

*Title:* **SCCE5 Test 3.2.1: In-loop color-space transform**

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## Abstract

This document describes the proposed technology and reports the simulation results of test 3.2.1. In the proposed method, the color-space transform converts prediction error in 4:4:4 chroma format into YCoCg color space. As a result, redundancy among three color components is allegedly reduced. One flag per coding unit may be signalled to indicate the usage of color-space transform.

Compared to the SCM-1.0 basis using intraBC with full-frame search, the proposed solution achieves average {G, B, R} BD-rate reductions of {18.0%, 6.1%, 7.8%}, {20.5%, 6.6%, 9.1%} and {20.0%, 4.1%, 6.6%} for AI, RA and LD, respectively, and average BD-rate reductions of {0.9%, 1.5%, 1.6%}, {0.8%, 1.5%, 1.6%} and {1.0%, 1.8%, 2.1%} for AI, RA and LD, respectively, in YCbCr coding. For lossless coding, the bit-rate savings of the proposed solution are up to 4.3% for the AI case.

Compared to the SCM-1.0 basis using intraBC with 2-CTU search, the proposed solution achieves BD-rate reductions of {17.8%, 5.9%, 7.5%}, {20.3%, 6.4%, 8.9%} and {20.2%, 4.1%, 6.6%} for AI, RA and LD, respectively, and reductions of {0.6%, 1.4%, 1.4%}, {0.8%, 1.5%, 1.7%} and {1.1%, 1.8%, 2.2%} for AI, RA and LD, respectively, in YCbCr coding. For lossless coding, the savings are up to 4.3% for the AI case.

## 1 Introduction

At the 17th JCT-VC meeting, two proposals [2] [3] on in-loop color-space transform were determined to be further studied in SCCE5. In this proposal, a joint solution is described wherein the color-space transform is performed in the residual domain, i.e., just before invoking the cross-component prediction

(CCP) and conventional transform during the encoding process. Each CU adaptively enables or disables color-space transform based on a rate-distortion criterion.

## 2 Proposed method

The decoding flow for the proposed in-loop color-space transform is depicted in Figure 1. The added module, namely inverse color transform, is highlighted. When one block is coded with color transform enabled, after the conventional inverse DCT/DST transform and CCP, the inverse color transform is invoked to convert the residual domain back to the original domain. A flag is signaled to indicate the usage of color-space transform in a CU. For intra BC and inter modes, such a flag is signaled only when there is at least one non-zero coefficient in the current CU. For intra modes, such a flag is signaled only when the chroma mode of the first PU (i.e., top-left PU within one CU) is coded with DM mode.

Two different color-space transforms are applied depending on whether the CU is coded losslessly or in a lossy manner. The forward and the inverse color-space transforms for lossy coding use the YCoCg transform matrices, which are defined as follows:

$$\text{Forward: } \begin{bmatrix} C'_0 \\ C'_1 \\ C'_2 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 0 & -2 \\ -1 & 2 & -1 \end{bmatrix} \begin{bmatrix} C_0 \\ C_1 \\ C_2 \end{bmatrix} / 4 \quad \text{Inverse: } \begin{bmatrix} C_0 \\ C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & -1 \\ 1 & 0 & 1 \\ 1 & -1 & -1 \end{bmatrix} \begin{bmatrix} C'_0 \\ C'_1 \\ C'_2 \end{bmatrix}$$

wherein the original color space ( $C_0, C_1, C_2$ ) may correspond to (R, G, B) or (Y, U, V). For lossless coding, the YCoCg-R transform in [1] is used.

The forward color transform in lossy coding is not normalized, which results in signal decline when the transform is applied. Considering that the norm of the forward transform is roughly equal to one quarter of square root of 6 for  $C_0$  and  $C_2$ , and half of square root of 2 for  $C_1$ , delta QPs of (-5, -3, -5) are used to compensate such decline for the three color components, respectively. That is, when the color-space transform is applied, the quantization parameter is set equal to (QP - 5, QP - 3, QP - 5) for the three components, respectively, where QP is the 'normal' QP value for the CU. In the deblocking process, the normal QP value is used for all blocks.

