|  |  |
| --- | --- |
| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  17th Meeting: Valencia, ES, 27 March – 4 April 2014 | Document: JCTVC-Q0204r4 MPEG document: m33340r4 |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **HEVC verification test results** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Information | | |
| *Author(s) or Contact(s):* | TK Tan | Tel: Email: | +65 9799 3861 tktan@m-sph.com |
|  | Marta Mrak  Vittorio Baroncini Naeem Ramzan |  | Marta.Mrak@bbc.co.uk [vittorio@fub.it](mailto:vittorio@fub.it)  Naeem.Ramzan@uws.ac.uk |
|  |  |
| *Source:* | AHG on verification test preparation and testing | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Executive Summary

This document reports on the results for the HEVC video verification test.

The purpose of the HEVC verification test is to confirm that the objective of achieving a substantially greater bit-rate reduction over the AVC High Profile has been met by the HEVC standard.

A subjective evaluation was conducted comparing the HEVC Main profile to the AVC High profile. Twenty video sequences with resolutions ranging from 480p to UHD were tested (at 4 different bit-rates / quality levels).

Analysis of the subjective test results show that in 86% of the test points, HEVC and AVC have the same quality, even though the bit-rates of AVC are greater than or equal to approximately double the HEVC bit-rates.

The bit-rate savings are similar for the different resolutions tested, with slightly more savings for sequences with higher resolutions. The average bit-rate savings for test sequences with UHD, 1080p, 720p and 480p resolutions are estimated at approximately 64%, 62%, 56% and 52%, respectively.

The results confirmed that the HEVC Main profile achieves the same subjective quality as AVC High profile while requiring on average approximately 59% less bit-rate.

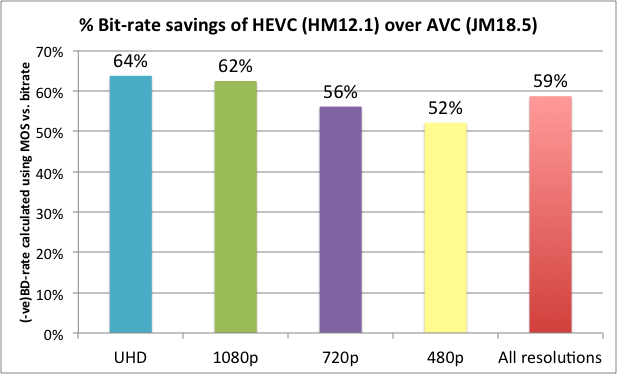


Figure : Average bit-rate savings of HEVC compared to AVC.

# Verification test logistics

The subjective test was carried out at the following test sites.

* British Broadcasting Corporation (BBC) R&D (UHD and 720p test sets)
* School of Computing, University of West of Scotland (1080p and 480p test sets)

The tests were conducted according to the verification test environment and methodology as described in the HEVC verification test plan [1] and reproduced in this document in Annex A. The specific set-up of the test sites, in addition to or which supersedes the guidelines in Annex A, is shown in Table 1.

Table : Test site information and set up.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test performed | UHD test set | 1080p test set | 720p test set | 480p test set |
| Site | BBC | UWS | BBC | UWS |
| Display (resolution setting) | TVLogic 56” LUM-560W (3840 x 2160) | HP 30” ZR30W (1920 x 1080) | Pioneer 50” PDP-5000EX (1920 x 1080) | HP 30” ZR30W (1920 x 1080) |
| Sitting position and viewing distance  (H is the screen height) | 3 viewers at 1.5H (front row),  2 viewers at 2H (back row) | 2 simultaneous displays,  1 viewer at 3H per display | 3 viewers at 2H (front row),  2 viewers at 3H (back row) | 2 simultaneous displays,  1 viewer at 3H per display |
| Total number of viewers | 19 (front row),  13 (back row) | 16 | 19 (front row),  14 (back row) | 16 |

# Verification test results

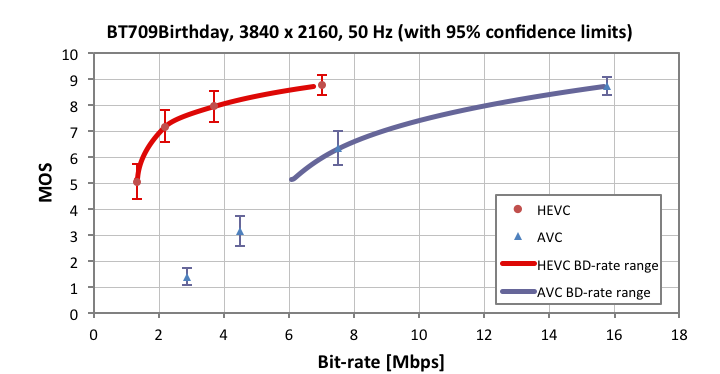
The verification test was conducted using the HM12.1 (reference HEVC codec) and JM18.5 (reference AVC codec). Four picture resolutions UHD, 1080p, 720p and 480p were tested. Each resolution was represented by 5 test sequences, giving a total of 20 test sequences as listed in Table 4 in Annex B. For each test sequence 4 test points coded using the HM12.1 and JM18.5 reference software were chosen. See section B.1 in Annex B for the coding conditions used. The JM18.5 test points were chosen such that the quality levels of the sequences span the entire range of the mean opinion score (MOS) scale. The HM12.1 test points were then selected such that the bit-rates are approximately half the bit-rates of the corresponding JM18.5 test points. See Table 5 in Annex B for the summary of the quantization (QP) selection and encoded bit-rates.

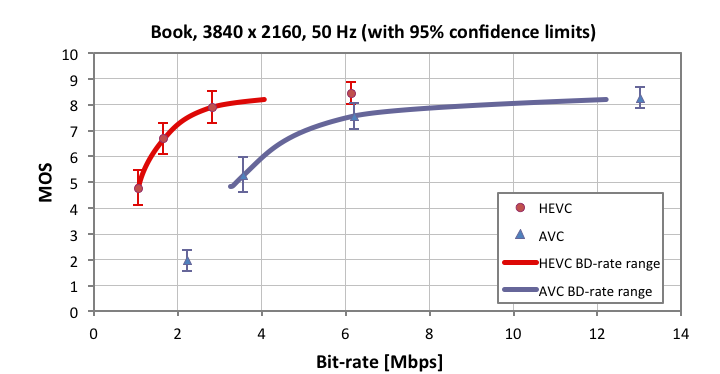
The test results were collected, processed and presented in the plots of MOS vs. bit-rates as shown in Figure 2, Figure 3, Figure 4 and Figure 5 below for the UHD, 1080p, 720p and 480p resolution sequences, respectively.

