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| *Title:* | Some observations on visual quality of Hybrid Log-Gamma (HLG) TF processed video (CE7) | | |
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# Abstract

This document summarizes some of the observations made by us on the visual quality of the video when the Hybrid Log-Gamma (HLG) Transfer Function is used. The focus here is on the backward compatibility to the SDR systems. It was observed that when HLG processed video is displayed on a legacy SDR TV, hue in various parts of the video gets shifted depending upon the brightness of the color samples. It is shown that this shift in hue is caused by the shift in the chromaticity of samples. This is different than what is expected by various color appearance models (e.g. Hunt effect, Stevens effect and others) describing how the perceived colorfulness changes with luminance. The main cause of this brightness-dependent shift in chromaticity appears to be due to the fact that for brighter intensities the forward HLG TF is not the same as BT.709/BT.1886 that the legacy TVs assume. That causes a luminance dependent error in the chromaticity produced by those TVs. One of the impacts of this effect is that as an object moves from a brighter to less bright area in the same sequence, its color changes noticeably.

# Introduction

The exploratory experiment 7 (CE7) was established at the 113th MPEG meeting (N15800). One of the purposes was to the do informal evaluation of the visual quality of the decoded HDR and SDR video.

Hybrid Log-Gamma (HLG) Transfer Function (TF) is designed to possibly provide backward compatibility with the “legacy” SDR systems. At this stage, in MPEG’s work, the “legacy” systems are taken to be the SDR systems not needing color gamut conversion (i.e., for example, not needing BT.2020 to BT.709 color gamut conversion) but needing only the dynamic range conversion. If the legacy SDR TV cannot process BT.2020 container then it is assumed the BT.2020 container is removed externally and the video is provided with appropriate format. Figure 1, taken from N15800 [1], shows at a high level the end-to-end chain associated with HLG based distribution.

There are two categories of experiments described in N15800 [1]. In the first one (category CE7.1) a fixed system gamma function is used, and in the second one (category CE7.2) the system gamma is varied. In this document we describe the observations associated with the visual quality of the video in CE7.1.

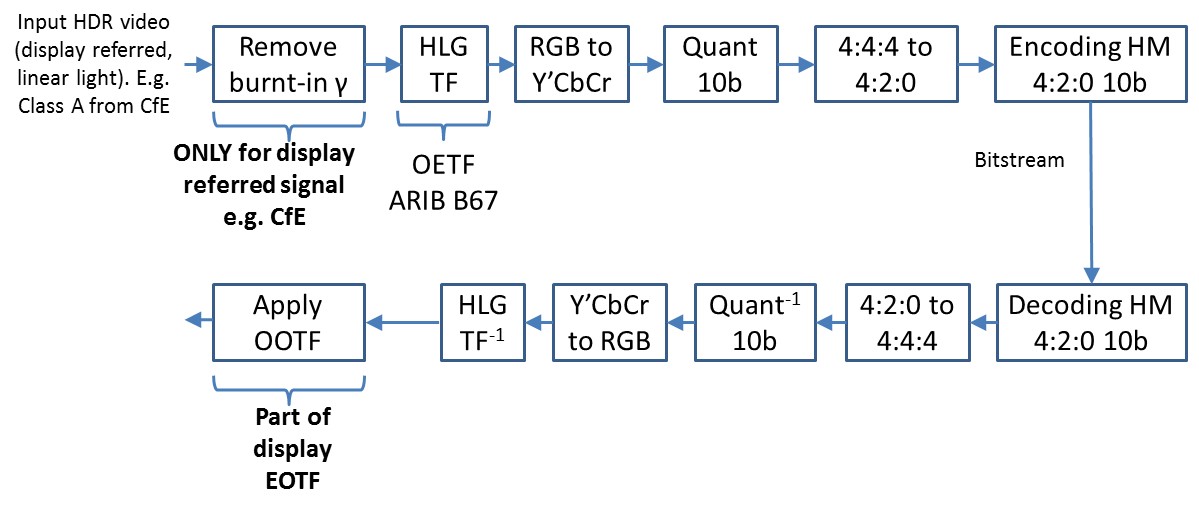


Figure 1. Generation of HLG TF based bit stream and video.

