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DYNAMIC HDR CONVERTER TESTING RESULTS

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This report has been produced with the assistance of the following entities:

EBU Members & Associates: Rafael Bujosa (BBC), Daniel-Dee Lofthouse-Smith, Simon Thompson (BBC R&D), Pierre Routhier (CBC/Radio-Canada), Roberto Iacoviello, Sabino Mantovano (RAI CRIT).

Third parties: David Adams (Sky UK), all participating vendors.

EBU Project Manager: Frans de Jong

Abstract

At an EBU HDR test event in 2018, the picture quality that can be achieved using HDR cameras was investigated. It was found that more aesthetically pleasing HDR could be created by controlling cameras whilst monitoring the HDR signal, rather than whilst monitoring a down-mapped SDR signal. More of the available dynamic range could be used. However, this technique was not practical at the time of the tests, as HDR monitors were too expensive, and the automatic conversion from HDR to SDR required for live production, did not work well with static converters. Whilst HDR monitors are still expensive, dynamic HDR converters are now available commercially.

In this Technical Report we discuss the state-of-the-art in HDR to SDR conversion, and the tests undertaken by the EBU Strategic Programme on Production. Supplements to this Technical Report will contain specific test results that are available only to EBU Members and Associates, and the vendor concerned.

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Dynamic HDR Converter Tests

1. Introduction

At an EBU test event in 2018, the EBU Video Systems group investigated the picture quality that can be achieved using HDR cameras. It was found that more aesthetically pleasing HDR could be created by controlling cameras whilst monitoring the HDR signal, rather than whilst monitoring a down-mapped SDR signal [1]. More of the available dynamic range could be used. However, this technique was not practical at the time of the tests, as HDR monitors were too expensive and the automatic conversion from HDR to SDR required for live production, did not work with static converters. Whilst HDR monitors are still expensive, dynamic HDR converters are now available on the market.

The EBU Video Systems group organised a test session with a range of vendors in late summer 2023. As with EBU documents discussing codec trials, only a generic overview of the market is presented in this public document. Specific test results are provided separately for EBU Members and Associates, and the vendor concerned.

This Technical Report is not an EBU Recommendation, but we strongly suggest the testing regime and usage described in the conclusions be taken into account by Members prior to using dynamic HDR to SDR or SDR to HDR conversions in their programmes.

Tests were undertaken by expert viewers from EBU Members and from the vendors. For each test the video sequence was played from a professional playout server via SDI with the correct video payload ID, both the input and output video were monitored using reference monitors [2] and waveform monitors and the output was recorded in the ProRes HQ422 format [3].

1.1 Definitions

SDI	The Serial Digital Interface is a family of digital video interfaces first standardized by the SMPTE in 1989 and subsequently adopted by the ITU-R. Additional SDI standards have been introduced to support increasing video resolutions (HD, UHD and beyond), frame rates, and colour depths.
HDR Converter	A device that transforms a high dynamic range video signal (ITU-R BT.2100 [4]) to standard dynamic range (ITU-R BT.709 [5] or ITU-R BT.2020 [6]) and/or vice-versa
Static HDR Converter	A dynamic range converter which has a fixed mathematical relationship between the input and the output, using either a look-up table or a parametric transform
Dynamic HDR Converter	A dynamic range converter which changes the mathematical relationship between the input and output based on an analysis of the input.
Spatial Dynamic HDR Converter	A dynamic range converter which analyses different areas of a video frame separately and applies tailored mathematical conversions to each.

1.1 Content Used

Name	Frame Size	Frame Rate	Type (ITU-R BT. ...)	Description
CBC Snow Sports	3840x2160	60/1.001	2100 HLG	Fast action sequences taken during the day and at night. Shot RAW then post-processed.
BBC Test Sequence	3840x2160	50	2100 HLG	Sequence shot specifically for testing dynamic converters, includes fades, cuts, graphics, pans and zooms between brightness regions, etc.
RAI HDR Test Sequence	3840x2160	50	2100 HLG	Test sequence of broadcast content including drama, opera, sport and documentary.
Sky Europe Test Sequence	1920x1080	50	2100 HLG	Sport sequence (Cricket) including a pronounced artistic look.
RAI SDR Test Sequence	1920x1080	50	709	Test sequence of broadcast content including drama, opera, sport and documentary.

