DELIVERY REQUIREMENTS SUPPLEMENT: DELIVERY OF PROGRAMMES WITH HIGH DYNAMIC RANGE

Abstract

This document supplements the DPP's AMWA AS-11 Programme Delivery Document. It should be read in conjunction with the relevant associated documents.

UHD standards and practices are evolving quickly and the processes for High Dynamic Range (HDR) production are not yet fully understood. This document will receive regular updates as more is learned about these processes. Check that you are using the latest version of this and any related documents. The DPP welcomes comments and suggestions from those involved with the production and delivery of HDR programmes.

https://www.thedpp.com/tech/delivery/uk/

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INTRODUCTION

This supplement details the DPP guidance for technical and operational practices used during the production of HDR programmes using either the Perceptual Quantization (PQ) or the Hybrid Log-Gamma (HLG) options of ITU-R BT.2100. Both PQ and HLG are supported within the DPP UHD Delivery Specifications, but the choice is solely at the discretion of the broadcaster.

Please ensure that you have discussed this before the production begins to ensure that you are working to the correct delivery format.

For the avoidance of doubt, any reference to ITU-R BT.2100 also includes ITU-R BT.2020, including colour gamut and levels.

High Dynamic Range (HDR) televisions deliver images that look correct on displays that produce much brighter highlights and improved detail in dark areas. It is vital that viewers have a comfortable viewing experience with consistency between scenes and at junctions between programmes especially between HDR and Standard Dynamic Range (SDR) programmes. There will only be a single version of an HDR programme so account should be taken of the need to be able to derive conventional SDR signals from the HDR programmes that have been produced in PQ or HLG.

1 HDR PRODUCTION GUIDANCE

1.1 Production using PQ

Production in PQ has no additional complexity when compared to SDR production. During capture, the scene may be exposed to produce the desired appearance on a reference monitor. The difference in PQ production versus SDR production is that it is possible to encode information above the capabilities of the reference monitor if that monitor cannot reach 10 000 cd/m2 . In this case, more detail may be revealed on a display with a higher peak luminance level.

During set-up, camera controls such as gain and shutter and others may be pre-adjusted to make best use of camera sensor capabilities to establish a creative intent.

During capture, the iris may then be adjusted taking consideration of the reference levels listed below as well as the creative intent.

1.2. Production using HLG

HLG has been designed to enable a straightforward migration towards HDR television production, with few changes to SDR production working practices. The compatible nature of the HLG signal allows standard dynamic range monitors to be used in non-critical monitoring areas. HDR monitors are only necessary for critical monitoring, such as when colour grading, camera racking and monitoring programme and preview outputs in a production gallery.

2 DISPLAYS

HDR images should be viewed on displays that support the ITU-R BT.2100 colour space (this is identical to the ITU-R BT.2020 colour space).

2.1.1. PQ Displays

PQ images should be viewed on displays that support the full ITU-R BT.2100 colour space and can reach 10 000 cd/m2 for peak white signals. In practice, monitors that are available cannot reach the extent of the ITU-R BT.2100 gamut or the peak brightness of the PQ signal.

Monitors that support PQ may or may not include tone-mapping to bring high brightness signals down to the capability of that monitor. Some monitors may clip at their peak output capability (e.g. 2000 cd/m2). Some monitors may contain tone mapping that provides a soft-clip. If a soft-clip is desired for use with a monitor that only provides a hard clip, an external Look-up-table (LUT) can be employed to provide any desired tone mapping.

If the ITU-R BT.2100 PQ signal is presented to a monitor that expects a ITU-R BT.709 input, the image will appear dim and washed out; colours will be desaturated and there will be some hue shifts. An external 3D LUT can provide the down mapping function necessary to bring both colour and brightness into the ITU-R BT.709 colour volume, thus allowing satisfactory display on the legacy ITU-R BT.709 monitor. While this allows viewing on the ITU-R BT.709 monitor, the resulting images should not be used to make critical judgements of the HDR production.

2.1.1 HLG Displays

For best results, when displaying HLG signals on SDR screens, the SDR monitor should support the ITU-R BT.2100 colour monitoring. However, for simple confirmation of the presence or absence of a signal, ITU-R BT.709 colour monitoring may be sufficient. ITU-R BT.709 colour monitors will, however, show a de-saturated image with visible hue shifts.

High quality HLG HDR programmes can be produced using conventional 10-bit infrastructure and 10-bit production codecs, with similar bitrates used for standard dynamic range production. The use of 12-bit production systems will, however, give greater headroom for downstream signal processing.

3 REFERENCE LEVEL GUIDANCE

Currently there is not enough experience for accurate and consistent PQ or HLG reference levels requirements to be published. For guidance, the tables below give indicative figures for both standards. The brightness of PQ and HLG HDR produced content is expected to vary around the nominal reference levels, offering room for artistic freedom.

For operational guidance, the terms of %PQ and %HLG are used. These percentages represent signal values that lie between the minimum and maximum non-linear values normalised to the range 0 to 100%.