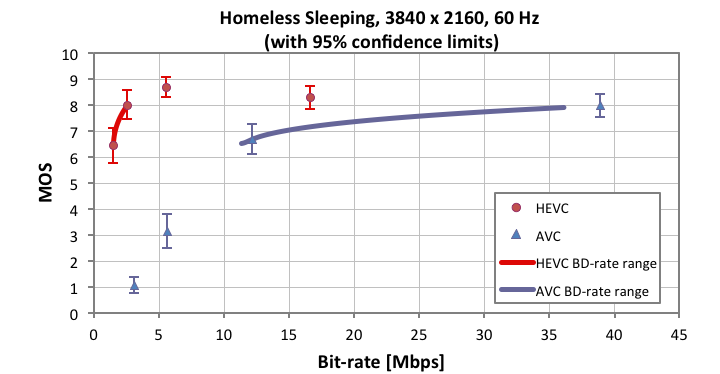
The eleven-grade MOS scale from 0 to 10 as shown in the plots may be interpreted as follows.

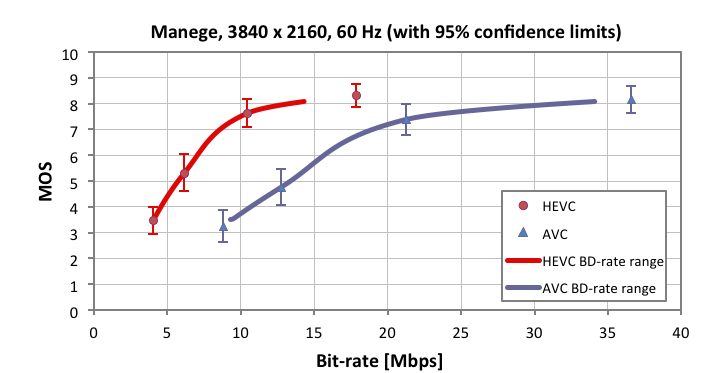
|  |  |
| --- | --- |
| 10 - | The number 10 denotes a quality of reproduction that is perfectly faithful to the original. No further improvement is possible. |
| 9 - | Excellent |
| 8 - |  |
| 7 - | Good |
| 6 - |  |
| 5 - | Fair |
| 4 - |  |
| 3 - | Poor |
| 2 - |  |
| 1 - | Bad |
| 0 - | The number 0 denotes a quality of reproduction that has no similarity to the original. A worse quality cannot be imagined. |

## Plots of MOS vs. bit-rates









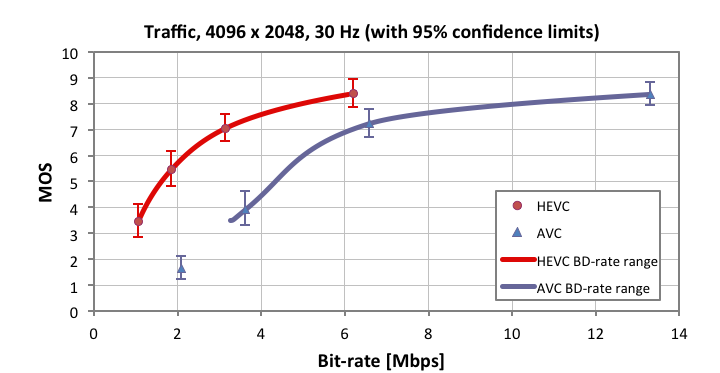
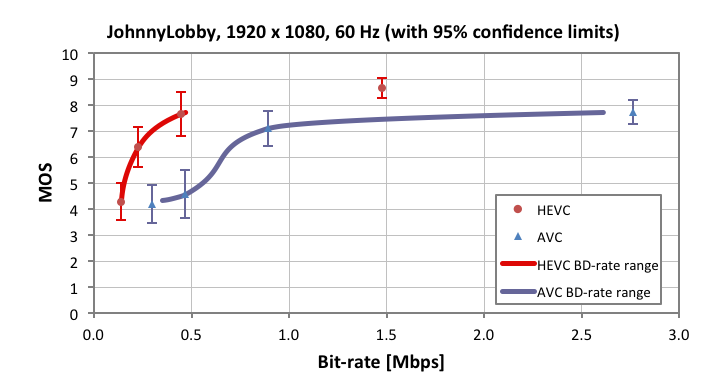
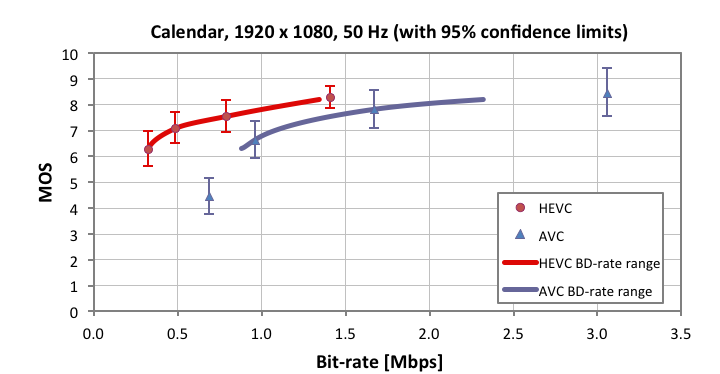
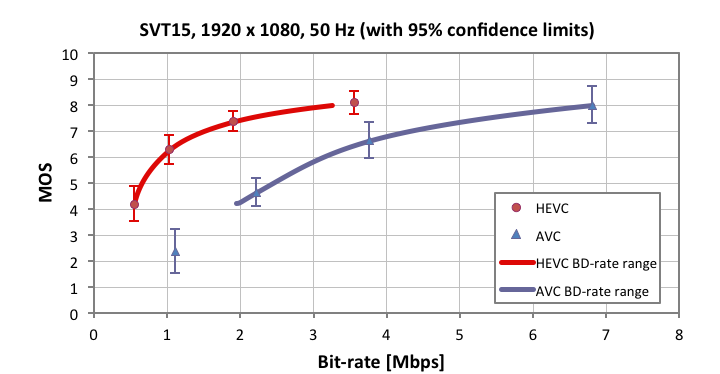
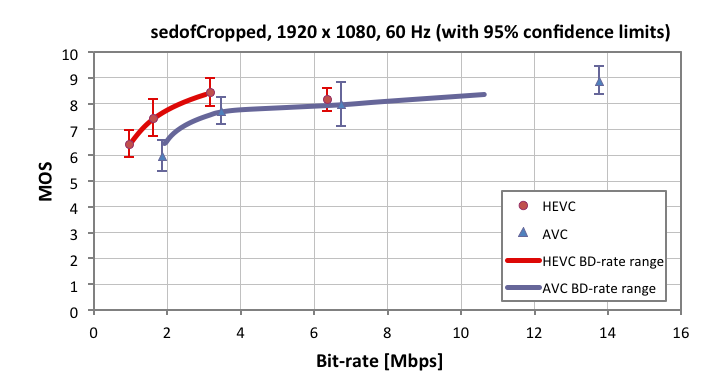


