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| **Joint Video Exploration Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  28th Meeting: Torino, IT, 15–21 July 2017 | Document: JCTVC-AB0040r1 |

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| *Title:* | **AHG9: Experiments on using local QP adaptation in the context of an HLG container** | | |
| *Status:* | Input document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This document reports experiments related to HLG content coding. The approach is based on the luma-based QP adaptation used in the current HM and JEM anchors. The dQP table used for BT.2100 PQ content is converted based on the HLG conversion chain of display-referred linear-light content. Various derived dQP tables, for different content peak luminance, have been tested. For non-native HLG HDR content (content initially provided in EXR or BT.2100 PQ format), reported BD-rate gains are of 2.0% for tPSNR-Y, 1.2% for PSNRL100, 1.5% for wPSNR-Y, 3.2% for DE100, 0.6% and 2.4% for wPSNR-U and V. For native HLG content, reported BD-rate gains are of 1.2% for tPSNR-Y, 1.5% for PSNRL100, 1.9% for wPSNR-Y, 2.4% for DE100, 4.7% and 3.0% for wPSNR-U and V. Partial visual observations are also reported.

# Introduction

In [1] a QP adaptation approach is described to perceptually improve the coding of HDR content in a BT.2100 PQ container. The approach consists in deriving a local dQP value, per block, based on the average value of the prediction signal. The solution is non-normative (the dQP values are explicitly coded in the stream). The table plotted in Figure 1 has been experimentally built from visual testing, and is used for generating the JCT-VC and JVET HDR anchors.

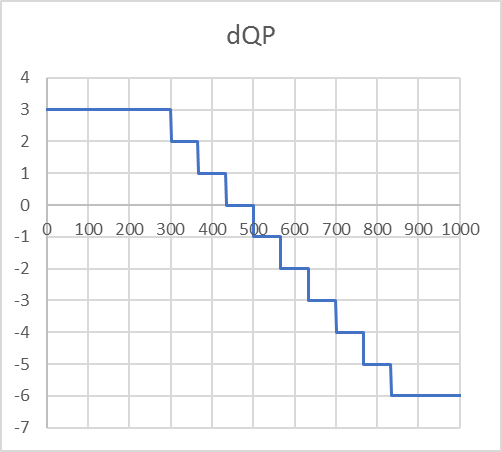
 

Figure 1. Suggested dQP table for PQ video signal.

The goal of the experiments reported in this contribution were to explore a similar solution for HLG content coding.

# Mapping from HLG to PQ

For the experiments reported in this contribution, the dQP table used for HDR in BT.2100 PQ container was considered as a reference table. The goal is then from this PQ-adapted dQP table to derive other tables adapted to HDR in BT.2100 HLG container. To derive these new tables, the approach consists first in deriving mapping functions from HLG signals to PQ representation.

The used approach is illustrated in Figure 2. We consider a given content gamut (BT.709, P3D65 or BT.2020), and a content peak luminance. For all scanned values in the RGB cube, considered as normalized linear-light values, a conversion to PQ Y’CbCr and HLG Y’CbCr is achieved, following the conversion process recommended respectively in [1] and [2]. This enables to gather statistics on the mapping from HLG to PQ luma values. From these statistics, an average mapping look-up-table is derived.



Figure 2. Derivation of the mapping from HLG to PQ.

We have observed that the resulting mapping tables for BT.709 and for P3D65 content gamuts are very close. As most of the content produced today, and especially used in JCT-VC and JVET, has been graded with BT.709 or P3D65 monitors, we consider the mapping functions built for a P3D65 content gamut. These mapping tables are plotted in Figure 3 for various peak luminance values. They are referred below as mapping functions fHLG-PQ ( x ).