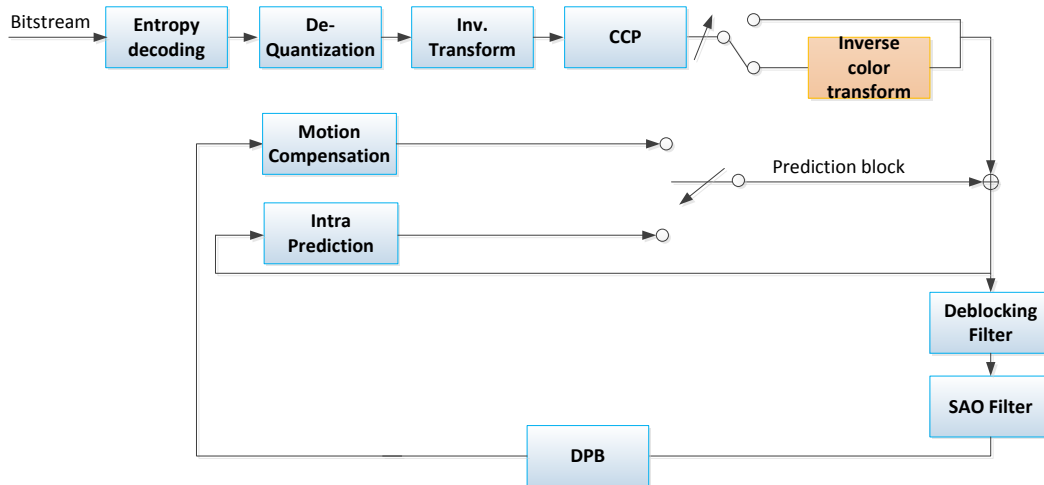


Figure 1. Decoding flowchart of in-loop color-space transform scheme

## 3 Encoder speedup

To reduce the complexity of encoder, the proposed method in [2] is applied in this contribution. In addition, whether to check the second rate-distortion (RD) loop (with or without color transform for YUV or RGB inputs, respectively) of the current CU is dependent on the RD cost of its parent CU with smaller depth. For example, if the RD cost of the first loop is smaller than that of the second loop for the parent CU of the current CU, the second loop is not invoked for current CU. Furthermore, when color transform is enabled for intra blocks, the chroma and luma components shall share the same prediction mode, i.e.,

the chroma mode is equal to DM mode as it is done for CCP in HEVC Range Extensions. Therefore, there is no need to check other chroma modes except DM mode when color transform is enabled.

## 4 Non-normative coding tools

Based on the characteristics of RGB test sequences, two more non-normative coding tools are introduced in this proposal to further improve the coding efficiency of in-loop color-space transform. The detailed descriptions of the two tools are given in the following sub-sections.

### 4.1 Modified block vector estimation process for IntraBC

When the original video input is in RGB, if the current CU is coded in IntraBC mode, and adaptive color transform is enabled, the RD performance using the block vectors derived in YCoCg domain is usually better than using the block vectors derived in RGB domain. Therefore, block vectors are estimated in the YCoCg color space for CUs coded with IntraBC and with adaptive color transform on.

### 4.2 Weighted distortion for chroma component

It is observed that when the lambda for the chroma component is increased compared to that for the luma component, the overall performance for RGB coding could be further improved although the quality of chroma components may be sacrificed a little bit. The modified lambda value for the chroma component is dependent on the input quantization parameter.

$$\lambda_{chroma} = \frac{\lambda_{luma}}{W_{QP}}$$

wherein  $W_{QP}$  is equal to  $2^{\frac{\text{delta}(QP)}{3}}$  and the delta(QP) is defined in the following table:

**Table 1. Specification of delta**

| QP        | [0, 14] | [15, 29] | [30, 36] | [37, 38] | [39, 40] | [41, 42] | [43, 52] |
|-----------|---------|----------|----------|----------|----------|----------|----------|
| delta(QP) | 0       | -1       | -2       | -3       | -4       | -5       | -6       |

## 5 Complexity Analysis

Since the proposed color-transform is applied in the residual domain, the decoder complexity of the proposed method involves the inverse color-space transform after inverse transform and CCP. The additional complexity is minor since only addition and shift operations are required.