Figure : MOS vs. bit-rate plots for UHD sequences









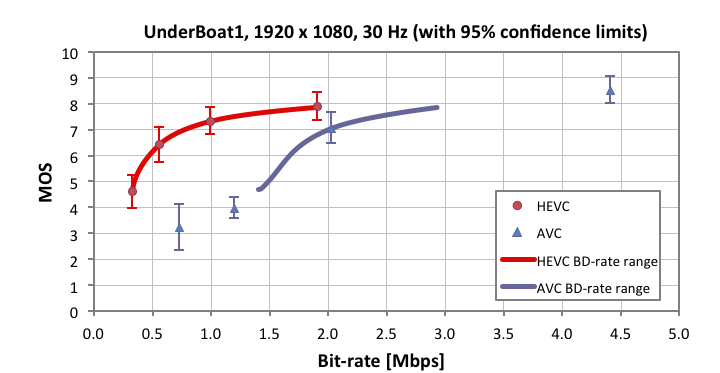
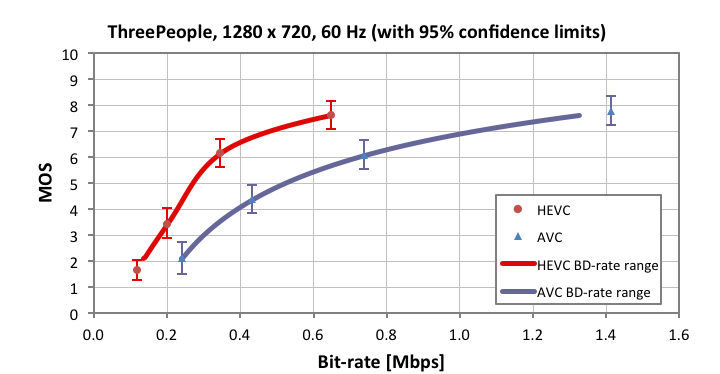
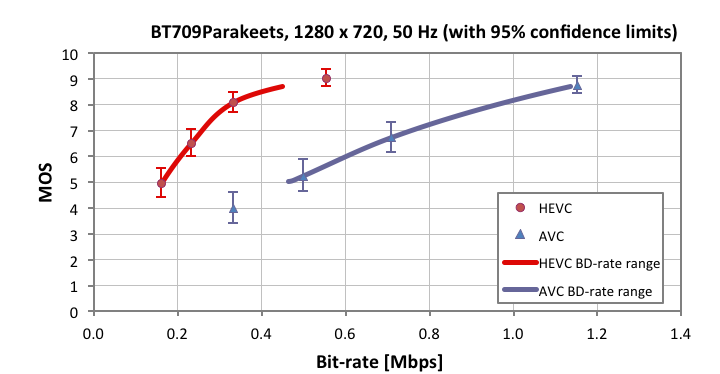
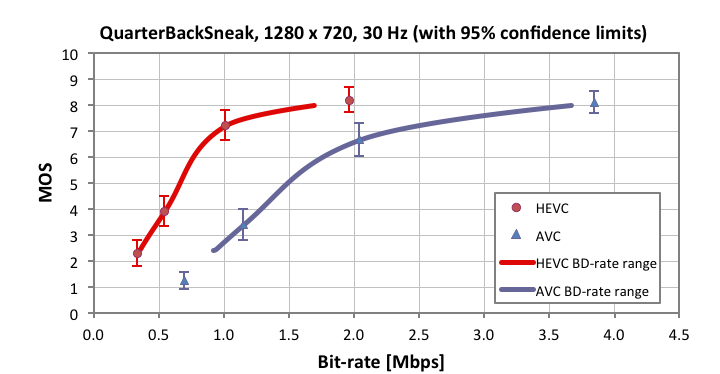
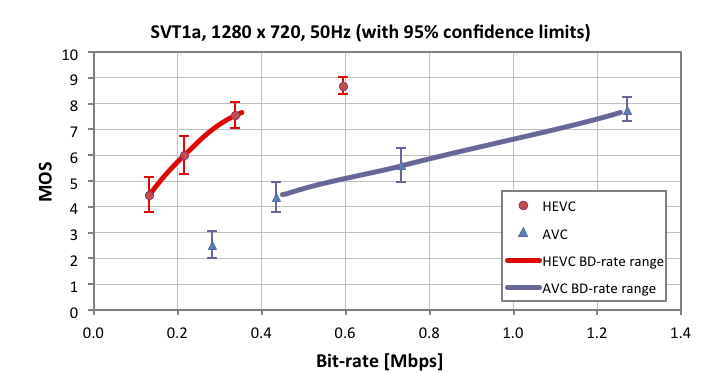


