing |  |  | **✓** |
| S03 | CircuitLayoutPresentation |  |  | **✓** |
| S04 | ClearTypeSpreadsheet | **✓** |  | **✓** |
| S05 | EnglishDocumentEditing | **✓** |  | **✓** |
| S06 | KristenAndSaraScreen | **✓** |  |  |

During the execution of the test of step 1 two test sequences (ClearTypeSpreadsheet and EnglishDocumentEditing) were used for both color spaces allowing a sort of crosschecking of the results.

Table List of test cases in Step 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sequence**  **code** | **Sequence name** | **Test** | | |
| **RGB** | **YUV 4:2:0** | **YUV 4:4:4** |
| S01 | BigBuckBunnyStudio |  | **✓** | **✓** |
| S02 | ChineseDocumentEditing | **✓** | **✓** |  |
| S03 | CircuitLayoutPresentation | **✓** | **✓** |  |
| S04 | ClearTypeSpreadsheet |  | **✓** |  |
| S05 | EnglishDocumentEditing |  | **✓** |  |
| S06 | KristenAndSaraScreen |  | **✓** | **✓** |

The initial selection of the bit rates (generated by selected QP values) for the three encoders had to be reconsidered to allow a valid visual assessment of the decoded video clips. This new selection of the bit rates required a time-consuming effort dedicated to additional decoding of bitstreams at the test site. Tens of newly decoded bitstreams were preliminary assessed by the GBTech experts to select QP values more appropriate to perform a valid formal subjective assessment.

The GBTech Laboratory allowed the use in parallel of two viewing areas where two commercial top level TV sets were used as monitors[[1]](#footnote-1); all TV sets internal features were disabled to avoid non-faithful presentation of the images. Three test subjects were seated in front of a monitor at a viewing distance of 2.5H. The ambient light was below 20 cd/m2 and a light source set to 30 cd/m2 was illuminating the wall behind the monitors. The viewing area was completely isolated from any external light or audio noise source. The ceiling, floor and walls were made of non-reflecting dark grey material.

The monitors were driven for the play-out of the video clips using two identical PC equipped with high speed M2 SSD drives (in Raid 0 configuration), last generation motherboards based on Z270 chip-set, i7-7700 4.50 GHz Intel CPUs and 64G of DDR-4 RAM. The play out of video was done using the new version of the MUP[[2]](#footnote-2) video player improved to display planar RGB video clips and to play in a synchronized way on two different PCs.

To void any influence of the display technology, the groups of three viewers were seated changing the display at any test sessions; in other worlds each group of three subjects watched four test sessions on the OLED and the other four test sessions on the Samsung. No statistical evidence of difference in evaluation scores among data coming from observations made on different displays was noted.

### Test method

The test method is derived from the DCR (Degradation Category Rating) as specified in Recommendation ITU-T P.910 [2]with some variation in the timing of the Basic Test Cell (see Figure 3) and in the adoption of an 11 grades impairment scale, as defined in Recommendation ITU-R BT.2095 [3], ranging from "0" (lowest quality) to "10" (highest quality).

The structure of the Basic Test Cell (BTC) of DCR method is made of the following steps (see Figure 3):

* a mid grey screen showing the letter “A” in the middle (1 second);
* the SRC video clip (original not coded);
* a mid grey screen showing the letter “B” in the middle (1 second);
* the coded video clip to evaluate;

a mid grey screen showing the message “Vote\_N”, where N is a progressive number indicating the BTC to vote.



Figure DCR Basic Test Cell (BTC)

The score was collected on paper scoring sheets.

Eighteen young university students all aging below 30 years were selected as the test subjects after being carefully screened for visual acuity and colour blindness. They have also been carefully trained on both the test protocol and the kind of impairments they have to detect.

The Test Sessions were preceded by a training activity during which a detailed explanation of the test scope, the test method, and the vote procedure was provided.

A short (10 BTCs) training session has been conducted after the training explanation, to let the viewers practice with the scoring procedure and to allow them to familiarise with the video content to assess. Some explanations were also provided about the kind of impairments they would have to look for.