Not all sequences adhered to the video signal levels specified in ITU-R BT.2408. The vendors had no knowledge of the sequences ahead of the testing. This mimics certain real-world conditions.

2. General Observations

All devices were capable of producing ITU-R BT.709 SDR from an ITU-R BT.2100 HLG HDR source, but not all were capable of utilising the extended gamut and signal range allowed within EBU R 103 [7].

All devices were either tuneable or had multiple operating conditions that could be set by the end user.

The different profiles available allowed the end user to vary how conservative the transform is and how strictly the transform expects the input video to follow the signal reference levels specified in Report ITU-R BT.2408 [8].

The resulting image quality can be exceptional with, for the majority of frames, highlight compression and gamut correction outperforming static LUT based converters. However, artefacts were visible in a small number of sequences.

Whilst the devices can be tuned or have different settings applied, it is not always straightforward to test these settings to optimise the algorithm. In practice, some of the optimisations may not be useful when using the device for a large range of input content, genres and formats. That is to say, it may be possible to over-tune the algorithm for a specific genre that will not be optimal for other genres. One of the devices had an automatic setting, i.e., without the need for tuning, that does not clip any highlight resulting in an SDR image that is slightly darker. It should be noted that optimisation for the input signal also happens with static HDR converters, namely by selecting different LUTs or parameters. Also in those cases, care should be taken to choose the appropriate configuration that works for the expected incoming signal.

When converting from HDR to SDR, the following effects may be encountered[1]:

- **Video signal clipping**. When a luminance breakpoint of less than the peak HDR luminance was chosen as the operating mode, video signals above the breakpoint had a tendency to clip. Care should be taken to ensure an operating mode is chosen where this is minimised. This was especially apparent when the ITU-R BT.2408 HDR Reference White level (as used for graphics)

[1] Not all effects may be present in all converters.

was chosen as in live video productions, this level is often exceeded. When using conservative settings, this did not appear worse than would be expected from an ITU-R BT.709 camera with minimal knee set.

- **Amplification of noise in low luminance areas**. This was especially apparent when the shadows were lifted by the processing. This typically occurred when a lower luminance setting was chosen. This was visible in all cases but when conservative settings were used was not objectionable.
- **Changes in graphics levels**. Two variants of this effect were noticed. In spatial converters, the graphic's luma level changed across the graphic, depending on the background. In non-spatial converters, depending on the mode chosen, the graphic's luma level-– sometimes had an overall shift based on changes in the background, for example shot changes. Not all changes were visually perceptible and, of those that were, not all were objectionable.
- **Temporal overshoots**. E.g., when undertaking a fade from black or inserting graphics. Due to the averaging over a number of frames, an image can be seen to "overshoot" in brightness and then slowly reduce to a steady state. This is only an issue for converters with a long averaging filter.

It should be noted that some of the more extreme issues may only be present in video that contains shot changes, fades and graphics, i.e., the vision mixer output.

During testing, it was also found that certain video sequences exist that are critical for the particular devices under test. These have been made available to the vendors concerned.

Two of the devices were capable of undertaking ITU-R BT.709 SDR to ITU-R BT.2100 HLG conversion and also of round-tripping[2]. Again, these devices had a range of operating luminance levels, and it was possible to create nice looking video from an SDR input with the following caveats:

- SDR text is placed at the brightness of the operating point, therefore care is needed that text is not displayed at peak HDR luminance, and
- SDR content with image faults such as clipping, compression artefacts and analogue artefacts may well have the perceived annoyance of these artefacts increased.

Again, conservative parameter settings can be used to limit the range of luminance used which reduced the visibility of artefacts and the brightness of text.