## 6 Simulation Results

Two sets of coding performance comparisons are reported. To check the best performance of in-loop color-space transform, the non-normative coding tools, as described in section 4 are enabled and the corresponding results are presented in sub-section 6.1. The simulation results for the proposed method without non-normative coding tools are also provided, and details could be found in sub-section 6.2. For each test set, the method is tested on the top of SCM1.0. The common test conditions for SCC [4] are used.

### 6.1 Coding performance with non-normative coding tools

In this section, the experimental results of the proposed method with non-normative coding tools are presented.

Table 2 and Table 3 report the coding gain of the whole proposal for the lossy and lossless coding, respectively, under SCC test conditions with full IntraBC. For lossy coding, the proposed solution achieves the average {G, B, R} BD-rate reductions of {18.0%, 6.1%, 7.8%}, {20.5%, 6.6%, 9.1%} and

{20.0%, 4.1%, 6.6%} for AI, RA and LD, respectively, and the average BD-rate reductions of {0.9%, 1.5%, 1.6%}, {0.8%, 1.5%, 1.6%} and {1.0%, 1.8%, 2.1%} for AI, RA and LD, respectively, in YCbCr coding. For lossless coding, the bit-rate savings of the proposed solution could be up to 4.3% for the AI case.

Table 4 and Table 5 report the coding gain of the whole proposal for the lossy and lossless coding, respectively, under SCC test conditions with local IntraBC. The proposed solution achieves the average {G, B, R} BD-rate reductions of {17.8%, 5.9%, 7.5%}, {20.3%, 6.4%, 8.9%} and {20.2%, 4.1%, 6.6%} for AI, RA and LD, respectively, and the average BD-rate reductions of {0.6%, 1.4%, 1.4%}, {0.8%, 1.5%, 1.7%} and {1.1%, 1.8%, 2.2%} for AI, RA and LD, respectively, in YCbCr coding. For lossless coding, the bit-rate savings of the proposed solution could be up to 4.3% for the AI case.

**Table 2. Coding gains of full proposal compared to anchor (Lossy, SCM1.0 with full-frame IntraBC)**

|                                         | All Intra |        |        | Random Access |        |        | Low delay B |        |        |
|-----------------------------------------|-----------|--------|--------|---------------|--------|--------|-------------|--------|--------|
|                                         | G/Y       | B/U    | R/V    | G/Y           | B/U    | R/V    | G/Y         | B/U    | R/V    |
| RGB, text & graphics with motion, 1080p | -10.7%    | -4.6%  | -4.8%  | -10.1%        | -3.4%  | -3.6%  | -8.7%       | -1.9%  | -1.7%  |
| RGB, text & graphics with motion,720p   | -17.2%    | -4.7%  | -7.9%  | -19.9%        | -5.3%  | -10.2% | -20.2%      | -3.7%  | -8.6%  |
| RGB, mixed content, 1440p               | -20.9%    | -7.7%  | -7.7%  | -27.6%        | -11.0% | -10.4% | -28.2%      | -8.4%  | -7.3%  |
| RGB, mixed content, 1080p               | -15.9%    | -3.6%  | -4.8%  | -19.9%        | -5.4%  | -6.2%  | -20.1%      | -1.2%  | -1.9%  |
| RGB, Animation, 720p                    | -25.2%    | -17.7% | -14.9% | -25.6%        | -16.0% | -11.6% | -24.3%      | -11.3% | -5.0%  |
| RGB, camera captured, 1080p             | -25.3%    | -5.1%  | -9.9%  | -27.9%        | -5.4%  | -14.0% | -26.2%      | -1.8%  | -12.1% |
| YUV, text & graphics with motion, 1080p | -2.0%     | -1.4%  | -1.8%  | -1.3%         | -1.1%  | -1.5%  | -1.7%       | -1.8%  | -1.8%  |
| YUV, text & graphics with motion,720p   | -1.3%     | -1.4%  | -2.1%  | -1.9%         | -1.7%  | -2.7%  | -2.1%       | -2.1%  | -3.5%  |
| YUV, mixed content, 1440p               | -0.1%     | -1.1%  | -1.2%  | 0.2%          | -1.1%  | -0.9%  | 0.2%        | -1.0%  | -1.0%  |
| YUV, mixed content, 1080p               | -0.2%     | -0.5%  | -0.6%  | 0.1%          | -0.2%  | -0.7%  | 0.1%        | -1.6%  | -1.0%  |
| YUV, Animation, 720p                    | 0.2%      | -6.7%  | -3.8%  | -0.1%         | -7.1%  | -3.3%  | -0.1%       | -6.4%  | -4.2%  |
| YUV, camera captured, 1080p             | 0.1%      | -0.1%  | 0.0%   | 0.4%          | -0.1%  | 0.2%   | 0.3%        | -0.1%  | -0.1%  |
| Enc Time[%]                             | 141%      |        |        | 110%          |        |        | 109%        |        |        |
| Dec Time[%]                             | 100%      |        |        | 96%           |        |        | 97%         |        |        |