The training session included a representative set of whole quality range of the video test material to allow a better detection of any possible impairment and a proper ranking of the test cases.

### Test sessions design and schedule

To control the level of the stress and fatigue of the viewers, the test of Step 1 is made of 8 test sessions: four YUV 4:4:4 and four RGB.

The test of Step 2 is made of 12 test sessions, six for YUV 4:2:0 test and 4 to complete the RGB and YUV 4:4:4 tests.

Each test session does not exceed 20 minutes length, including a stabilization phase made of three Basic Test Cells (BTCs) inserted at the beginning of each session to allow a smooth creation of the quality scale to the viewers.

The activity of a group of three subjects foresees the execution of a maximum of four test sessions during the same day. A group of three subjects may work the day after.

The execution of the test activities with the participation of 18 viewing subjects in Step1 required 4 working days, and the execution of the test activities in Step 2 required 6 working days.

## Step 1 Results

Here reported below are the graphs of the results of formal subjective assessment conducted in Step 1.

Each graph reports the results for each encoder (red JM, blue HM referring to SCM-w/o-SCC, and Green SCM), for a given coding configuration (AI, LB and RA) and for a given test sequence.

The Y axis reports the mean opinion score (MOS) value for the selected QP values, while the X axis reports the bitstream lengths (in Kbytes).

### Step 1 results for RGB color space

As reported in Table 5 the test for the RGB color space were done using S01 S04 S05 and S06 only.

Figures from 4 to 15 show the values and the graphs of the 18 combinations of test sequences and coding configurations for the RGB color space.

Table List of video sequences tested in Step 1 for the RGB color space

|  |  |  |
| --- | --- | --- |
| **Sequence code** | **Test sequence name** | **RGB** |
| S01 | BigBuckBunnyStudio | **✓** |
| S04 | ClearTypeSpreadsheet | **✓** |
| S05 | EnglishDocumentEditing | **✓** |
| S06 | KristenAndSaraScreen | **✓** |

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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | R26 | 5.38 | 113.683 | | JM | R30 | 2.88 | 85.815 | | JM | R34 | 1.50 | 60.381 | | JM | R36 | 1.06 | 49.110 | | HM | R26 | 5.44 | 59.351 | | HM | R30 | 3.13 | 44.028 | | HM | R34 | 2.06 | 31.257 | | HM | R36 | 1.13 | 26.193 | | SCM | R26 | 8.38 | 49.371 | | SCM | R30 | 6.63 | 36.328 | | SCM | R34 | 3.88 | 26.340 | | SCM | R36 | 2.88 | 22.177 | |

Figure MOS curves and table for test sequence S01 with AI coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | R22 | 9.00 | 271.925 | | JM | R26 | 8.50 | 232.861 | | JM | R30 | 7.38 | 196.780 | | JM | R34 | 5.88 | 175.184 | | HM | R26 | 8.38 | 165.907 | | HM | R20 | 8.31 | 146.852 | | HM | R30 | 7.63 | 126.381 | | HM | R34 | 6.00 | 113.302 | | SCM | R34 | 7.38 | 20.829 | | SCM | R36 | 6.00 | 18.513 | | SCM | R38 | 4.50 | 16.069 | | SCM | R40 | 3.69 | 14.823 | |

Figure MOS curves and table for test sequence S04 with AI coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | R22 | 8.94 | 320.162 | | JM | R26 | 8.69 | 258.050 | | JM | R30 | 7.19 | 205.495 | | JM | R34 | 6.00 | 175.256 | | HM | R20 | 9.06 | 192.443 | | HM | R26 | 8.56 | 162.288 | | HM | R30 | 6.75 | 132.268 | | HM | R34 | 4.81 | 114.948 | | SCM | R34 | 7.06 | 33.284 | | SCM | R36 | 6.44 | 29.204 | | SCM | R38 | 6.19 | 25.139 | | SCM | R40 | 3.69 | 22.908 | |