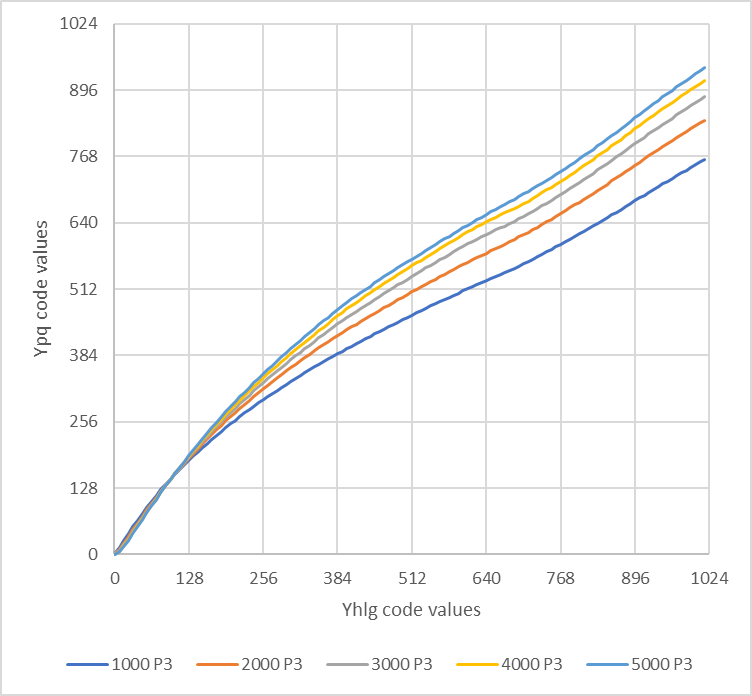


Figure 3. Mapping functions from HLG to PQ representation for P3 content gamut.

# Derivation of the dQP tables for HLG

The PQ dQP table was initially built based on an analysis of the mapping function fPQ of a signal represented a BT.2100 PQ container, into the same signal represented into an SDR-like container. The derivative of this function, f′PQ, corresponds to a scaling function from which the dQP value can be deduced as:

dQP = Int( –6 \* log2( f′PQ ( x ) ) ) (eq.1)

As described in [3], the scaling function f′PQ ( x ) was experimentally tuned as follows:

f′PQ( x ) = 2^max( –3, min(6, 0.015\*x – 1.5 – 6) ) / 6 ) (eq.2)

in line with the dQP table of Figure 1.

When considering an HLG signal, a similar approach can apply. The mapping fHLG of an HLG signal to an SDR-like signal can as a concatenation of a conversion from HLG to PQ, then PQ to an SDR-like representation. This corresponds to the following formula:

fHLG ( x ) = fPQ ( fHLG-PQ ( x ) ) (eq.3)

The corresponding scaling function is derived as:

f′HLG ( x ) = f′PQ ( fHLG-PQ ( x ) ) \* f′HLG-PQ ( x ) (eq.4)

from which the dQP value can be derived as:

dQPHLG ( x ) = Round( –6 \* log2( f′HLG ( x ) ) ) (eq.5)

Figure 4 plots the derivatives (f′ HLG-PQ) of the mapping functions from HLG to PQ plotted in Figure 3.

Figure 4. Derivatives of mapping functions from HLG to PQ representation for P3 content gamut.

Figure 5 plots the different concatenated dQP tables resulting from (eq.5), for various peak luminance (and P3D65 content gamut). It can be noted that the curves have rather similar shapes. Moving from one curve to another one can be done by using a QP offset. Which could mean that one table would be enough whatever the considered content peak luminance, the adjustment being potentially done use a global offset (such as slice\_qp\_offset).

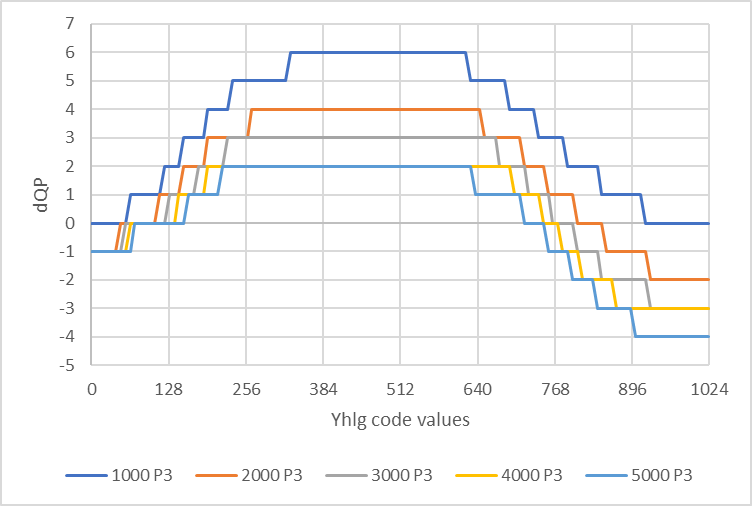


Figure 5. dQP tables for HLG, for various peak luminance (considering P3D65 content gamut).