Figure : MOS vs. bit-rate plots for 1080p sequences









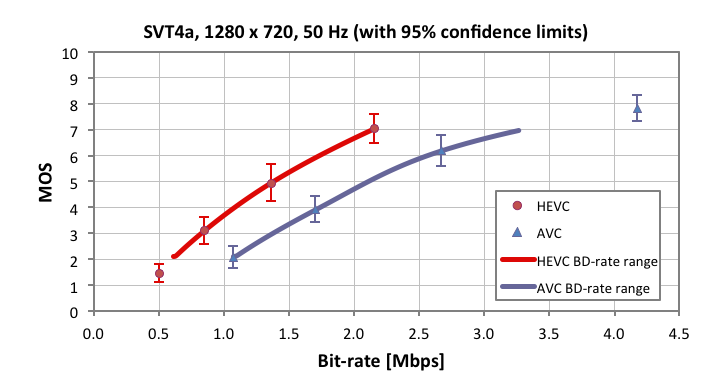
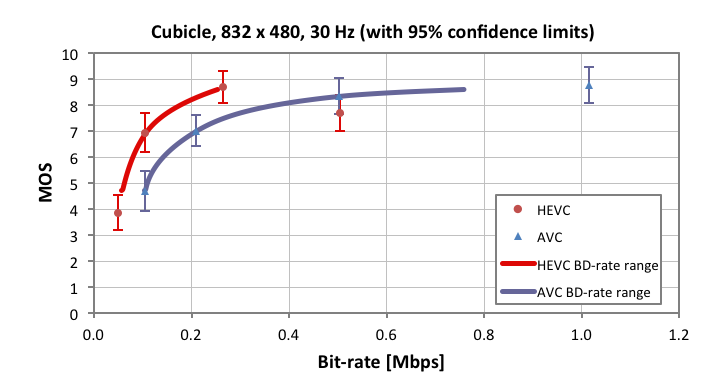
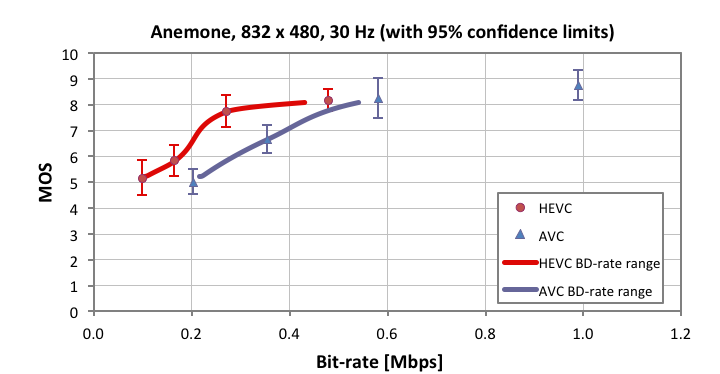
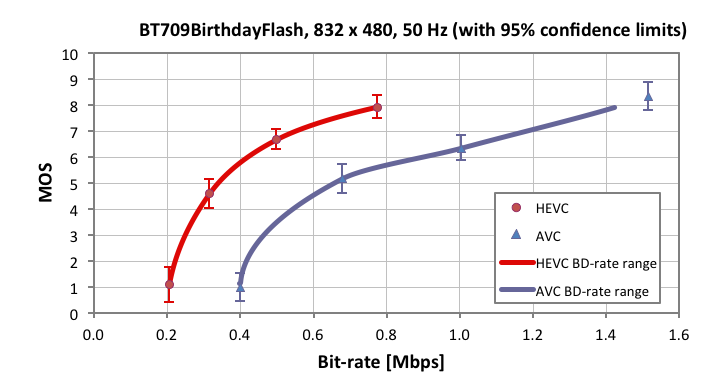
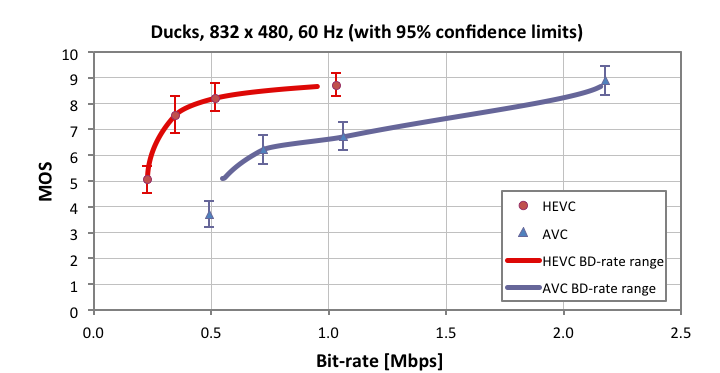


Figure : MOS vs. bit-rate plots for 720p sequences









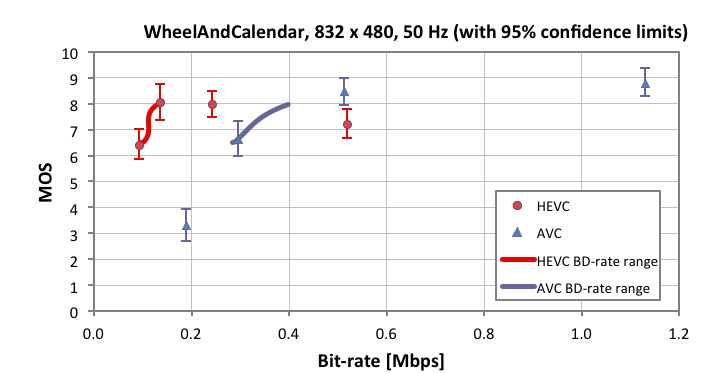


Figure : MOS vs. bit-rate plots for 480p sequences

## Analysis of MOS vs. bit-rate plots

All the plots in Figure 2, Figure 3, Figure 4 and Figure 5, with the exception of the WheelAndCalender sequence, show that the rate distortion (RD) curves of the HEVC test points are located substantially to the left of the RD-curves of the AVC test points. This shows that indeed, HEVC is achieving a greater bit-rate reduction over the AVC.

Table 2 shows the number of test points for the cases where the MOS confidence intervals (CI) of the HEVC test points overlap with the MOS CI of the AVC test points where the bit-rates of AVC are

1. greater than approximately double the bit-rates of HEVC.
2. equal to approximately double the bit-rates of HEVC.
3. less than approximately double the bit-rates of HEVC.

Table : Count of HEVC test points with overlapping MOS CI

|  |  |  |  |
| --- | --- | --- | --- |
|  | Number of HEVC test points having overlapping MOS CI with AVC test points where the bit-rates of AVC is | | |
|  | greater than approximately 2 x bit-rates HEVC | approximately 2 x bit-rates HEVC | less than approximately 2 x bit-rates HEVC |
| Total UHD | 12 | 10 | 2 |
| Total 1080p | 15 | 14 | 6 |
| Total 720p | 10 | 13 | 2 |
| Total 480p | 10 | 14 | 6 |
| Total All | 47 | 51 | 16 |
| Overall percentage | 41% | 45% | 14% |

The total count of 114 is greater than the 80 HEVC test points as a few of the HEVC test points have MOS CI that overlap with more than one MOS CI of the AVC test points. There were also HEVC test points with MOS CI that did not overlap with any MOS CI of any AVC test points. These non-overlapping cases were counted as either the greater than or the less than cases depending on whether the test point was above or below the AVC test point having double the bit-rate, respectively.

Table 2 shows that 45% of the HEVC test points have the same quality as AVC at approximately double the bit-rates of the HEVC test points. Another 41% of the HEVC test points have the same quality as AVC at greater than approximately double the bit-rates of the HEVC test points. In contrast, only 14% of the HEVC test points have the same quality as AVC at less than approximately double the bit-rates of the HEVC test points.

Statistically, 86% of the data show that the quality of HEVC is indistinguishable from the quality of AVC at bit-rates that are greater than or equal to approximately double the HEVC bit-rates. Even though the inspection of the RD-curves and the overlapping MOS CI give high confidence that HEVC is achieving a greater bit-rate reduction over the AVC that is very likely above 50%, the test data points were not sufficiently dense to precisely quantify the amount of the greater bit-rate reduction. In order to do this the approach in the next section was employed.