3.1 PQ Reference

To select the optimum indoor reference level, skin tones from both broadcast content and home cinema release content were analysed. By segmenting HDR indoor and outdoor scenes, it was found that outdoor skin tones are an average of 1.7 stops brighter than indoor skin tones. Assuming a 1.7 stop increase in brightness from an indoor to outdoor scene, the exposure for an 18% grey card outdoors would be set to 45 %PQ.

Tentative reference levels for PQ production

	Well Lit Indoor Sunlit Outdoor		Well Lit Indoor Sunlit Outdoor	
	cd/m2	% PQ	cd/m2	% PQ
18% Grey Card	17	34	57	45
Diffuse Card	140	54	425	66

3.2. HLG Reference

For HLG content, it is suggested that such variations be limited to around +/- 0.5 stops (scene light) to avoid uncomfortable changes in brightness between dark and bright content items. It may be possible to relax these constraints in due course, once objective measures for brightness have been adopted. In practice the nominal levels should be used for studio content under controlled lighting, with the upper and lower bounds, for example, used in daylight outdoor and indoor scenes.

Tentative reference levels for HLG production on a 1000 cd/m2 display

	-0.5 stops		Nominal Reference		+0.5 stops	
Reflectance	cd/m2	% HLG	cd/m2	% HLG	cd/m2	% HLG
18% Grey Card	17	32%	26	38%	39	45
90% Reflectance Card	116	66%	176	73%	267	79%

Graphics reference			200	75%		

4 USING SDR CONTENT IN HDR PROGRAMMES

As this is an evolving area, Recommendations and Standards governing the use of SDR content in HDR programmes are still being finalised by the relevant Standards bodies. When published, these Recommendations and Standards will be integrated into the relevant DPP delivery Document. In the interim, this supplement provides a general overview and operational guidelines.

There are two options for processing SDR material into HDR programmes.

Option 1 simply maps the SDR images into the HDR signal, maintaining the dynamic range of the original image. This method does not change how the SDR content will look, it will display on the PQ HDR reference monitor the same as it displayed on the reference SDR monitor.

Option 2 where the SDR material is boosted it in level and/or non-linearly stretched to enhance/brighten highlights and/or darken areas of the picture. Such methods should be used with care as some content may suffer if automatically up-converted without suitable creative and technical control being applied. Where this content is then displayed on SDR equipment, it may not produce the expected results.

Currently, unless a second version of the programme is made and graded for SDR, Option 1 is the preferred method.

4.1 SDR into PQ

Standard dynamic range ITU-R BT.2020 content should be converted to PQ by applying the ITU-R BT.1886 display EOTF and then applying the inverse PQ EOTF. As a guide, the peak signal of standard dynamic range content should be set to approximately 100 cd/m2 or 51% PQ.

This method means subsequent HDR-to-SDR down conversion, performed by dynamic processing (where the HDR signal is analysed and then appropriately tone-mapped down to a target brightness) will produce the same SDR signal as in the original content. That is, the round-trip SDR-to-PQ-to-SDR, will result in no change to the SDR signal.

4.2 SDR into HLG

The process of converting SDR content into HLG is mathematically reversible. This means that when the HLG signal is converted for display on SDR equipment, the SDR material is not degraded (other than some minor re-quantisation) compared with the original SDR content.

Both SDR ITU-R BT.2020 and ITU-R BT.709 content can simply be-remapped in to the HLG HDR container.

5 CONVERSION

Transcoding between PQ and HLG signals is specified in the report ITU-R BT.2390. When the peak brightness of the HLG and PQ displays are the same, the original and transcoded signals will look identical.

Typically for PQ content, the brightness of low-lights and mid-tones remains the same, regardless of the peak brightness of the display. Brighter PQ displays offer increased headroom for specular highlights, but the overall image brightness remains unchanged.

HLG however, is based on relative brightness. As the display's peak brightness increases so does the brightness of the entire image. The headroom for specular highlights is constant number of stops, but the brighter image makes it suitable for viewing in brighter environments.

When, for example, a 4000 cd/m2 PQ signal is transcoded to HLG using the method specified in ITU-R BT.2390, it will appear identical on a 4000 cd/m2 HLG display but it may appear darker when shown on a 1000 cd/m2 HLG display in brighter environments.

As the PQ and HLG systems have different characteristics, a format conversion rather than a simple transcode is required.

5.1 Baseline PQ to HLG Conversion

The simplest method for conversion from any peak brightness PQ signal to HLG is provided by combining a PQ EETF e.g. as described in section 5.4.1 of ITU-R BT.2390, with the transcoding method specified in Section 7 of ITU-R BT.2390.

The EETF is first applied to the PQ signal to convert it for a target display of 1000 cd/m2. The HLG inverse EOTF for a 1000 cd/m2 display (gamma = 1.2) is then applied to derive the HLG signal.

5.2 Baseline HLG to PQ Conversion

When converting between HLG and PQ signals, a straightforward transcode is possible - as specified in ITU-R report BT.2390. However, a target PQ display brightness of 1000 cd/m2 is recommended to ensure consistent brightness between the HLG and PQ signals.