Figure MOS curves and table for test sequence S05 with AI coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | R20 | 8.13 | 267.073 | | JM | R28 | 7.00 | 229.636 | | JM | R34 | 5.00 | 183.909 | | JM | R38 | 3.94 | 160.250 | | HM | R20 | 8.50 | 169.883 | | HM | R26 | 6.88 | 136.691 | | HM | R34 | 3.31 | 106.526 | | HM | R38 | 2.00 | 92.018 | | SCM | R20 | 9.06 | 69.726 | | SCM | R28 | 7.31 | 51.811 | | SCM | R34 | 4.63 | 38.975 | | SCM | R38 | 3.44 | 33.670 | |

Figure MOS curves and table for test sequence S06 and AI coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP26 | 6.38 | 4.951 | | JM | QP30 | 3.94 | 3.443 | | JM | QP34 | 3.13 | 2.415 | | JM | QP36 | 1.88 | 1.998 | | HM | QP26 | 8.38 | 2.834 | | HM | QP30 | 6.50 | 1.985 | | HM | QP34 | 2.94 | 1.351 | | HM | QP36 | 2.06 | 1.126 | | SCM | QP26 | 8.69 | 2.523 | | SCM | QP30 | 7.88 | 1.692 | | SCM | QP34 | 3.31 | 1.167 | | SCM | QP36 | 2.81 | 0.945 | |

Figure MOS curves and table for Sequence S01 and LB coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP22 | 8.56 | 10.194 | | JM | QP26 | 7.94 | 8.582 | | JM | QP30 | 7.13 | 7.171 | | JM | QP34 | 6.06 | 6.401 | | HM | QP20 | 8.81 | 5.850 | | HM | QP26 | 8.44 | 5.817 | | HM | QP30 | 7.56 | 4.495 | | HM | QP34 | 7.31 | 4.061 | | SCM | QP34 | 7.25 | 0.825 | | SCM | QP36 | 6.50 | 0.750 | | SCM | QP38 | 5.63 | 0.656 | | SCM | QP40 | 3.13 | 0.602 | |

Figure MOS curves and table for test sequence S04 with LB coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP22 | 9.00 | 12.773 | | JM | QP26 | 8.19 | 10.409 | | JM | QP30 | 7.81 | 8.123 | | JM | QP34 | 7.56 | 7.113 | | HM | QP20 | 9.38 | 7.252 | | HM | QP26 | 8.94 | 6.208 | | HM | QP30 | 7.88 | 5.100 | | HM | QP34 | 7.69 | 4.505 | | SCM | QP34 | 7.69 | 1.348 | | SCM | QP36 | 7.50 | 1.190 | | SCM | QP38 | 7.25 | 1.034 | | SCM | QP40 | 6.13 | 0.948 | |

Figure MOS curves and table for test sequence S05 with LB coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP20 | 8.94 | 7.339 | | JM | QP28 | 7.88 | 5.682 | | JM | QP34 | 5.38 | 4.325 | | JM | QP38 | 4.31 | 3.758 | | HM | QP20 | 8.56 | 4.315 | | HM | QP26 | 7.75 | 3.239 | | HM | QP34 | 6.25 | 2.463 | | HM | QP38 | 4.50 | 2.132 | | SCM | QP20 | 8.56 | 2.510 | | SCM | QP28 | 7.50 | 1.635 | | SCM | QP34 | 6.13 | 1.148 | | SCM | QP38 | 6.06 | 0.959 | |

Figure MOS curves and table for test sequence S06 with LB coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP26 | 6.94 | 4.951 | | JM | QP30 | 5.56 | 3.443 | | JM | QP34 | 2.81 | 2.415 | | JM | QP36 | 1.94 | 1.998 | | HM | QP26 | 8.06 | 2.834 | | HM | QP30 | 6.69 | 1.985 | | HM | QP34 | 3.88 | 1.351 | | HM | QP36 | 2.44 | 1.126 | | SCM | QP26 | 8.63 | 2.523 | | SCM | QP30 | 8.00 | 1.692 | | SCM | QP34 | 5.56 | 1.167 | | SCM | QP36 | 2.81 | 0.945 | |