## MOS BD-rate

In this section the average bit-rate savings of HEVC compared to AVC for each sequence were computed from the MOS vs. bit-rate data in the same manner that was done in [2][3] to further quantify the bit-rate savings that was achieved.

In the first measurement (MOS BD-rate), the bit rate savings are averaged over the whole range where the same MOS scores for both HEVC and AVC can be interpolated from subjective test results shown in the plots in section 3.1. The interval, over which the BD-rate is averaged, is shown as solid lines in each of the plots.

In addition, a second measurement (MOS>=7 BD-rate) was also calculated for the range of MOS scores greater than or equal to 7, which would be a better reflection of the bit-rate savings at quality levels that are “good” to “excellent” which are more suitable for actual services.

Table 3 shows the MOS BD-rate and MOS>=7 BD-rate for the sequences in this test. The BD-rate measure described in [4][5] is used with MOS scores taking the place of PSNR. A piece wise cubic interpolation used in the HEVC common conditions results spreadsheet is used instead of the original cubic spline interpolation.

Table : MOS BD-rate and MOS>=7 BD-rate.

|  |  |  |  |
| --- | --- | --- | --- |
| Resolution | Sequence | MOS BD-rate | |
|  |  | MOS 0 to 10 | MOS >= 7 |
| UHD | BT709Birthday | -75% | -70% |
| Book | -66% | -65% |
| HomelessSleeping | \* | \* |
| Manege | -56% | -56% |
| Traffic | -58% | -50% |
|  |  |  |  |
| 1080p | JohnnyLobby (LD) | -70% | -73% |
|  | Calendar | -52% | -46% |
|  | SVT15 | -69% | -60% |
|  | sedofCropped | -53% | -56% |
|  | UnderBoat1 | -68% | -52% |
|  |  |  |  |
| 720p | ThreePeople (LD) | -48% | -53% |
|  | BT709Parakeets | -66% | -65% |
|  | QuarterBackSneak | -58% | -58% |
|  | SVT01a | -73% | -73% |
|  | SVT04a | -36% | -35% |
|  |  |  |  |
| 480p | Cubicle (LD) | -45% | -45% |
|  | Anemone | -42% | -40% |
|  | BT709BirthdayFlash | -49% | -50% |
|  | Ducks | -72% | -74% |
|  | WheelAndCalender | \* | \* |
|  |  |  |  |
| Averages | Average UHD | -63.8% | -60.2% |
|  | Average 1080p | -62.5% | -57.3% |
|  | Average 720p | -56.1% | -56.8% |
|  | Average 480p | -52.1% | -52.4% |
|  | Average All | -58.7% | -56.7% |

\* In order for the BD-rate interpolation to work correctly, the MOS values should exhibit a smooth curve, and the interval of the averaging (shown as solid lines in the plots in section 3.1) should be interpolated from at least three MOS scores that are monotonically increasing with bit-rate. The sequences HomelessSleeping and WheelAndCalender did not satisfy this requirement and hence was not included in these results.

# Conclusions

Analysis of the subjective test results show that in 86% of the test points, HEVC and AVC have the same quality, even though the bit-rates of AVC are greater than or equal to approximately double the HEVC bit-rates.

By applying the MOS BD-rate measurement on the results of the subjective test, it is estimated that the HEVC Main profile achieves the same subjective quality as AVC High profile while requiring on average approximately 59% less bit-rate.

Therefore it is concluded that the objective of achieving a substantially greater bit-rate reduction over the AVC High Profile has been met by the HEVC standard.

# References

1. TK Tan, et. al.,, **“HEVC verification test plan”**, document JCTVC-P1011, Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11, San Jose, CA, January 2014.
2. T. K. Tan, A. Fujibayashi, Y. Suzuki, and J. Takiue, **“Objective and Subjective Evaluation of HM5.0”**, document JCTVC-H0116, Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11, San Jose, CA, February 2012.
3. Jens-Rainer Ohm, et. al., “**Comparison of the Coding Efficiency of Video Coding Standards – Including High Efficiency Video Coding (HEVC)**”, invited paper to IEEE CSVT, Special Issue on Emerging Research and Standards in Next Generation Video Coding (HEVC), December 2012.
4. Gisle Bjøntegaard, **“Calculation of Average PSNR Differences Between RD Curves”***,* ITU-T SG16/Q6, 13th VCEG Meeting, Austin, Texas, USA, April 2001, Doc. VCEG-M33.
5. Gisle Bjøntegaard, **"Improvements of the BD-PSNR model"**, ITU-T SG16/Q6, 35th VCEG Meeting, Berlin, Germany, July, 2008, Doc.VCEG-AI11.

# Acknowledgements

The ad hoc group wishes to thank all the organizations and individuals who contributed to the HEVC verification test:

* 4EVER, BBC, Kamerawerk, NTIA, Plannet, Inc., SVT, Technicolor and Vidyo for donating the test sequences.
* NTT DOCOMO, Inc. for providing the resources to prepare the test material.
* British Broadcasting Corporation (BBC) R&D and School of Computing, University of West of Scotland for conducting the subjective test.
* Dr. Vittorio Baroncini (MPEG Test Chairman) for his guidance and coordination the subjective test.

### Annex A (reproduced from the HEVC verification test plan [1])

### *Description of testing environment and methodology*

The test procedure foreseen for the formal subjective evaluation will consider two main requirements:

* to be as much as possible reliable and effective in verifying the performance in terms of subjective quality (and therefore adhering the existing recommendations);
* to take into account the evolution of technology and laboratory set-up oriented to the adoption of FPD (Flat Panel Display) and video server as video recording and playing equipment.

Therefore, one of the test methods described in [A1] are planned to be used, applying some modification to them, in relation to the kind of display, the video recording and play-back equipment.

A.1 Test method

The test method adopted for this evaluation is DCR (Degradation Category Rating) [A1].

A.1.1 Degradation Category Rating (DCR)

This 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 will be used under the schema of evaluation of the quality (and not of the impairment); for this reason a quality rating scale made of 11 levels will be adopted, ranging from "0" (lowest quality) to "10" (highest quality). The test will be held in three different laboratories located in countries speaking different languages: This implies that it is better not to use categorical adjectives (e.g. excellent good fair etc.) to avoid any bias due to a possible different interpretation by naive subjects speaking different languages.

All the video material used for these tests will consist of video clips of 10 seconds duration.

The structure of the Basic Test Cell (BTC) of DCR method is made by two consecutive presentations of the video clip under test; at first the original version of the video clip is displayed, immediately afterwards the coded version of the video clip is presented; then a message displays for 5 seconds asking the viewers to vote.