**Table 3. Coding gains of full proposal compared to anchor (Lossless, SCM1.0 with full-frame IntraBC)**

|                                         | All Intra               |                           | Random Access           |                           | Low Delay B             |                           |
|-----------------------------------------|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|
|                                         | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) |
| RGB, text & graphics with motion, 1080p | 1.7%                    | 1.7%                      | 1.3%                    | 1.1%                      | 1.2%                    | 0.9%                      |
| RGB, text & graphics with motion,720p   | 0.9%                    | 1.0%                      | 0.7%                    | 1.1%                      | 0.7%                    | 1.1%                      |
| RGB, mixed content, 1440p               | 2.1%                    | 2.1%                      | 1.1%                    | 1.1%                      | 1.1%                    | 1.1%                      |
| RGB, mixed content, 1080p               | 1.7%                    | 1.7%                      | 0.4%                    | 0.4%                      | 0.2%                    | 0.2%                      |
| RGB, Animation, 720p                    | 4.3%                    | 4.3%                      | 1.5%                    | 1.5%                      | 1.5%                    | 1.5%                      |
| RGB, camera captured, 1080p             | 0.4%                    | 0.2%                      | -0.2%                   | -0.2%                     | -0.1%                   | -0.2%                     |
| YUV, text & graphics with motion, 1080p | 0.4%                    | 0.4%                      | 0.4%                    | 0.3%                      | 0.5%                    | 0.3%                      |
| YUV, text & graphics with motion,720p   | 0.2%                    | 0.1%                      | 0.5%                    | 0.2%                      | 0.6%                    | 0.2%                      |
| YUV, mixed content, 1440p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, mixed content, 1080p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, Animation, 720p                    | 1.6%                    | 1.6%                      | 0.3%                    | 0.3%                      | 0.3%                    | 0.3%                      |
| YUV, camera captured, 1080p             | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| Enc Time[%]                             | 147%                    |                           | 122%                    |                           | 108%                    |                           |
| Dec Time[%]                             | 102%                    |                           | 101%                    |                           | 99%                     |                           |