Figure MOS curves and table for test sequence S01 with RA coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP22 | 9.00 | 10.194 | | JM | QP26 | 8.94 | 8.582 | | JM | QP30 | 7.44 | 7.171 | | JM | QP34 | 6.75 | 6.401 | | HM | QP26 | 8.88 | 5.850 | | HM | QP20 | 8.69 | 5.817 | | HM | QP30 | 8.00 | 4.495 | | HM | QP34 | 7.38 | 4.061 | | SCM | QP34 | 8.31 | 0.825 | | SCM | QP36 | 7.88 | 0.750 | | SCM | QP38 | 7.63 | 0.656 | | SCM | QP40 | 6.44 | 0.602 | |

Figure MOS curves and table for test sequence S04 with RA coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP22 | 8.88 | 12.773 | | JM | QP30 | 8.75 | 10.409 | | JM | QP26 | 8.13 | 8.123 | | JM | QP34 | 6.88 | 7.113 | | HM | QP20 | 9.19 | 7.252 | | HM | QP26 | 8.75 | 6.208 | | HM | QP30 | 8.69 | 5.100 | | HM | QP34 | 8.25 | 4.505 | | SCM | QP34 | 7.63 | 1.348 | | SCM | QP38 | 7.38 | 1.190 | | SCM | QP36 | 7.31 | 1.034 | | SCM | QP40 | 6.00 | 0.948 | |

Figure MOS curves and table for test sequence S05 with RA coding configuration

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  |  |  | | --- | --- | --- | --- | | Codec | QP | MOS | Bitstreams (MB) | | JM | QP20 | 8.56 | 7.339 | | JM | QP28 | 8.31 | 5.682 | | JM | QP34 | 6.63 | 4.325 | | JM | QP38 | 5.00 | 3.758 | | HM | QP20 | 9.00 | 4.315 | | HM | QP26 | 8.81 | 3.239 | | HM | QP34 | 7.00 | 2.463 | | HM | QP38 | 4.63 | 2.132 | | SCM | QP20 | 8.38 | 2.510 | | SCM | QP28 | 8.19 | 1.635 | | SCM | QP34 | 7.25 | 1.148 | | SCM | QP38 | 6.44 | 0.959 | |

Figure MOS curves and table for test sequence S06 with RA coding configuration

### Step 1 results for YUV color space in 4:4:4 sampling format

As reported in Table 6, the tests for the YUV color space were done using S02 S03 S04 and S05 only.

Figures from 16 to 27 show the values and the graphs of the 12 combinations of test sequences and coding configurations for the RGB color space.

Table List of cases and sequences tested in Step 1 for the YUV color space in 444 sampling format

|  |  |  |
| --- | --- | --- |
| **Sequence code** | **Sequence name** | **YUV 4:4:4** |
| S02 | ChineseDocumentEditing | **✓** |
| S03 | CircuitLayoutPresentation | **✓** |
| S04 | ClearTypeSpreadsheet | **✓** |
| S05 | EnglishDocumentEditing | **✓** |

Figure MOS curves for test sequence S02 with AI coding configuration

Figure MOS curves for test sequence S03 with AI coding configuration

Figure MOS curves for test sequence S04 with AI coding configuration

Figure MOS curves for test sequence S05 with AI coding configuration

Figure MOS curves for test sequence S02 with LB coding configuration

Figure MOS curves for test sequence S03 with LB coding configuration

Figure MOS curves for test sequence S04 with LB coding configuration

Figure MOS curves for test sequence S05 with LB coding configuration

Figure MOS curves for test sequence S02 with RA coding configuration

Figure MOS curves for test sequence S03 with RA coding configuration

Figure MOS curves for test sequence S04 with RA coding configuration

Figure MOS curves for test sequence S05 with RA coding configuration

## Step 2 results

Here reported below are the graphs of the results of formal subjective assessment conducted in Step 1.

As in 3.3, each graph reports the results for each encoder (red JM, blue HM referring to SCM-w/o-SCC, and Green SCM), for a given coding configuration (AI, LB and RA) and for a given test sequence.

The Y axis reports the mean opinion score (MOS) value for the selected QP values, while the X axis reports the bitstream lengths (in Kbytes).

### Step 2 results for YUV color space in 4:2:0 sampling format

As reported in Table 7 the tests for the RGB color space were done using all test sequences, S01, S02,… S06.