*Figure 6 - DCR BTC*

The presentation of the video clips will be preceded by a mid-grey screen displaying for one second.

A.2 How to express the visual quality opinion with DCR

The viewers will be asked to express their vote putting a mark on a scoring sheet.

The scoring sheet for a DCR test is made of a section for each BTC; each section has a box wherein which the viewer shall write the score ranging from 0 to 10. By writing a score of “10”, the subject will express an opinion of “best” quality, while by writing a score of “0” the subject will express an opinion of “worst” quality.

The vote has to be written when the message "Vote N" appears on the screen. The number "N" is a numerical progressive indication on the screen aiming to help the viewing subjects to use the appropriate box of the scoring sheet.

Scoring sheet Class C IVC english

*Figure 7 -Example of DSIS test method scoring sheet*

A.4 Training and stabilization phase

The outcome of a test is highly dependent on a proper training of the test subjects.

For this purpose, each subject has to be trained by means of a short practice (training) session.

The video material used for the training session must be different from those of the test, but the impairments introduced by the coding have to be as much as possible similar to those in the test.

The stabilization phase uses the test material of a test session; three BTCs, containing one sample of best quality, one of the worst quality and one of medium quality, are duplicated at the beginning of the test session. By this way, the test subjects have an immediate impression of the quality range they are expected to evaluate during that session.

The scores of the stabilization phase are discarded. Consistency of the behaviour of the subjects will be checked inserting in the session a BTC in which original is compared to original.

A.5 The laboratory set-up

The laboratory for a subjective assessment will be set up according to [A1], except for the selection of the display and the video play-out server.

For UHD video clips, high quality LCD monitors will be used with diagonal size equal to or higher than 56'' and able to accept resolutions of up to 3840x2160. Play-out of 3840x2048 video clips is done at the native resolution using the central area of the screen; the remaining part of the screen is set to a mid grey level (128 in 0-255 range)". In the case where the width of the sequence exceeds 3840, the left and right sides of the picture would be cropped and only the centre 3840 pixels are shown.

For other resolutions, High quality LCD monitors (or TV set) are used, having a diagonal size equal or higher of 40” and capable to accept resolution equal to 1920 x 1080. When using TV sets all the local colour and contrast features must be disabled (where applicable).

Play-out of 1080p, 720p and 480p video clips is done at the native resolution using the central area of the screen; the remaining part of the screen is set to a mid grey level (128 in 0-255 range).

The video play server, or the PC, used to play video has to be able to support the display of UHD, 1080p, 720p and 480p video formats, at 24, 30, 50 and 60 frames per second, without any limitation, or without introducing any additional temporal or visual degradation.

A.5.1 Viewing distance

The viewing distance varies according to the physical dimensions of the active part of the video; this will lead to a viewing distance varying from 1.5H to 4H, where H is equal to the height of the active part of the screen, depending on the size of the active part of the screen and its native resolution.

The number of subjects seating in front of the monitor is a function of the monitor size and of the selected viewing distance.

A.5.2 Viewing environment.

The test laboratory has to be carefully protected from any external visual or audio pollution.

Internal general light has to be low (just enough to allow the viewing subjects to fill out the scoring sheets) and a uniform light has to be placed behind the monitor, in a way no direct light hits the viewing subjects seated in front of the screen; the light behind he monitor must be dimmed to an intensity as specified in Table 4 of Recommendation ITU-T P.911 (“Typical viewing and listening conditions as used in audio-visual quality assessment”). No other light source is admitted, and in particular any light source directed to the screen or creating reflections; ceiling, floor and walls of the laboratory have to be made of non-reflecting material (e.g. carpet or velvet) and should have a colour tuned as close as possible to mid grey.

A.6 Overall test effort and subjects’ involvement

The duration of the test will depend on the number sequences tested in each category / resolution assigned to the test laboratories; in any case each viewing session will not run for more than 20 minutes and the same viewing subject will not participated to the test run for more than six hours in total. The same subject may not be enrolled for two consecutive days. Young humans subjects, equally distributed in gender, are hired, selecting them for an age from 18 to 30 and, highly preferably among University students of scientific faculties. Viewing subjects are compensated for their participation to the testing activities (compensation may be done in money or services).

A.7 Statistical analysis and presentation of the results

The data collected from the score sheets, filled out by the viewing subjects, will be stored in an Excel spread sheet.

Four spread-sheets will be prepared: four containing the results for UHD, 1080p, 720p and 480p (Main profile).

For each coding condition the Mean Opinion Score (MOS) and associated Confidence Interval (CI) values will be given in the spread-sheets.

The MOS and CI values will be used to draw graphs. The Graphs will be drawn grouping the results for each video test sequence. No graph grouping results from different video sequences will be considered.

From the “raw” data subject reliability should be calculated and the method used to assess subject reliability should be reported. Some criteria for subjective reliability are given in [A2] and [A3].

As an example, the reliability of a subject, could be achieved computing the correlation index between each score provided by a subject to the general MOS value assigned for that test point; in this regard a correlation index equal or superior to 0,75 (computed making the mean of all the correlation values) could be considered as valid for the acceptance of the subject

A.8 References:

1. International Telecommunication Union Standardization Sector; Recommendation ITU-T P.910 “Subjective video quality assessment methods for multimedia applications”
2. Pseudo Isochromatic Plates, engraved and printed by *The Beck Engraving Co., Inc*., Philadelphia and New York, United States.
3. KIRK (R.E.): Experimental Design – Procedures for the Behavioural Sciences, 2nd Editions, *Brooks/Cole Publishing Co*., California, 1982.

### Annex B

### *Preparation of test material*

B.1 Test conditions

The following were the test conditions used for the HEVC verification test.

1. Number of sequences and video resolutions:
   1. 5 sequences for each resolution (480p, 720p, 1080p and UHD)
2. Bitstreams
   1. Generated with HM 12.1 for HEVC bitstreams
   2. Generated with JM 18.5 for AVC bitstreams
3. Encoding parameters
   1. Fixed QP.
      1. 4 bit rate points per sequences covering the whole MOS range as much as possible.
   2. Bit depth
      1. 8 bits for 480p, 720p, 1080p and UHD.
   3. Coding structure depending on the nature of the sequence.
      1. Random access, RA (Storage/Streaming)
         1. Intra refresh at approximately 1 second intervals.
            1. Intra interval of 64 was used for sequences with 50 or 60 fps.
            2. Intra interval of 32 was used for sequences with 30 fps.
         2. Picture reordering allowed.
      2. Low delay, LD (Video conferencing)
         1. No Intra refresh.
         2. Without picture reordering.
   4. Other settings as in the configuration files
      1. cfg/encoder\_randomaccess\_main.cfg or encoder\_lowdelay\_main.cfg for HM
      2. bin/HM-like/encoder\_JM\_RA\_B\_HE.cfg or bin/HM-like/encoder\_JM\_LB\_HE.cfg configurations for JM18.5  
         Note: for encoder\_JM\_RA\_B\_HE.cfg the parameter Log2MaxFNumMinus4 was set to 2 instead of 0, so that the bitstream could be played by some players.