# Experimental results

## Using content non-natively in BT.2100 HLG format

The tests were done using the various HDR content used in JCT-VC and JVET, not natively in HLG format (content initially provided in EXR or BT.2100 PQ format). The different sequences were converted to the BT.2100 HLG format, following the linear-light 4:4:4 RGB to HLG Y’CbCr 4:2:0 conversion process described in [2]. The different converted HLG content were then processed by the encoding/decoding chain, and performance was evaluated using HDRMetrics (v0.15 of HDRTools package).

The reference is the HM16.15 without any luma-based local dQP adaptation, and any chroma QP adaptation. Tests were done using the HM16.15 in RA configuration.

The tests were made with different dQP tables depicted in Figure 5. For each table, two sets of tests were made, one without using the chroma QP adaptation, and one using the chroma QP adaptation. When the chroma QP adaptation was activated, the following parameters were used for both Cb and Cr components, obtained after a few steps of iterative tuning:

* WCGPPSEnable=1
* WCGPPSChromaQpScale=-0.2
* WCGPPSChromaQpOffset=4
* WCGPPSCbQpScale=1
* WCGPPSCrQpScale=1

Figure 6 shows the shape of the chroma QP adaptation for the Cb component compared to the one used in the HM HDR anchors. The curve (cbQP1) is less aggressive than in the anchors.

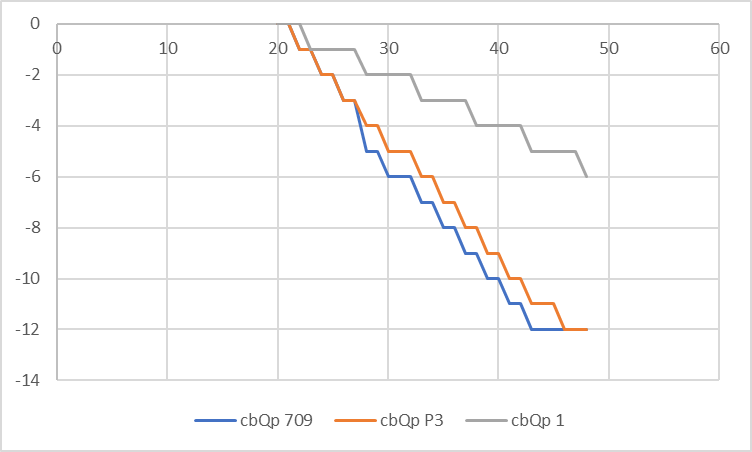


Figure 6. chroma QP adaptation.

The HDR metrics were computed end-to-end. For the wPSNR metrics, which are based on a BT.2100 PQ representation, the HLG signal was reconverted to BT.2100 PQ for generating the metrics.

The complete set of results is reported in one of the attached xls files. A summary is reported in the following tables.

Table 1 recaps the average results obtained with the different dQP tables, without chroma QP adaptation (top table) or with chroma QP adaptation (bottom QP table). The cell named “AVG Y/L” corresponds to an average of the luma/luminance related-metrics (tPSNR-Y, PSNRL100, wPSNR-Y). The cell named “AVG Chr” corresponds to an average of the chroma/chrominance related-metrics (DE100, wPSNR-U, wPSNR-V).

The various dQP tables all lead to slight gains for the different considered metrics. When no chroma QP adaptation is used, the AVG Y/L gains are from 1.4% to 1.7%, and the AVG Chr gains are from 1.3% to 2.1%. When chroma QP adaptation is used, the AVG Y/L losses are from 0.0% to 0.4%, and the AVG Chr gains are from 12.1% to 15.0%.

Table 1. Average BDR variations for various dQP tables.





Per sequence results are reported in Table 2, without chroma QP adaptation (top table) or with chroma QP adaptation (bottom QP table), with the metrics AVG Y/L and AVG Chr.