**Table 4. Coding gains of full proposal compared to anchor (SCM1.0 with local IntraBC)**

|                                         | All Intra |        |        | Random Access |        |        | Low delay B |        |        |
|-----------------------------------------|-----------|--------|--------|---------------|--------|--------|-------------|--------|--------|
|                                         | G/Y       | B/U    | R/V    | G/Y           | B/U    | R/V    | G/Y         | B/U    | R/V    |
| RGB, text & graphics with motion, 1080p | -10.5%    | -4.3%  | -4.3%  | -10.2%        | -3.2%  | -3.2%  | -8.9%       | -1.6%  | -1.4%  |
| RGB, text & graphics with motion,720p   | -17.2%    | -4.5%  | -7.8%  | -19.6%        | -5.2%  | -9.9%  | -20.5%      | -3.8%  | -8.9%  |
| RGB, mixed content, 1440p               | -19.9%    | -7.0%  | -7.0%  | -26.8%        | -10.6% | -10.2% | -28.3%      | -8.4%  | -7.3%  |
| RGB, mixed content, 1080p               | -15.6%    | -3.4%  | -4.7%  | -19.3%        | -5.2%  | -6.1%  | -20.4%      | -1.5%  | -2.2%  |
| RGB, Animation, 720p                    | -25.2%    | -17.7% | -14.9% | -25.6%        | -16.0% | -11.6% | -24.3%      | -11.4% | -5.0%  |
| RGB, camera captured, 1080p             | -25.3%    | -5.1%  | -9.9%  | -27.9%        | -5.3%  | -14.0% | -26.2%      | -1.8%  | -12.1% |
| YUV, text & graphics with motion, 1080p | -1.6%     | -1.2%  | -1.6%  | -1.4%         | -1.3%  | -1.6%  | -1.8%       | -1.7%  | -1.8%  |
| YUV, text & graphics with motion,720p   | -0.9%     | -1.1%  | -1.7%  | -1.8%         | -1.7%  | -3.0%  | -2.3%       | -2.2%  | -4.0%  |
| YUV, mixed content, 1440p               | 0.0%      | -1.4%  | -1.4%  | 0.1%          | -0.9%  | -1.0%  | 0.2%        | -1.2%  | -0.9%  |
| YUV, mixed content, 1080p               | -0.1%     | -0.6%  | -0.6%  | 0.0%          | -0.6%  | -0.8%  | -0.2%       | -0.7%  | -1.4%  |
| YUV, Animation, 720p                    | 0.2%      | -6.7%  | -3.8%  | 0.0%          | -6.8%  | -3.3%  | -0.1%       | -6.0%  | -3.8%  |
| YUV, camera captured, 1080p             | 0.1%      | -0.1%  | -0.1%  | 0.5%          | 0.1%   | 0.2%   | 0.3%        | -0.2%  | -0.2%  |
| Enc Time[%]                             | 142%      |        |        | 111%          |        |        | 112%        |        |        |
| Dec Time[%]                             | 99%       |        |        | 97%           |        |        | 98%         |        |        |

**Table 5. Coding gains of full proposal compared to anchor (Lossless, SCM1.0 with local-frame IntraBC)**

|                                         | All Intra               |                           | Random Access           |                           | Low Delay B             |                           |
|-----------------------------------------|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|
|                                         | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) |
| RGB, text & graphics with motion, 1080p | 1.3%                    | 1.4%                      | 0.9%                    | 0.9%                      | 0.9%                    | 0.7%                      |
| RGB, text & graphics with motion,720p   | 1.0%                    | 1.0%                      | 0.8%                    | 1.1%                      | 0.7%                    | 1.1%                      |
| RGB, mixed content, 1440p               | 1.7%                    | 1.7%                      | 1.0%                    | 1.0%                      | 1.1%                    | 1.1%                      |
| RGB, mixed content, 1080p               | 1.5%                    | 1.5%                      | 0.4%                    | 0.4%                      | 0.1%                    | 0.1%                      |
| RGB, Animation, 720p                    | 4.3%                    | 4.3%                      | 1.5%                    | 1.5%                      | 1.5%                    | 1.5%                      |
| RGB, camera captured, 1080p             | 0.4%                    | 0.2%                      | -0.2%                   | -0.2%                     | -0.1%                   | -0.2%                     |
| YUV, text & graphics with motion, 1080p | 0.4%                    | 0.5%                      | 0.4%                    | 0.3%                      | 0.4%                    | 0.3%                      |
| YUV, text & graphics with motion,720p   | 0.2%                    | 0.1%                      | 0.5%                    | 0.2%                      | 0.6%                    | 0.2%                      |
| YUV, mixed content, 1440p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, mixed content, 1080p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, Animation, 720p                    | 1.6%                    | 1.6%                      | 0.3%                    | 0.3%                      | 0.4%                    | 0.4%                      |
| YUV, camera captured, 1080p             | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| Enc Time[%]                             | 148%                    |                           | 105%                    |                           | 107%                    |                           |
| Dec Time[%]                             | 102%                    |                           | 94%                     |                           | 99%                     |                           |

## 6.2 Coding performance with encoder optimization disabled

In this section, the experimental results of the proposed method with non-normative coding tools are presented. The performance of YCbCr coding is kept unchanged.