B.2 Test Sequences

The following test sequences were selected for the subjective test.

Table : Selected test sequences and properties

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sequence | Source [Copyright] | Width x Height | Frame rate | Bit depth | Length (frames) | RA / LD |
| BT709Birthday | Technicolor [C3] | 3840x2160 | 50 | 8 | 500 | RA |
| Book | BBC [C4] | 3840x2160 | 50 | 8 | 500 | RA |
| manage | 4EVER [C2] | 3840x2160 | 60 | 8 | 600 | RA |
| HomelessSleeping | Kamerawerk [C8] | 3840x2160 | 60 | 8 | 600 | RA |
| traffic | Plannet, Inc [C1] | 4096x2048 | 30 | 8 | 300 | RA |
| JohnnyLobby | Vidyo [C7] | 1920x1080 | 60 | 8 | 600 | LD |
| Calendar | BBC [C4] | 1920x1080 | 50 | 8 | 500 | RA |
| SVT15 | SVT [C6] | 1920x1080 | 50 | 8 | 500 | RA |
| sedofCropped | 4EVER [C2] | 1920x1080 | 60 | 8 | 600 | RA |
| UnderBoat1 | NTIA [C5] | 1920x1080 | 30 | 8 | 300 | RA |
| ThreePeople | Vidyo [C7] | 1280x720 | 60 | 8 | 600 | LD |
| BT709Parakeets | Technicolor [C3] | 1280x720 | 50 | 8 | 500 | RA |
| QuarterBackSneak1 | NTIA [C5] | 1280x720 | 30 | 8 | 300 | RA |
| SVT01a | SVT [C6] | 1280x720 | 50 | 8 | 500 | RA |
| SVT04a | SVT [C6] | 1280x720 | 50 | 8 | 500 | RA |
| Cubicle | Vidyo [C7] | 832x480 | 30 | 8 | 300 | LD |
| Anemone | NTIA [C5] | 832x480 | 30 | 8 | 300 | RA |
| BT709BirthdayFlash | Technicolor [C3] | 832x480 | 50 | 8 | 500 | RA |
| Ducks | Plannet, Inc [C1] | 832x480 | 60 | 8 | 600 | RA |
| WheelAndCalendar | BBC [C4] | 832x480 | 50 | 8 | 500 | RA |

B.3 Encoding Results

The following table shows the JM18.5 and HM12.1 encoding results on the sequences shown in Table 4. The QP parameters were selected such that the bit-rate of the HM12.1 bitstreams are approximately half of the bit-rate of the corresponding JM18.5 bitstreams. The range of the QP values was also selected so that the subjective quality of the encoded sequence span as large a range of the MOS range as possible.

Table : JM18.5 and HM12.1 encoding results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | JM18.5 | | HM12.1 | |  |
|  |  | QPISlice | kbps (a) | QPISlice | kbps (b) | Bit-rate Difference (a - b)/b |
| UHD | BT709Birthday | 24 | 15769 | 27 | 7023 | 55% |
|  |  | 30 | 7509 | 32 | 3701 | 51% |
|  |  | 35 | 4501 | 37 | 2175 | 52% |
|  |  | 40 | 2866 | 42 | 1321 | 54% |
|  | Book | 22 | 13009 | 24 | 6123 | 53% |
|  |  | 27 | 6192 | 29 | 2814 | 55% |
|  |  | 32 | 3563 | 33 | 1662 | 53% |
|  |  | 37 | 2212 | 37 | 1047 | 53% |
|  | HomelessSleeping | 23 | 38876 | 25 | 16608 | 57% |
|  |  | 26 | 12168 | 27 | 5526 | 55% |
|  |  | 31 | 5617 | 31 | 2581 | 54% |
|  |  | 37 | 3112 | 35 | 1488 | 52% |
|  | menage | 27 | 36607 | 31 | 17840 | 51% |
|  |  | 31 | 21261 | 35 | 10466 | 51% |
|  |  | 35 | 12731 | 39 | 6139 | 52% |
|  |  | 38 | 8819 | 42 | 4021 | 54% |
|  | traffic | 27 | 13309 | 31 | 6205 | 53% |
|  |  | 32 | 6583 | 36 | 3137 | 52% |
|  |  | 37 | 3618 | 40 | 1844 | 49% |
|  |  | 42 | 2090 | 44 | 1056 | 49% |
| 1080p | JohnnyLobby | 23 | 2761 | 24 | 1477 | 46% |
|  | (low delay) | 27 | 895 | 28 | 445 | 50% |
|  |  | 31 | 468 | 32 | 227 | 51% |
|  |  | 35 | 298 | 36 | 139 | 54% |
|  | Calendar | 23 | 3057 | 26 | 1407 | 54% |
|  |  | 27 | 1668 | 30 | 787 | 53% |
|  |  | 32 | 958 | 34 | 487 | 49% |
|  |  | 36 | 686 | 38 | 322 | 53% |
|  | SVT15 | 28 | 6805 | 31 | 3549 | 48% |
|  |  | 32 | 3767 | 35 | 1903 | 49% |
|  |  | 36 | 2214 | 39 | 1028 | 54% |
|  |  | 41 | 1109 | 43 | 547 | 51% |
|  | sedofCropped | 27 | 13762 | 31 | 6345 | 54% |
|  |  | 31 | 6726 | 35 | 3165 | 53% |
|  |  | 35 | 3462 | 39 | 1619 | 53% |
|  |  | 39 | 1863 | 42 | 971 | 48% |
|  | UnderBoat1 | 24 | 4407 | 27 | 1910 | 57% |
|  |  | 29 | 2026 | 31 | 990 | 51% |
|  |  | 33 | 1196 | 35 | 554 | 54% |
|  |  | 37 | 729 | 39 | 325 | 55% |
| 720p | ThreePeople | 25 | 1414 | 28 | 648 | 54% |
|  | (low delay) | 29 | 739 | 32 | 346 | 53% |
|  |  | 33 | 433 | 36 | 200 | 54% |
|  |  | 38 | 240 | 40 | 117 | 51% |
|  | BT709Parakeets | 26 | 1151 | 30 | 553 | 52% |
|  |  | 30 | 709 | 34 | 333 | 53% |
|  |  | 33 | 499 | 37 | 232 | 54% |
|  |  | 37 | 332 | 40 | 161 | 52% |
|  | QuarterBackSneak | 22 | 3844 | 25 | 1959 | 49% |
|  |  | 27 | 2039 | 30 | 1009 | 51% |
|  |  | 32 | 1145 | 35 | 541 | 53% |
|  |  | 37 | 694 | 39 | 336 | 52% |
|  | SVT01a | 27 | 1271 | 31 | 594 | 53% |
|  |  | 31 | 733 | 35 | 336 | 54% |
|  |  | 35 | 435 | 38 | 215 | 51% |
|  |  | 39 | 283 | 41 | 132 | 53% |
|  | SVT04a | 28 | 4178 | 32 | 2154 | 48% |
|  |  | 31 | 2665 | 35 | 1361 | 49% |
|  |  | 34 | 1699 | 38 | 849 | 50% |
|  |  | 37 | 1072 | 41 | 503 | 53% |
| 480p | Cubicle | 22 | 1014 | 24 | 505 | 50% |
|  | (low delay) | 25 | 502 | 27 | 264 | 48% |
|  |  | 30 | 210 | 32 | 106 | 49% |
|  |  | 35 | 105 | 37 | 49 | 53% |
|  | Anemone | 25 | 990 | 29 | 478 | 52% |
|  |  | 29 | 581 | 33 | 271 | 53% |
|  |  | 33 | 353 | 37 | 164 | 54% |
|  |  | 38 | 202 | 41 | 99 | 51% |
|  | BT709BirthdayFlash | 29 | 1515 | 33 | 774 | 49% |
|  |  | 32 | 1003 | 37 | 499 | 50% |
|  |  | 35 | 679 | 41 | 315 | 54% |
|  |  | 39 | 399 | 44 | 205 | 49% |
|  | Ducks | 27 | 2178 | 31 | 1033 | 53% |
|  |  | 32 | 1063 | 36 | 517 | 51% |
|  |  | 35 | 719 | 39 | 344 | 52% |
|  |  | 38 | 492 | 42 | 226 | 54% |
|  | WheelAndCalender | 22 | 1129 | 25 | 519 | 54% |
|  |  | 27 | 513 | 30 | 243 | 53% |
|  |  | 32 | 295 | 35 | 136 | 54% |
|  |  | 37 | 190 | 39 | 93 | 51% |