Table 3 provides a different picture, without chroma QP adaptation, for AVG Y/L (top) and AVG Chr (bottom). From these data, we can categorize the results as follows:

* Improved performance: FireEater, Market, SunRise, Hurdles, Starting, Showgirl, BikeSparkler cut1, MargicHour\_cut3, MagicHour\_cut2
* Similar performance: BikeSparkler cut2, MagicHour\_cut1, WarmNight\_cut1, BalloonFestival
* Decreased performance: GarageExit, WarmNight\_cut2

In conclusion, in terms of objective HDR metrics, the usage of a luma-based adaptive QP using one of the dQP tables depicted in Figure 5 is globally beneficial. The dQP table 2000, without chroma QP adjustment, seems to give a satisfactory compromise, with BDR gains:

* for luma/luminance of 2.0% for tPSNR-Y, 1.2% for PSNRL100, 1.5% for wPSNR-Y, which gives an average value AVG Y/L of 1.6%;
* for chroma/chrominance of 3.2% for DE100, 0.6% and 2.4% for wPSNR-U and V, which gives an average value AVG Chr of 2.1%.

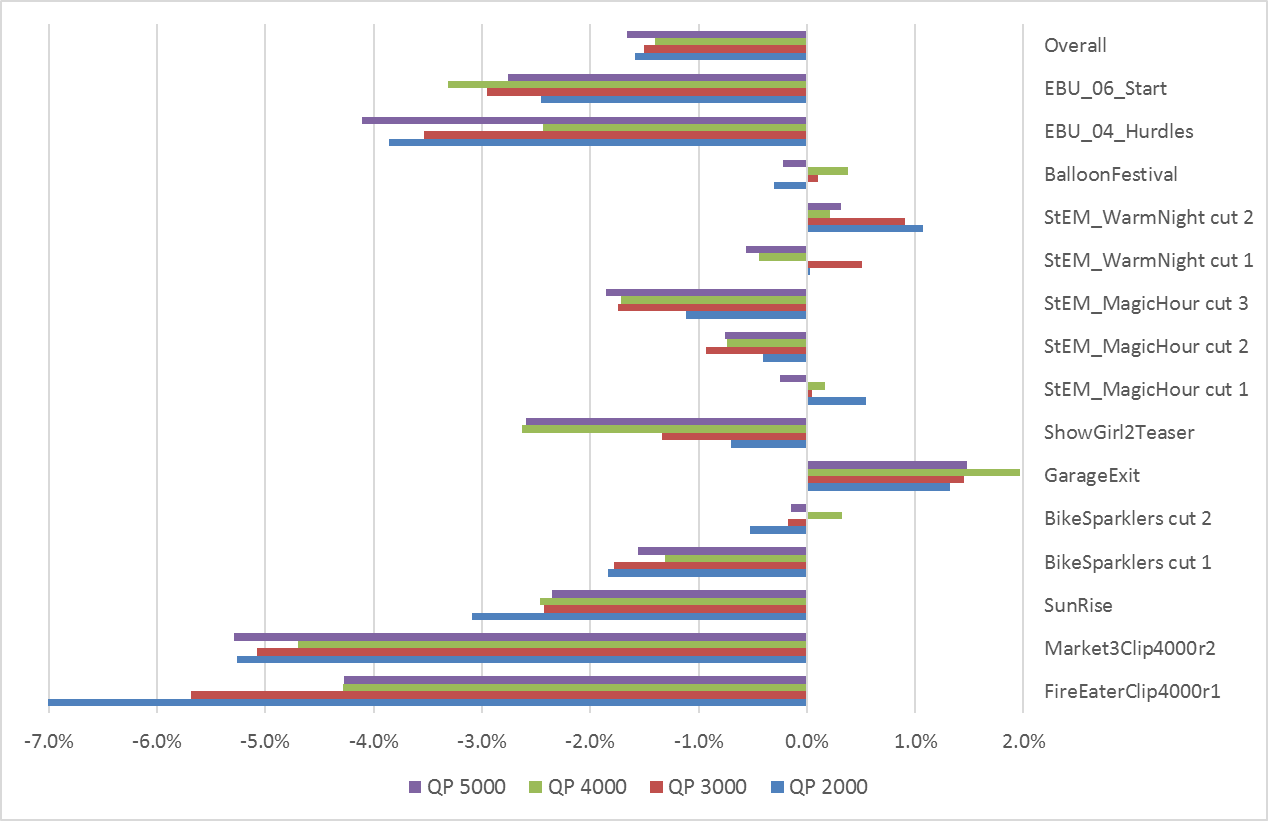
The usage of a chroma QP adaptation changes the balance luma/chroma, with AVG Y/L gain of 0.0% and AVG Chr gain of 15.1%.