6 UHD QC

6.1 Introduction

As with all High Definition (HD) and Standard Definition (SD) programmes, prior to delivery and distribution, all UHD and HDR content needs to go through a rigorous Quality Control (QC) process. This is especially pertinent if the programme is destined for international distribution and delivery to On-Demand platforms that may have technical requirements that are not familiar. Some questions that need to be addressed on a platform-by-platform basis may include:

- What monitoring and AQC devices are needed?
- What are the requirements for PSE for UHD and HDR
- Are there any specific requirements that need to be fulfilled to ensure backwards-compatibility
- What constitutes a QC pass or fail?

6.2 UHD QC environment

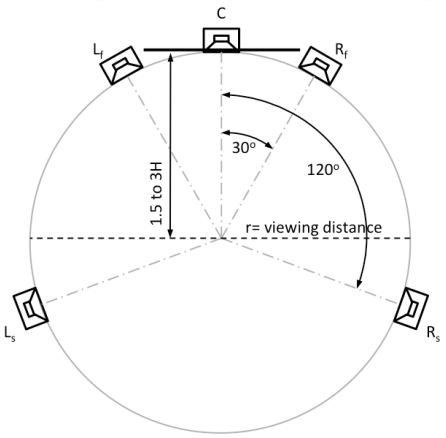
A correctly set up HD QC area will likely need very little adjustment to carry out UHD QC. It should be noted that all displays and AQC devices must be capable of processing any content where the video meets the requirements of ITU-R BT.2020* and ITU-R BT.2100*

For HDR QC the room ambient lighting will need to be adjusted for HDR QC.

*Currently the formats are limited to 1080p (25 and 50 fps) and 2160p (25 and 50 fps) 6.3. Layout The diagram below is a guide for setting up QC areas.

6.3 Layout

The diagram below is a guide for setting up QC areas.



6.3.1 Display

There is no doubt you will need a UHD/4K display and the ability to playback UHD and 4K content. It is also important that both broadcast and consumer content can be viewed and checked.

It is acceptable to use a smaller (30" plus) "broadcast quality" UHD HDR display for critical colour and dynamic range viewing but a larger (50" plus) consumer set should be included off axis for resolution and focus checks.

HDR images should be viewed on displays that support the ITU-R BT.2100 colour space (this is identical to the ITU-R BT.2020 colour space). See the section on Displays for further details.

6.3.2 Viewing distance

Viewing distances are based on the human visual system and the "line" structure of the image.

There is still discussion about the relative viewing distances for UHD QC but as an interim guide and to allow the person carrying out the QC to see the entire image, it is acceptable for the viewing distance to be between 1.5 and 3 times the screen's picture height.

6.3.3 Speaker positioning

The speaker layout is the same as required for HD content - speakers should be approximately ear height relative to the QC viewing position. It should be noted that in order to comply with the DPP's UHD Delivery Specification, programmes must be delivered with multi-channel audio.

6.4 File Formats

File formats are really wrappers with essence, metadata and instruction sets either in a single container (e.g. AS-11) or connected by a set of core constraints (e.g. IMF)

6.4.1 AS-11 DPP X1

Programmes for delivery as Ready for Transmission

6.4.2 IMF

IMF is NOT a file. This supplement does not deal with checking IMF Packages to ensure compliance to an Application. The details in the supplement can be used to QC the essence files from a CPL via a suitable player or to simply QC the individual MXF essence elements.

6.4.3 Codecs

It is expected that a UHD QC area can replay and measure to broadcast standards the following codecs with a frame size of 3840 x 2160 progressive scan

- ProRes 422HQ and 444(4) XQ
- H.264 up to and including Level 5.2

6.5 Quality Assessment

6.5.1 Image Quality

It is expected that the general quality of the images must be:

- Consistent throughout (remembering 25% of the content can be non-UHD)
- Should normally achieve a score of 5 on the ITU-R BT.500 Impairment and Quality Scale
- Should be comfortable to watch for the duration of the programme
- Be viewable (not too dark or too bright) on a consumer display under the normal domestic lighting conditions described in ITU-R BT.500

6.5.2 PSE for HDR content

Until more is known, HDR programmes must "pass" a standard HD PSE check. If a PSE device can handle the UHD image size, it is acceptable to test an HLG HDR file with no conversion.

NOTE: Only PSE devices and versions on the DPP Broadcasters approved list can be used to test programmes. This guidance will be revised as and when UHD and HDR options become available.

6.5.3 Audio

Broadcasters require UHD programmes to have a 5.1 Surround Sound and a Stereo audio mix. Other than this, the audio QC requirements are exactly the same as HD. In the future it is expected UHD programmes will include Object and/or other multi "dimensional" sound systems. Further advice will be given well in advance of any requirements for QC of other audio formats.

Version Control:

Version	Date	Notes
V2.0	01-01-2001	Second release

Document Accuracy:

Every attempt has been made to ensure that the information contained in this document is accurate. Errors in this document should be reported to the DPP on info@thedpp.com