# CE7.1 Backward Compatibility (BC) using fixed system gamma for the MPEG test sequences

Several bit streams were generated by BBC for Categories 7.1a and 7.1b (gamma = 1.6). Test materials and coding conditions are described in N15800 [1]. We were able to match the md5sums provided by BBC for those bit streams. We were also able to generate video corresponding to the ShowGirl sequence. The decoded bitstreams were played back on a legacy SDR TV. The legacy SDR TV used here does not understand a BT.2020 container format. Therefore, conversion from BT.2020 container to BT.709 was first performed externally on the decoded video before displaying it on the SDR TV via HDMI. In the conversion, the decoded BT.2020 video was first converted to linear RGB assuming a source gamma of 2.2 (BT.1886), and then converted to BT.709. For reference, the original EXR sequences were also viewed on a SIM2 HDR display.

In the SDR backward compatibility experiment we provided the video to an SDR TV display as well as to a SIM2 HDR TV. We are finding that, in general, the video on the SDR TV looks washed out and there is significant change in the color hue in comparison to that in the original video. This is true even when the video is not compressed or lightly compressed. So, this does not seem to be associated with compression. Figures 2 - 3 show these distortions in two MPEG test sequences. The pictures shown here were captured by a camera pointing to the legacy SDR TV that does not understand HDR and BT.2020. The corresponding original video is shown on the SIM2 HDR display in Figures 2(a) and 3(a), while Figures 2(b) and 3(b) show side-by-side portions of the 7.1a and 7.1b streams on the legacy SDR TV.

Although the shift in hue is noticed in a very wide range of colors, the most noticeable shift in hue in these sequences was observed in the colors that are in the region along the Red-Green curve of the CIE diagram. For example, in the Hurdles Test Sequence (Figure 2) the color of the ground looks quite different than the original orange color. In the GarageExit Test Sequence the orange in the conduit in the background looks significantly different than that in the original sequence (Figure 3). Also, the pictures on the SDR TV look “washed out”. The pictures generated by 7.1b looked significantly more “washed out” than those in 7.1a.

The amount and the direction of the shift in hue seems to be also a function of the brightness of the object. The part that is even more noticeable is that if an object moves from a less bright area to brighter area, the hue changes quite noticeably. We have an ARRIS internal video consisting of racing cars. The original color of the cars is orange where the RGB values are approximately in the ratio of 2:1:0.3 in BT.2020. Two different original HDR frames of this sequence are shown in Figure 4a and 5a on a SIM2 HDR display. In Figure 4 the car in the front has bright light shining on it. In Figure 5 that car does not have as bright a light as in Figure 4. As the cars move from brighter (Figure 4) to less bright areas (Figure 5), the color shifts from yellow-orange (Figure 4b) to orange (Figure 5b) when the (uncompressed BT.709) HLG is viewed on the SDR TV. As this shift is observed within the same video sequence, it does not seem to be associated with any internal processing a TV might be doing.

To test it further in a more controllable experiment, an EXR test pattern of three orange color bars in BT.709 with RGB ratios of roughly 105:18:3 was generated. The color bars had a maximum Red intensity of about 290, 1050, and 1800 nit. Since these bars are computer generated, no burnt in gamma removal was performed (gamma = 1). Assuming a maximum brightness of 3630 nit, a YCbCr 10-bit 4:2:0 HLG version was generated and played back on a display that has the ability to display in SDR and HDR (HLG) modes. Figure 6 (a) and (b) show camera snapshots of the last two color bars in SDR and HDR modes, respectively, which give an idea of the perceived color on the display, although the colors are better seen directly on the display. (The first bar with lowest brightness is not shown as its color is not properly reflected in the camera snapshots.) In the SDR mode the brighter color bar on the right appears to have an orange-yellowish hue shift compared to the less bright color bar, similar to our ARRIS car sequence observation, while in HDR mode both bars appear to have a consistent orange hue.

For the three input color bars, the corresponding (x,y,Y) color space values are shown in the left column in Table 1. The right column shows the result of these values after having gone through an HLG TF (with max 3630 nit) followed by a TF with gamma = 2.0 (TF normalized to match HLG at low brightness), in an attempt to simulate a display gamma. For the first bar (input Red=290), the output reflects the same input values as TF inverts the HLG TF. However, as brightness increases in the second and third bar, the output chromaticity values start to deviate from the input as the HLG TF and gamma TF start to differ. In this case, the output x component decreases while the output y component increases. This may help to explain how the orange color bar hue shifts from orange to yellow-orange as the brightness is increased.