Figures from 28 to 46 show the values and the graphs of the 18 combinations of test sequences and coding configurations for the RGB color space.

Table List of the sequences tested in Step 2 for YUV Color space in 4:2:0 sampling format

|  |  |  |
| --- | --- | --- |
| **Sequence code** | **Sequence name** | **YUV 4:2:0** |
| S01 | BigBuckBunnyStudio | **✓** |
| S02 | ChineseDocumentEditing | **✓** |
| S03 | CircuitLayoutPresentation | **✓** |
| S04 | ClearTypeSpreadsheet | **✓** |
| S05 | EnglishDocumentEditing | **✓** |
| S06 | KristenAndSaraScreen | **✓** |

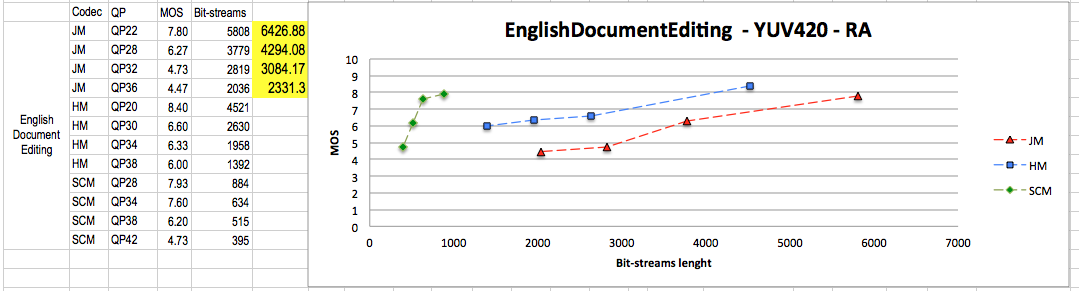


Figure MOS curves for test sequence S05 with RA coding configuration

### Step 2 results for RGB color space

As reported in Table 8 the tests for the RGB color space were done using test sequences S02 and S03.

Figures from 47 to 53 show the values and the graphs of the 6 combinations of test sequences and coding configurations for the RGB color space.

Table List of the sequences tested in Step 2 for RGB color space

|  |  |  |
| --- | --- | --- |
| **Sequence code** | **Sequence name** | **RGB** |
| S02 | ChineseDocumentEditing | **✓** |
| S03 | CircuitLayoutPresentation | **✓** |

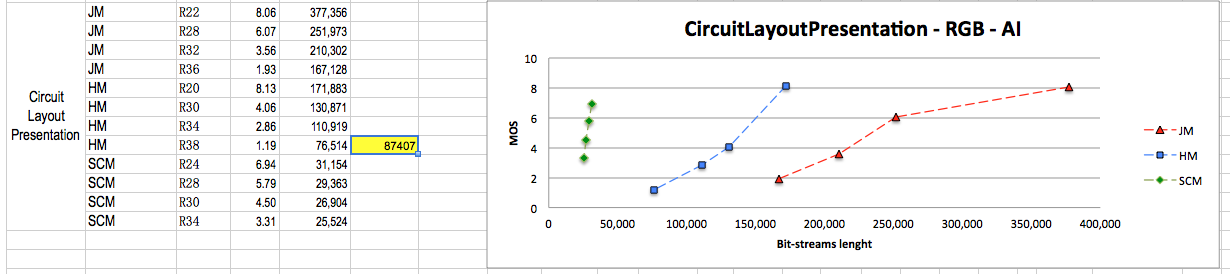


Figure MOS curves for test sequence S03 with RA coding configuration

### Step 2 results for YUV color space in 4:4:4 sampling format

As reported in Table 7 the tests for the YUV color space in 4:4:4 sampling format were done using test sequences S01 and S06.

Figures from 54 to 60 show the values and the graphs of the 6 combinations of test sequences and coding configurations for the YUV color space in 4:4:4 sampling format.