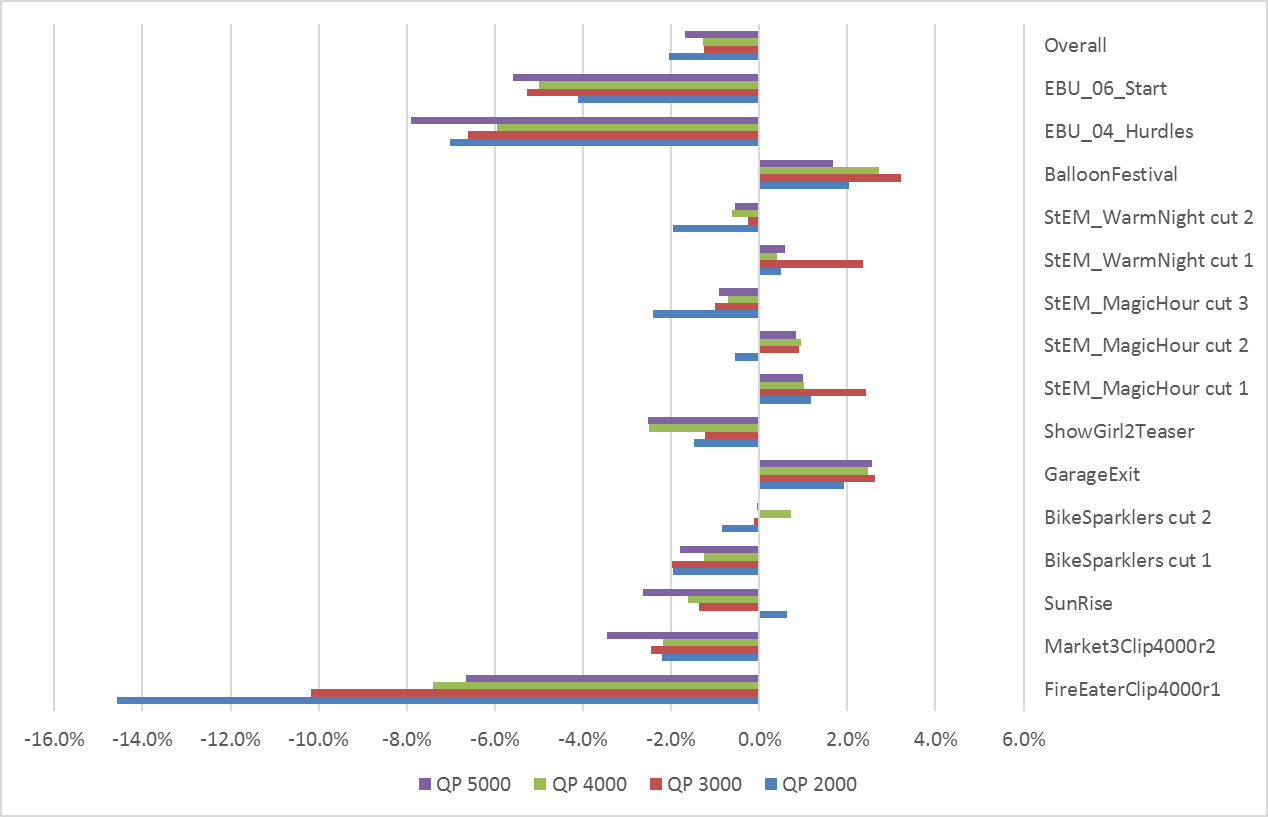
Table 2. Per sequence results for various dQP tables, without (top) or with (bottom) chroma QP adaptation.





Table 3. Per sequence results for various dQP tables, for AVG Y/L (top) and AVG Chr (bottom), without chroma QP adaptation.





## Using native BT.2100 HLG format

Results are also available using the HLG content made available to JVET. Only the dQP table 1000 has been used.