Table 6 and Table 7 report the coding gain of the whole proposal for the lossy and lossless coding, respectively, under SCC test conditions with full IntraBC. For lossy coding, the proposed solution achieves the average {G, B, R} BD-rate reductions of {15.0%, 7.0%, 8.2%}, {16.8%, 7.2%, 9.4%} and {16.6%, 6.3%, 8.5%} for AI, RA and LD, respectively, in RGB coding. For lossless coding, the bit-rate savings of the proposed solution could be up to 4.3% for the AI case.

Table 8 and Table 9 report the coding gain of the whole proposal for the lossy and lossless coding, respectively, under SCC test conditions with local IntraBC. The proposed solution achieves the average

{G, B, R} BD-rate reductions of {14.7%, 6.9%, 8.1%}, {16.6%, 7.2%, 9.3%} and {16.7%, 6.5%, 8.7%} for AI, RA and LD, respectively, in RGB coding. For lossless coding, the bit-rate savings of the proposed solution could be up to 4.3% for the AI case.

**Table 6 Coding gains of proposal (wo/ non-normative tools) compared to anchor (with full-frame IntraBC)**

|                                         | All Intra |        |        | Random Access |        |        | Low delay B |        |        |
|-----------------------------------------|-----------|--------|--------|---------------|--------|--------|-------------|--------|--------|
|                                         | G/Y       | B/U    | R/V    | G/Y           | B/U    | R/V    | G/Y         | B/U    | R/V    |
| RGB, text & graphics with motion, 1080p | -7.4%     | -3.4%  | -3.4%  | -6.3%         | -2.8%  | -2.9%  | -5.5%       | -2.2%  | -2.1%  |
| RGB, text & graphics with motion,720p   | -14.4%    | -5.9%  | -8.2%  | -15.8%        | -5.7%  | -9.6%  | -16.5%      | -5.7%  | -9.5%  |
| RGB, mixed content, 1440p               | -18.5%    | -9.2%  | -9.0%  | -23.8%        | -11.3% | -10.8% | -24.6%      | -10.7% | -9.5%  |
| RGB, mixed content, 1080p               | -13.5%    | -5.3%  | -5.9%  | -16.1%        | -6.2%  | -6.3%  | -16.4%      | -4.2%  | -4.6%  |
| RGB, Animation, 720p                    | -22.5%    | -20.3% | -16.9% | -21.6%        | -18.4% | -13.4% | -20.1%      | -16.4% | -9.1%  |
| RGB, camera captured, 1080p             | -21.2%    | -6.5%  | -11.4% | -25.9%        | -7.8%  | -17.0% | -23.5%      | -4.9%  | -16.5% |
| YUV, text & graphics with motion, 1080p | -2.0%     | -1.4%  | -1.8%  | -1.3%         | -1.1%  | -1.5%  | -1.7%       | -1.8%  | -1.8%  |
| YUV, text & graphics with motion,720p   | -1.3%     | -1.4%  | -2.1%  | -1.9%         | -1.7%  | -2.7%  | -2.1%       | -2.1%  | -3.5%  |
| YUV, mixed content, 1440p               | -0.1%     | -1.1%  | -1.2%  | 0.2%          | -1.1%  | -0.9%  | 0.2%        | -1.0%  | -1.0%  |
| YUV, mixed content, 1080p               | -0.2%     | -0.5%  | -0.6%  | 0.1%          | -0.2%  | -0.7%  | 0.1%        | -1.6%  | -1.0%  |
| YUV, Animation, 720p                    | 0.2%      | -6.7%  | -3.8%  | -0.1%         | -7.1%  | -3.3%  | -0.1%       | -6.4%  | -4.2%  |
| YUV, camera captured, 1080p             | 0.1%      | -0.1%  | 0.0%   | 0.4%          | -0.1%  | 0.2%   | 0.3%        | -0.1%  | -0.1%  |
| Enc Time[%]                             | 146%      |        |        | 112%          |        |        | 110%        |        |        |
| Dec Time[%]                             | 101%      |        |        | 98%           |        |        | 97%         |        |        |