|  |  |  |
| --- | --- | --- |
|  | Input Red=290 | Output |
| x | 0.5414 | 0.5414 |
| y | 0.3811 | 0.3811 |
| Y | 97.81 | 97.81 |

|  |  |  |
| --- | --- | --- |
|  | Input Red=1050 | Output |
| x | 0.5414 | 0.5112 |
| y | 0.3811 | 0.3968 |
| Y | 354.15 | 282.31 |

|  |  |  |
| --- | --- | --- |
|  | Input Red=1800 | Output |
| x | 0.5414 | 0.4865 |
| y | 0.3811 | 0.4096 |
| Y | 607.12 | 419.12 |

Table 1. Input and output color space values for three color bars with increasing intensity, where the output is computed after applying an HLG TF to the input (using max 3630 nit) followed by a TF function with gamma = 2.0.

In another example, an EXR test pattern of four blue color bars in BT.709 with RGB ratios of roughly 39:12:255 was generated. The color bars had a maximum blue intensity of about 450, 900, 1800, and 3600 nit. Since these bars are computer generated, no burnt in gamma removal was performed (gamma = 1). Assuming a maximum brightness of 3630 nit, a YCbCr 10-bit 4:2:0 HLG version was generated, and Figure 7 (a) and (b) show camera snapshots of the color bars in SDR and HDR modes, respectively. In the SDR mode the brighter two color bars on the right have a magenta-purplish hue shift compared to the less bright blue color bars, while in HDR mode all bars appear to have a consistent blue hue.



(a)



(b)

Figure 2. Hurdles frame 0 - (a) original HDR, (b) QP = 23, 7.1a (left) and 7.1b (right)



(a)

  
(b)

Figure 3. GarageExit frame 209 - (a) original HDR, (b) QP = 24, 7.1a (left) and 7.1b (right)



(a)



(b)

Figure 4. A scene in RaceCar with brighter light on the car - (a) original HDR, (b) original HLG

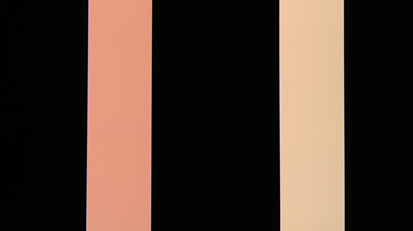


(a)

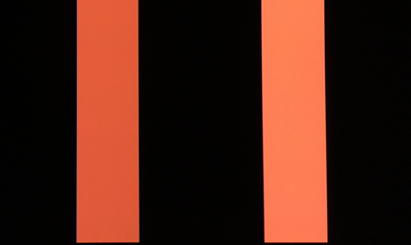


(b)

Figure 5. A scene in RaceCar with less bright light on the car - (a) original HDR, (b) original HLG



(a)