Table List of the sequences tested in Step 2 for YUV Color space in 4:4:4 sampling format

|  |  |  |
| --- | --- | --- |
| **Sequence code** | **Sequence name** | **YUV 4:4:4** |
| S01 | BigBuckBunnyStudio | **✓** |
| S06 | KristenAndSaraScreen | **✓** |

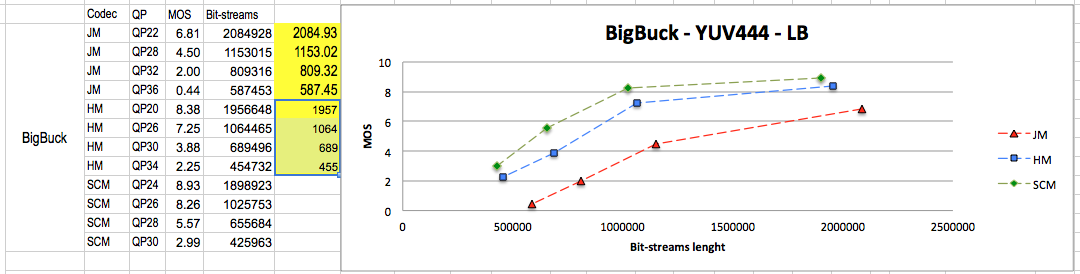


Figure MOS curves for test sequence S01 with LB coding configuration

## BD-rate savings for lossy compression mode

BD-rate savings of SCM over JM and SCM-w/o-SCC for RGB, YUV 4:4:4, and YUV 4:2:0 color sampling formats were calculated by using the actual 648 test points that were used in the subjective testing Step 1 and Step2 above.

The test data were collected into an Excel file similar to the result-reporting templates in JCTVC-X1015 [1]. Table 10, Table 11, and Table 12 below show the summary results. The details of BD-rate savings data are given in the attached Excel file.

Table BD-rate savings of SCM over JM and SCM-w/o-SCC for AI coding configuration

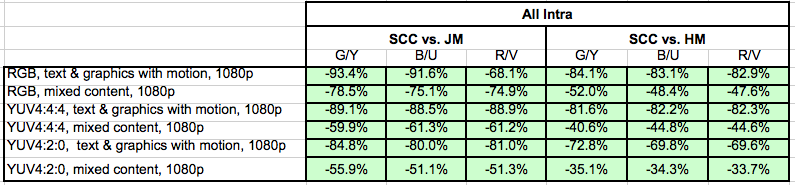


Table BD-rate savings of SCM over JM and SCM-w/o-SCC for AI coding configuration

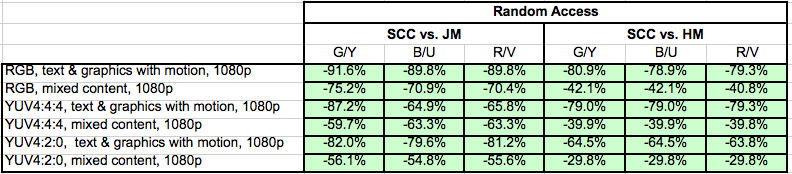
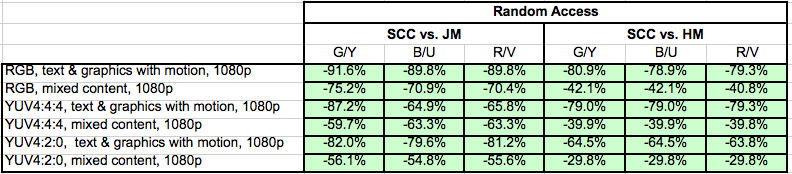


Table BD-rate savings of SCM over JM and SCM-w/o-SCC for LB coding configuration



## Lossless coding test results

The lossless coding efficiency of the three codecs is compared in Table 13, Table 14, and Table 15 below. The details of compression ratio for each sequence from each codec are given in the attached Excel file attached.