**Table 7. Coding gains of proposal (wo/ non-normative tools) compared to anchor (Lossless, full-frame IntraBC)**

|                                         | All Intra               |                           | Random Access           |                           | Low Delay B             |                           |
|-----------------------------------------|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|
|                                         | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) |
| RGB, text & graphics with motion, 1080p | 0.6%                    | 0.5%                      | 0.8%                    | 0.3%                      | 0.7%                    | 0.2%                      |
| RGB, text & graphics with motion,720p   | 0.8%                    | 0.9%                      | 0.7%                    | 1.0%                      | 0.7%                    | 1.1%                      |
| RGB, mixed content, 1440p               | 2.0%                    | 2.0%                      | 1.1%                    | 1.1%                      | 1.1%                    | 1.1%                      |
| RGB, mixed content, 1080p               | 1.6%                    | 1.6%                      | 0.4%                    | 0.4%                      | 0.1%                    | 0.1%                      |
| RGB, Animation, 720p                    | 4.3%                    | 4.3%                      | 1.5%                    | 1.5%                      | 1.5%                    | 1.5%                      |
| RGB, camera captured, 1080p             | 0.4%                    | 0.2%                      | -0.2%                   | -0.2%                     | -0.1%                   | -0.2%                     |
| YUV, text & graphics with motion, 1080p | 0.4%                    | 0.4%                      | 0.4%                    | 0.3%                      | 0.5%                    | 0.3%                      |
| YUV, text & graphics with motion,720p   | 0.2%                    | 0.1%                      | 0.5%                    | 0.2%                      | 0.6%                    | 0.2%                      |
| YUV, mixed content, 1440p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, mixed content, 1080p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, Animation, 720p                    | 1.6%                    | 1.6%                      | 0.3%                    | 0.3%                      | 0.3%                    | 0.3%                      |
| YUV, camera captured, 1080p             | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| Enc Time[%]                             | 146%                    |                           | 119%                    |                           | 109%                    |                           |
| Dec Time[%]                             | 101%                    |                           | 100%                    |                           | 101%                    |                           |