Round tripping worked well provided that the same settings were used in the SDR-HDR and HDR-SDR conversions. However, any detail lost in the initial conversion could not be recovered.

For some of the devices tested, it should be noted that the conservative setting in HDR-SDR converters (using the entire HDR range) and in SDR-HDR converters (only using the ITU-R BT.2408 HDR Reference White range) do not match. Some trade-offs between the performance of the HDR-SDR and the SDR-HDR converters may be needed.

Further work is required to understand if:

- Dynamic converters may be used alongside or as a round-tripping source for static converters and vice-versa, and if
- Dynamic converters can be used as a round tripping source for a dynamic converter which uses a different algorithm.

[2] Because of time constraints the round-tripping tests were limited in scope. More investigation of options present in the converters may lead to better results.

3. Specific Observations

These are available only to EBU Member organisations as Supplements to this document.

4. Conclusions

Dynamic HDR converters appear to allow a greater exposure range of the HDR signal and to offer a good performance in creating an aesthetically pleasing SDR image too. There are, however, some issues that require further investigation by EBU Members and vendors, including the use of dynamic HDR converters on video that contains graphics and scene changes of a specific nature.

There currently is no method to describe the transform being undertaken by a Dynamic HDR Converter, therefore it is difficult to match cameras to a feed that has been created using such a converter. The EBU is interested in supporting the development of solutions for this issue.

Further work is required to understand interoperability issues between different dynamic and/or static converters. This issue is especially relevant in the discussion of multilaterals when a host broadcaster is creating multilateral programme feeds, i.e., providing feeds to other broadcasters that may want to cut between this multilateral and their own venue cameras. To successfully match these camera signals with the multilateral feed, the characteristics of the down mapping used in the camera shading by the host broadcaster must be known. This is also an issue for static converters. Therefore, Members should follow the advice given in EBU R 153 [9] when acting as a host broadcaster. Members should only use dynamic HDR converters for creating multilateral programme feeds with the express permission of all broadcasters using the feed.

Members may wish to experiment with using dynamic converters on wholly-contained programmes or alongside static dynamic range converters.

Prior to use we suggest that the following tests be undertaken, with and without graphics, and the output monitored on a reference monitor and a waveform monitor:

- Switching between a bright and dark scene,
- Fading to and from a bright scene to black,
- Panning at different speeds between darker and brighter parts of a scene,
- Zooming at different rates in to and out of a bright area, such that the size of the bright area significantly changes,
- Quickly racking a camera, changing white balance, adjusting master black level etc., and
- Effect of the converter on downstream processing including contribution and distribution encoding, interaction with virtual studio software, etc.

The EBU notes:

- ITU-R BT.2408 is an informative report, not a normative text.
- Within ITU-R BT.2408, the HDR reference white level is described as ‘nominal’ and the text states that “in practice the measured white levels can be expected to vary significantly around this target value”.
- In practice, vision engineers often use a proxy, such as grass or skin tone (see table 2 in ITU-R BT.2408).
- Cameras are noisy, so even when the HDR reference white level is adhered to, it would be normal to place the centre of the signal on the reference level on the waveform monitor.

It is suggested that the preset modes which require strict ITU-R BT.2408 compliance should only be used for controlled lighting scenarios where there is little chance of lighting changes causing large areas of the image to become clipped.

For uncontrolled lighting, or for general use, more conservative settings should be used. In all cases, all lighting effects/changes should be tested with the dynamic converter prior to being used in programme production.

5. References

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[2] EBU Tech 3320, *'User Requirements for Video Monitors for Television Production, ver 4.1'*, Technical Report, European Broadcasting Union, Geneva, Switzerland, September 2019

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[4] ITU-R BT.2100, 'Image parameter values for high dynamic range television for use in production and international programme exchange', International Telecommunication Union, Geneva, Switzerland, August 2018

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[9] EBU R 153, *'Parameters for Live Contribution of UHD/HDR Programmes, ver 2.0'* Recommendation, European Broadcasting Union, Geneva, Switzerland, May 2020