White Paper

ATSC 3.0 and its Potential Impact on UHD Video Quality Assessment

Interra Systems, Inc.
1601 S. De Anza Boulevard, Suite 212
Cupertino, CA 95014
USA

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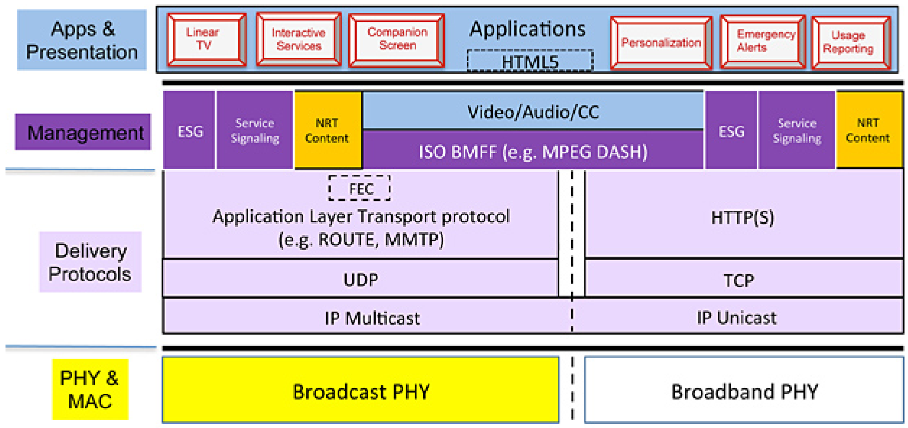
1. INTRODUCTION

ATSC 3.0 is currently being developed as the next generation standard for digital television. The standards committee clearly realizes that the viewing experience is no longer confined to a 'static' model of people watching TV in their homes. Rather, viewers are enjoying content wherever they may be – at home or outside, on a flat-screen TV, on a tablet or other mobile device.[11] As a matter of fact, content could be delivered via:

- Off the Air / Terrestrial
- Cable
- Internet / Wi-Fi
- Mobile / Cellular

In addition, content provision is now being considered at higher resolutions such as Ultra High Definition (UHD), in turn mandating better video compression techniques such as H.265 (HEVC) and H.266 (VVC, which could be possibly used to deliver 8K). The new ATSC standard allows for High Dynamic Range (HDR) and Wide Color Gamut (WCG) as well as High Frame Rate (HFR) video. (It is to be noted that currently, 4K HDR content is mainly available via OTT streaming services like Netflix, Amazon Prime or Disney+…)[13]
Audio quality improvements have been incorporated as well. The legacy ATSC 1.0 format currently uses Dolby AC-3, with 5.1 channel surround sound. On the other hand, ATSC 3.0 uses the newer Dolby AC-4, for broadcasts of up to 7.1.4 channel audio and support for object-based sound formats like Dolby Atmos[13]. Moreover, with different users having different end requirements (display devices as well as delivery systems), the content delivery is proposed to be made scalable using layered coding techniques. For those end users requiring the enhanced video format experience, this would allow delivery of an HD version (of a piece of content) for basic service over a robust Physical Layer Pipe (PLP) and an enhancement layer over a higher bitrate pipe to bring the video to say, UHD[11].



With ATSC 3.0 mandating these multi-delivery, multi-user requirements, the processing of native UHD content as well as the same content down-converted to lower resolution has its inherent challenges vis-à-vis Video Quality (VQ) monitoring. Therefore, a careful examination of the issues involved with UHD content delivery via HEVC within the ATSC 3.0 mandated ecosystem is necessary.

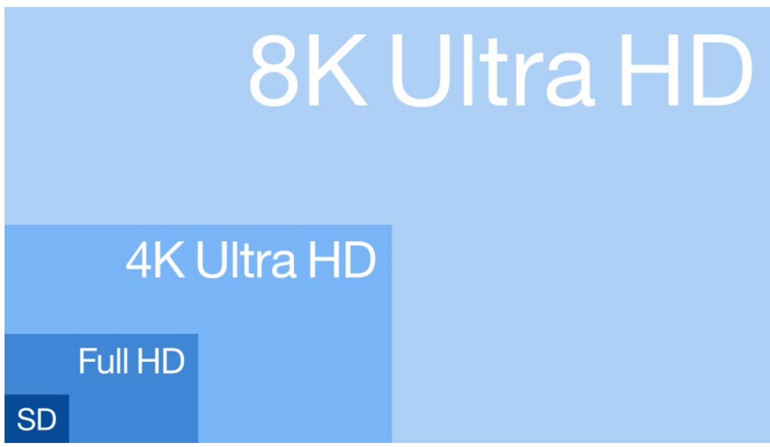
With these considerations in mind, we will first briefly discuss the UHDTV format below and follow it with a discussion on 4K content VQ issues.