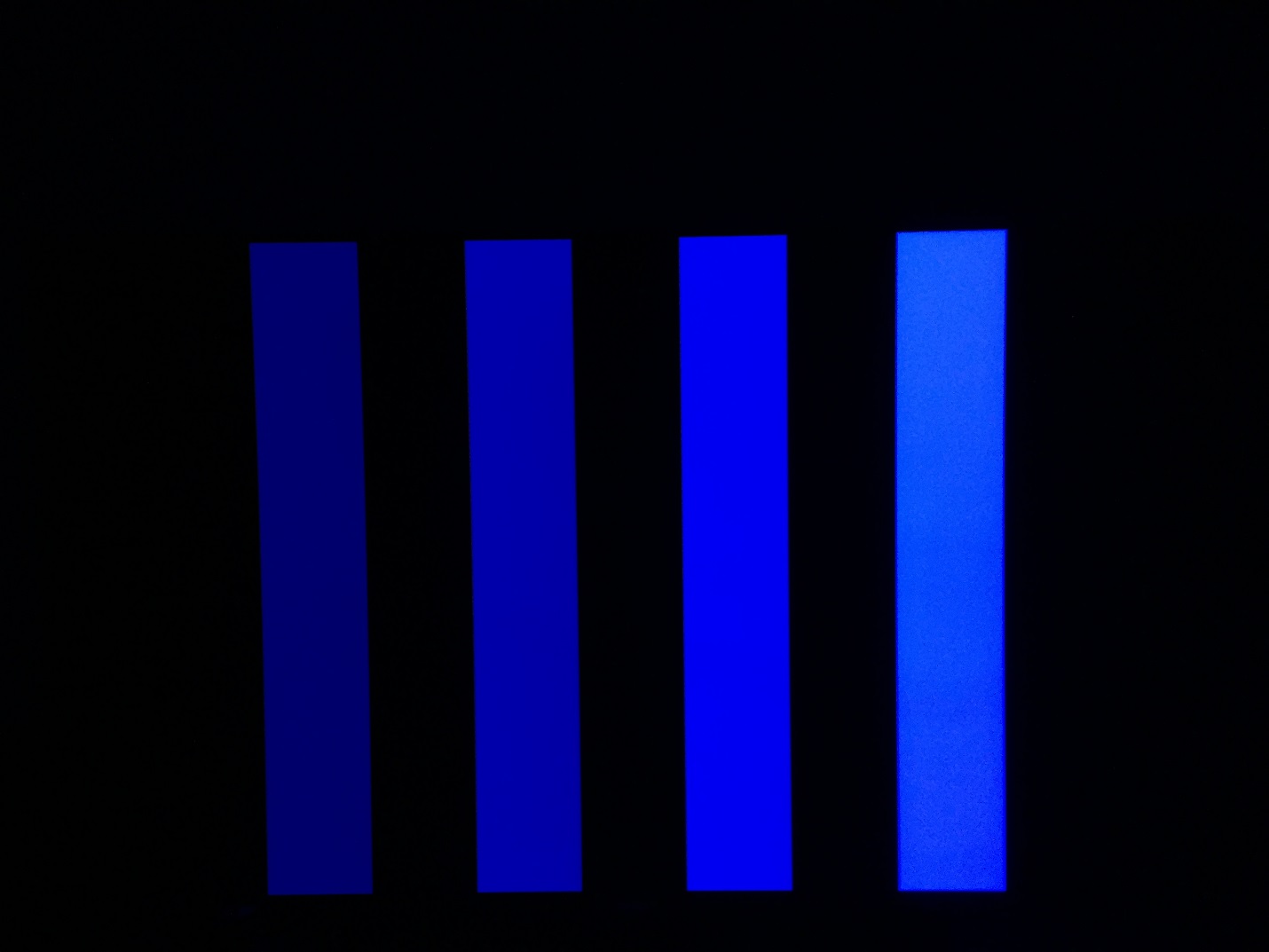


(b)

Figure 6. Color bars with different brightness - (a) on legacy SDR TV, (b) on new HDR (HLG) TV



(a)



(b)

Figure 7. Color bars with different brightness - (a) on legacy SDR TV, (b) on new HDR (HLG) TV

# Discussion

It was observed that when HLG processed video is displayed on a legacy SDR TV, the hue in various parts of the video gets shifted, based on the brightness of the color samples. Although this type of shift in hue is noticed in a very wide range of colors, the most noticeable shift in hue, in the sequences used in this test, was observed in the colors that are in the Orange region of the CIE diagram. It appears that in this region a relatively small shift in hue will cause Orange to look Yellow. One of the impacts of this effect (brightness-dependent-hue) is that as an object moves from a brighter to less bright area the color of the object changes in the same sequence. Additionally, if one side of the object has a different brightness than the other side, then the colors on those sides look different on the same SDR TV even though they are of the same color.

It was shown that this shift in hue is due to a shift in chromaticity coordinates of the SDR sample, therefore it is different than what is expected by various color appearance models (e.g. Hunt effect, Stevens effect and others) describing how the perceived colorfulness changes with luminance [2][3]. The main cause of the brightness dependent hue shift appears to be due to the fact that for brighter intensities the forward HLG TF is not the same as BT.709 or the inverse of BT.1886 that legacy TVs assume. This mismatch in the TF causes the hue distortion. As the mismatch increases with the brightness, the shift in the hue also increases.

# References

1. A. Luthra, E. Francois, L. van de Kerkhof, “Core Experiment 7 on investigating how to generate compressed HDR/SDR video using HLG and HEVC”, ISO/IEC JTC1/SC29/WG11 N15800, October 2015, Geneva, Switzerland.
2. <https://en.wikipedia.org/wiki/Color_appearance_mod>el
3. M. D. Fairchild, “Color Appearance Models: CIECAM02 and Beyond”, IS&T/SID 12th Color Imaging Conference, <http://rit-mcsl.org/fairchild/PDFs/AppearanceLec.pdf>.

# Patent rights declaration(s)

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