Table Lossless coding efficiency comparisons for AI

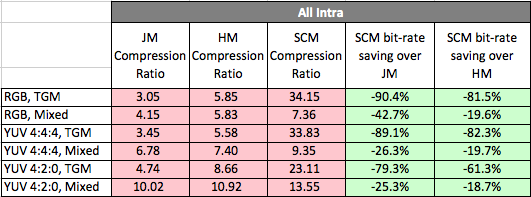


Table Lossless coding efficiency comparisons for AI

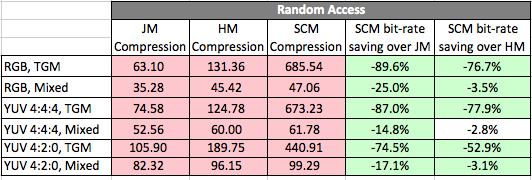
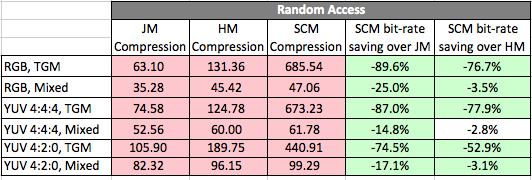


Table Lossless coding efficiency comparisons for LB



# Conclusions

Significant coding efficiency gain from the new coding tools specified in HEVC screen content coding extensions has been verified. For TGM content, the compression efficiency gain from SCM is 90% over JM and 80% over SCM without screen content tools, respectively, measured in BD rate savings for all lossy coding modes and bit rate savings for all lossless coding modes.

# References

1. JCTVC-X1016, “Common test conditions for screen content coding,” Geneva, CH, May 26 to June 1, 2016.
2. Rec. ITU-T P.910, Subjective video quality assessment methods for multimedia applications, April 2008.
3. Rec. ITU-R BT.2095, Subjective assessment of video quality using Expert Viewing Protocol, April 2016.

# Annex A. Test sequence md5sums

For the test sequences used in this verification test, the ‘md5sum’ values are provided in Table 16 below.

Table md5sum values of the test sequences

|  |  |  |
| --- | --- | --- |
| Format | File name | MD5 |
| RGB and 4:4:4 YUV\* | ChineseDocumentEditing\_1920x1080\_30\_8bit.zip | 5300fd95c19d179a6ddfa12288240d00 |
| CircuitLayoutPresentation\_1920x1080\_30\_8bit.zip | 186b11635d64b1c5e146750aa4b803b7 |
| ClearTypeSpreadsheet\_1920x1080\_30\_8bit.zip | 6499a6bb378a4ad5ec55c5bc29632f16 |
| EnglishDocumentEditing\_1920x1080\_30\_8bit.zip | 98f865d30a01460a10e2903ea44fec79 |
| RGB | BigBuck\_1920x1080\_60p\_8b444.zip | 8b92be4db9461cf8ee05adb35ef9f5c1 |
| KristenAndSaraScreen\_1920x1080\_60p\_8b444.zip | a4d9217ba38a4b9a4a6818ae22b49a7e |
| 4:4:4 YUV | BigBuck\_1920x1080\_60p\_8b444YUV.zip | 6402bc8c267e5ebc7d6726793a801444 |
| KristenAndSaraScreen\_1920x1080\_60p\_8b444YUV.zip | b4bd1eb10b97df273860908498001306 |
| 4:2:0 YUV | ChineseDocumentEditing\_1920x1080\_30\_8bit\_420.zip | dbce1e459826c487e962f56b63f1b5ab |
| CircuitLayoutPresentation\_1920x1080\_30\_8bit\_420.zip | 3269bae52ed3054ca81b7d311921a10f |
| ClearTypeSpreadsheet\_1920x1080\_30\_8bit\_420.zip | 77ea70821ac9915778d3030548aceb2d |
| EnglishDocumentEditing\_1920x1080\_30\_8bit\_420.zip | 3fdb7e41963bd4d7ee3b26586b699d93 |
| BigBuck\_1920x1080\_60p\_8b420.zip | 79404d73847560f4e2c2a74475fbd7a1 |
| KristenAndSaraScreen\_1920x1080\_60p\_8b420.zip | 9d21a8054265e94e32c2bb8e2f49b984 |
| \*Note: each of these zip files consists of both RGB and 4:4:4 YUV sequences. | | |

1. *LG OLED B6 (55” plane); Samsung 55KS7500 (44” curved);* [↑](#footnote-ref-1)
2. *MUP is a product of Tretag srl* [↑](#footnote-ref-2)