**Table 8 Coding gains of proposal (wo/ non-normative tools) compared to anchor (Lossy, with local IntraBC)**

|                                         | All Intra |        |        | Random Access |        |        | Low delay B |        |        |
|-----------------------------------------|-----------|--------|--------|---------------|--------|--------|-------------|--------|--------|
|                                         | G/Y       | B/U    | R/V    | G/Y           | B/U    | R/V    | G/Y         | B/U    | R/V    |
| RGB, text & graphics with motion, 1080p | -7.2%     | -3.4%  | -3.3%  | -6.3%         | -2.8%  | -2.9%  | -5.8%       | -2.3%  | -2.2%  |
| RGB, text & graphics with motion,720p   | -14.3%    | -6.0%  | -8.5%  | -15.5%        | -5.8%  | -9.5%  | -16.7%      | -6.0%  | -9.9%  |
| RGB, mixed content, 1440p               | -17.4%    | -8.4%  | -8.3%  | -23.1%        | -11.1% | -10.6% | -24.7%      | -10.9% | -9.8%  |
| RGB, mixed content, 1080p               | -12.9%    | -5.1%  | -5.7%  | -15.5%        | -6.0%  | -6.3%  | -16.6%      | -5.0%  | -4.9%  |
| RGB, Animation, 720p                    | -22.5%    | -20.4% | -16.9% | -21.7%        | -18.4% | -13.5% | -20.1%      | -16.5% | -9.2%  |
| RGB, camera captured, 1080p             | -21.2%    | -6.5%  | -11.4% | -25.8%        | -7.8%  | -17.0% | -23.5%      | -4.9%  | -16.5% |
| YUV, text & graphics with motion, 1080p | -1.6%     | -1.2%  | -1.6%  | -1.4%         | -1.3%  | -1.6%  | -1.8%       | -1.7%  | -1.8%  |
| YUV, text & graphics with motion,720p   | -0.9%     | -1.1%  | -1.7%  | -1.8%         | -1.7%  | -3.0%  | -2.3%       | -2.2%  | -4.0%  |
| YUV, mixed content, 1440p               | 0.0%      | -1.4%  | -1.4%  | 0.1%          | -0.9%  | -1.0%  | 0.2%        | -1.2%  | -0.9%  |
| YUV, mixed content, 1080p               | -0.1%     | -0.6%  | -0.6%  | 0.0%          | -0.6%  | -0.8%  | -0.2%       | -0.7%  | -1.4%  |
| YUV, Animation, 720p                    | 0.2%      | -6.7%  | -3.8%  | 0.0%          | -6.8%  | -3.3%  | -0.1%       | -6.0%  | -3.8%  |
| YUV, camera captured, 1080p             | 0.1%      | -0.1%  | -0.1%  | 0.5%          | 0.1%   | 0.2%   | 0.3%        | -0.2%  | -0.2%  |
| Enc Time[%]                             | 145%      |        |        | 112%          |        |        | 112%        |        |        |
| Dec Time[%]                             | 98%       |        |        | 99%           |        |        | 98%         |        |        |

**Table 9. Coding gains of proposal (wo/ non-normative tools) compared to anchor (Lossless, local IntraBC)**

|                                         | All Intra               |                           | Random Access           |                           | Low Delay B             |                           |
|-----------------------------------------|-------------------------|---------------------------|-------------------------|---------------------------|-------------------------|---------------------------|
|                                         | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Total) | Bit-rate saving (Average) |
| RGB, text & graphics with motion, 1080p | 0.5%                    | 0.3%                      | 0.6%                    | 0.1%                      | 0.6%                    | 0.1%                      |
| RGB, text & graphics with motion,720p   | 0.9%                    | 0.9%                      | 0.8%                    | 1.0%                      | 0.7%                    | 1.1%                      |
| RGB, mixed content, 1440p               | 1.7%                    | 1.6%                      | 1.0%                    | 1.0%                      | 1.1%                    | 1.1%                      |
| RGB, mixed content, 1080p               | 1.4%                    | 1.4%                      | 0.4%                    | 0.4%                      | 0.1%                    | 0.1%                      |
| RGB, Animation, 720p                    | 4.3%                    | 4.3%                      | 1.5%                    | 1.5%                      | 1.5%                    | 1.5%                      |
| RGB, camera captured, 1080p             | 0.4%                    | 0.2%                      | -0.2%                   | -0.2%                     | -0.1%                   | -0.2%                     |
| YUV, text & graphics with motion, 1080p | 0.4%                    | 0.5%                      | 0.4%                    | 0.3%                      | 0.4%                    | 0.3%                      |
| YUV, text & graphics with motion,720p   | 0.2%                    | 0.1%                      | 0.5%                    | 0.2%                      | 0.6%                    | 0.2%                      |
| YUV, mixed content, 1440p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, mixed content, 1080p               | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| YUV, Animation, 720p                    | 1.6%                    | 1.6%                      | 0.3%                    | 0.3%                      | 0.4%                    | 0.4%                      |
| YUV, camera captured, 1080p             | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      | 0.0%                    | 0.0%                      |
| Enc Time[%]                             | 146%                    |                           | 105%                    |                           | 107%                    |                           |
| Dec Time[%]                             | 101%                    |                           | 95%                     |                           | 96%                     |                           |

## 7 References

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## **8 Patent rights declaration(s)**

**Qualcomm Incorporation may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

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