2. UHDTV FORMAT – A BRIEF BACKGROUND

Currently, '4K' has become the common name for Ultra High Definition Television (UHDTV), although its resolution is only 3840 x 2160 (at a 16:9, or 1.78:1 aspect ratio), lower than the actual 4K industry standard of 4096 x 2160 (at a 19:10 or 1.9:1 aspect ratio) – as we will later note.[1a]

Moreover, when we refer to or discuss 4K we must also keep in mind the vehicle(s) for the compressed version of this format. Over the past three decades, the media industry as well as its various regulatory and standards bodies have been responsible for generating a series of compression standards, with each successive standard striving to improve compression efficiency while maintaining or even improving decoded picture quality. Over time, we have had (in progression): H.261 (p64 for teleconferencing) → H.262 (MPEG-2) →H.263 → H.264 (AVC) → H.265 (HEVC) and the recently released standards like H.266 (VVC), AV1 and MPEG-5 (EVC). Along with VP9 from Google, HEVC is the amongst latest currently deployed standards geared towards handling higher video resolutions such as 3840 x 2160 (4K UHD) and even 7680 x 4320 (8K UHD), both of which maintain the traditional HD 16:9 picture display aspect ratio.[1a]

The graphic below[1b] illustrates the relative size comparison of the capture/display formats (8K and below):



Relative comparison of common display formats vis-à-vis UHD/4K-8K

Furthermore, the actual 4K industry standard as mentioned in the first paragraph was established by the Digital Cinema Initiatives (DCI) consortium as a standard resolution of 4096 pixels × 2160 lines (8.8 megapixels, aspect ratio ~17:9) for 4K film projection. This is the native resolution for DCI-compliant 4K digital projectors / monitors and differs from the UHD definition mentioned earlier. Note that DCI 4K does not conform to the standard 1080p full HD aspect ratio (16:9), so it is not a multiple of the 1080p display.[1b]

This ongoing drive towards modern commercial display technology is primarily based upon the availability of enhanced brightness and color depth, enabling HDR and increasingly, WCG capability. With multiple optical to electrical (capture) and conversely, electrical to optical (display) transfer functions

(OETF/EOTF) and WCG standards like BT.2020, DCI –P3 and so on driving both content creation and display, along with the question of backwards compatibility with existing BT.709/BT.601-SDR displays, the issues regarding viewer experience in such an interoperable HDR/WCG environment clearly need closer attention.

With this background, the section below will discuss some of the Video Quality (VQ) issues related to UHD content streaming as well as the general handling of UHD video material that we will have to confront within the ATSC 3.0 mandate.

3. VQ TOPICS WITH UHD CONTENT THAT MERIT FURTHER CONSIDERATION

From the ongoing discussions in forums hosted by SMPTE and NAB as well as some of the available literature, the following issues appear to be of immediate relevance (- *more may be added as per their perceived relevance*):

3.1 VQ TOPICS THAT NEED TO BE REVISITED

a) Color Gamut

As discussed in some of the SMPTE presentations at the Annual Technology Conference, enhanced Color Gamut issues (i.e., 10 – 12 bits support as per Rec 2020[2]→could go up to 16 bits) should be considered.

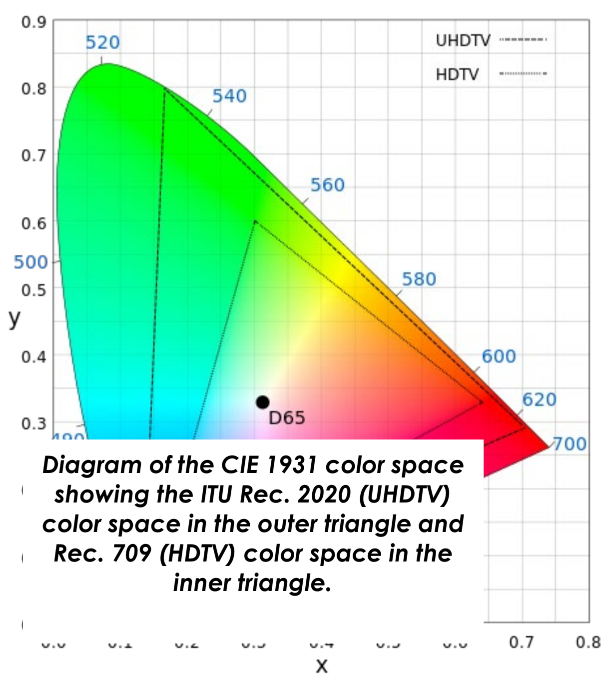


Diagram of the CIE 1931 color space showing the ITU Rec. 2020 (UHDTV) color space in the outer triangle and Rec. 709 (HDTV) color space in the inner triangle.