As in previous section, the HDR metrics were computed end-to-end. For the wPSNR metrics, which are based on a BT.2100 PQ container, the HLG signal was converted to a PQ container for generating the metrics.

For the test method, the reference is the HM16.15 without any luma-based local dQP adaptation, and any chroma QP adaptation.

### Results for AI configuration, 1 picture

Reported tests in this sub-section were done using the HM16.15 for 1 picture intra. Results are reported in Table 4. The complete set of results is reported in one of the attached xls files. When no chroma QP adaptation is used, small gains are observed in most cases. The gain for AVG Y/L is of 0.6%, and for AVG Chr of 0.3%.

Table 4. Per sequence results for dQP 1000 table, with (top) and without (bottom) chroma QP adaptation (1 picture AI configuration).





### Results for RA configuration

Results in table 5 relate to the RA configuration, comparing the test case (using QP adaptation) and the reference (no usage of the QP adaptation). In both cases, there is no chroma QP adaptation. The complete set of results is reported in one of the attached xls files. Gains are observed in most cases. The gain for AVG Y/L is of 1.6%, and for AVG Chr of 3.4%. Sequence HLG4 seems to particularly benefit from the QP adaptation approach. The impact for HLG2, HLG3, HLG6 and HLG7 seems limited.

These results are in line with the results reported in section 4.1 for HDR content non-natively in BT.2100 HLG representation.

Table 5. Per sequence results for dQP 1000 table, without chroma QP adaptation (RA configuration).



# Visual check

Due to lack of time, the visual checks were not exhaustive. The visual differences remain quite small and difficult to catch in video mode, even if in still picture mode, slight improvements in texture sharpness are generally observed. In static textured dark or bright areas, some slight improvements can be observed. The attached pdf and the pictures below show some illustrations of the observed visual improvements (using the dQP table 2000 for non-native HLG content, and the dQP table 1000 for native HLG content).

Below are some snapshots for the native HLG content (using the dQP table 1000).

HLG5, picture 0, lowest rate (left: no dQP, right: dQP)

For native HLG content, for the RA case, similar observations can be made as for non-native HLG content. Slight texture improvements can be observed using dQP, but often difficult to catch in video mode. For HLG4, more details can be observed even in video mode.

Snapshots for HLG4 are shown in the figures below, showing sharper texture on most part of the pictures.

HLG4, 1 picture 55 (left: no dQP, right: dQP)

HLG4, 1 picture 55 (left: no dQP, right: dQP)

# Conclusions

In this contribution, we reported experiments of the usage of the PQ dQP table, converted for HLG using the HLG conversion chain of display-referred signal described in [2].

It was observed that some of the tested dQP tables can provide BD-rate gains based on the recommended HDR metrics. For non-native HLG HDR content, gains using the dQP table 2000 are of 2.0% for tPSNR-Y, 1.2% for PSNRL100, 1.5% for wPSNR-Y, 3.2% for DE100, 0.6% and 2.4% for wPSNR-U and V. For native HLG content, gains of 0.9% for tPSNR-Y, 0.1% for PSNRL100, 0.7% for wPSNR-Y, -0.3% for DE100, 0.9% and 0.2% for wPSNR-U and V, are observed.

Partial visual observations made so far seem to be in line with the objective metrics results. However, the visual benefit still needs further evaluated.

# References

[1] J. Samuelsson, C. Fogg, A. Norkin, A. Segall, J. Ström, G. J. Sullivan, P. Topiwala, A. Tourapis (editors), Conversion and Coding Practices for HDR/WCG Y′CbCr 4:2:0 Video with PQ Transfer Characteristics (Draft 4), JCTVC-Z1017, Geneva, CH, 12-20 Jan 2017.

[2] E. François, D. Rusanovskyy, G. J. Sullivan, P. Topiwala, P. Yin (editors), Signalling, Backward Compatibility, and Display Adaptation for HDR/WCG Video (Draft 2), JCTVC-Z1012, Geneva, CH, 12-20 Jan 2017.

[3] J. Zhao, A. Segall, S.-H. Kim, K. Misra, “De-quantization and scaling for next generation containers”, JVET-B0054, Feb 2016, San Diego, USA.

# Patent rights declaration(s)

**Technicolor 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).**