### Annex C

### *Copyright of test sequences*

1. ***Plannet inc.***

The test sequence and all intellectual property rights therein remain the property of the owner below. This material can only be used for the purpose of developing HEVC standards. This material cannot be distributed with charge. The owner makes no warranties with respect to the material and expressly disclaims any warranties regarding its fitness for any purpose.

Owner of these sequences:

Owner: Plannet inc.

Production: Plannet inc. and IMAGICA Corp.

1. ***4EVER Consortium***

User agrees that the Sequences and all intellectual property rights therein remain the property of the 4EVER consortium members or their licensors.

These Sequences can only be used for internal research and test work dealing with Ultra High Definition, including research and test for standardization purposes. Attributing the work to 4EVER consortium will be done by attaching the following attribution notice to the Sequences:

***“Copyright © 2012-2013, all rights reserved to the 4EVER participants and their licensors. 4EVER consortium: Orange, Technicolor, ATEME, France Télévisions, INSA-IETR, Globecast, TeamCast, Telecom ParisTech, HighlandsTechnologies Solutions, www.4ever-project.com, contact: maryline.clare@orange.com. The 4EVER research Project is coordinated by Orange and has received funding from the French State (FUI/Oseo) and French local Authorities (Région Bretagne) associated to the European funds FEDER.”***

Your attribution must not be in any way that suggests that 4EVER endorses you or your use of the video sequences.

1. ***Technicolor R&D***

Technicolor R&D France SNC (“Technicolor”) is the legal owner of the video files in YUV video file format provided in the table above (“the Content”) and retains all right, title and interest (including copyright and authorship rights) in and to this Content.

Subject to compliance with the terms and conditions set forth in the present authorization of use, Technicolor hereby grants to any member of the HEVC and SHVC standardization group (“the User”), a personal, non- transferrable, non-sub-licensable, worldwide, royalty free license under Technicolor owned or controlled copyrights to display (and to copy and modify as technically necessary) the Content solely for the purpose of User’s internal processing, testing and assessment of the Content (or if relevant for the purpose of joint processing, testing and assessment of the Content with another “User”) in order to:

* evaluate the User’s contributions to the HEVC and SHVC standards (and if relevant to any multi- standard performed in JCT-VC context)
* evaluate Technicolor’s contributions to the HEVC and SHVC standards (and if relevant to any multi- standard performed in JCT-VC context)
* evaluate other third party HEVC and SHVC standards contributors’ contributions to HEVC and SHVC standards (and if relevant to any multi-standard performed in JCT-VC context)

1. ***British Broadcasting Corporation (BBC)***

The video sequences provided above and all intellectual property rights therein remain the property of the BBC. The BBC is making available the video sequences for use under the ***Creative Commons Attribution-NonCommercial 3.0 licence***.

You are free to use, share (to copy, distribute and transmit) or remix (to adapt) the BBC video sequences, provided that:

* **No-commercial**- you may not use these video sequences for commercial purposes; and
* **Attribution**- you attribute the work to the BBC by indicating that the video sequences (or elements thereof) were produced by the BBC. Your attribution must not be in any way that suggests that the BBC endorses you or your use of the video sequences.

1. ***The National Telecommunications and Information Administration (NTIA)***

<http://www.its.bldrdoc.gov/resources/video-quality-research/video-footage.aspx>

Standards committees can use CDVL R&D content within subjective tests to validate objective video quality models (e.g., ATIS, VQEG, ITU).

1. ***Sveriges Television AB (SVT), Sweden***

Individuals and organizations extracting sequences from this archive agree that the sequences and all intellectual property rights therein remain the property of Sveriges Television AB (SVT), Sweden. These sequences may only be used for the purpose of developing, testing and presenting technology standards. SVT makes no warranties with respect to the materials and expressly disclaim any warranties regarding their fitness for any purpose.

1. ***Vidyo, Inc.***

Vidyo donates the sequences to the public domain (JCTVC-P0042)

1. ***Kamerawerk***

The video sequences provided above and all intellectual property rights therein remain the property of the Kamerawerk. The Kamerawerk is making available the video sequences for use under the ***Creative Commons Attribution-NonCommercial 3.0 licence***.