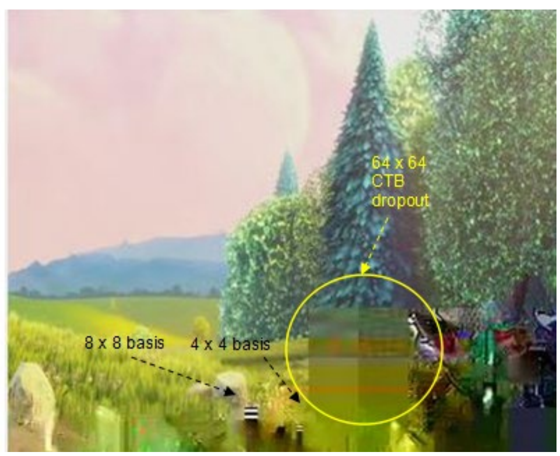
In this case, color gamut issues include identifying WCG content (either by correctly interpreting the content metadata, or else using other inference

Diagram of the CIE 1931 color space showing the ITU Rec. 2020 (UHDTV) color space in the outer triangle and Rec. 709 (HDTV) color space in the inner triangle.

methods); as well as handling the distortion-less conversion from a higher to a lower bit resolution – for interoperability with the legacy ITU Rec709 (as seen later on in Section 3 c). The Color Space plot[1a] shows the relative color space (inner triangle) occupied by the legacy Rec709 (HDTV) and the Rec2020 (UHDTV) color space (outer triangle) as mandated by Rec2020.

b) Block Error / Dropout Geometries

A wider set geometries of block / tile errors have to be addressed, (noting that HEVC, along with Google's VP9 and the legacy H.264 (AVC), is amongst the most common vehicle for 4K content). The example below shows a dropout capture with *basis function* geometries from 32 x 32 all the way to 4 x 4[6]:



Examples of how HEVC video failure / dropout profiles will consequently affect 4K

c) Up-converted SD/HD resolution content to 4K or beyond

Currently, true HD content is somewhat limited to streaming content from OTT streaming services like Netflix, Amazon Prime Video Disney+ and so on, and platforms like Ultraflix and YouTube. *So in the near to mid-term*, a significant amount of current content delivered in the guise of 4K may still be up-converted from native HD (or even lower).[3a] This up-conversion in turn brings with it inherent

VQ issues –such as loss of detail / blur as well as scaling of the block grid, burnt-in text / icon edges, digital noise / ghosting profiles and others.

d) Motion Tracking / Blurring in UHD / 4K or beyond

Keeping in mind the *larger* 4K/8K canvas - as per the diagram in Section 1, the impact on and hence the efficacy of the existing tools that evaluate and assess motion will also need to be reconsidered. Incidentally, this issue has been alluded to by Knee.[10] (See also Section 4, below, and the sub-section on Motion Blur).

3.2 AREAS THAT REQUIRE FURTHER INVESTIGATION

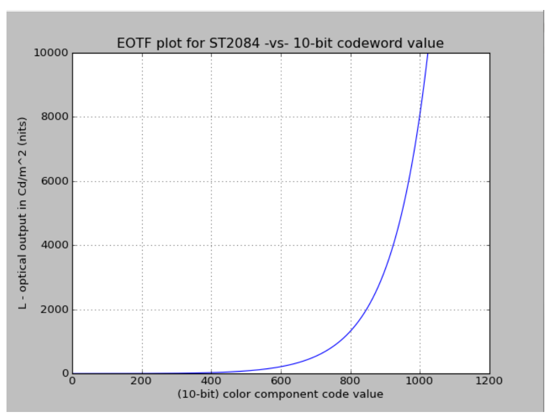
a. Heavier compression

- In relation to 4K streaming, the higher compression* associated with 4K delivery using H.265, VP9 and so on, also makes the perceptual VQ for the end user more susceptible to Packet Losses (*Made worse due to bandwidth constraints).

- Moreover, heavier compression may also result in issues such as blocking, as well as banding artifacts (i.e. posterization effects) in gently varying backgrounds when a lower bit depth is used. (Notice the sky portion of the two images below on a full HD monitor):

Effect of posterization / loss of bit-depth[12]

- It has been noted by Fred Dawson[15] that at high brightness levels, compression artifacts in Dolby PQ or HDR10 type panels could get accentuated if the bitrates are not sufficiently high. This can be explained by the steepness of the ST 2084 EOTF (Luminance L -vs- 10 bit code value) curve in brighter areas, shown below. So, compression related checks like Blockiness / Tiling, Ringing. Mosquito Noise in particular, may have to be performed in the post EOTF or linear L space:



ST 2084 EOTF (Luminance L -vs- 10 bit code value)

Therefore, it is clear that the above mentioned existing video checks for compression artefacts will have to be reevaluated for HDR content

b. Scalability

The concept of using scalability in video coding is being concurrently looking into by the industry to address the issue of receiver compatibility. Two basic approaches have been discussed17,18, namely Single layer and Multi-layer. In the Single layer approach such as the one proposed by Phillips, the compressed content is basically created with HDR and the associated metadata is used to convert or map the HDR content to a standard SDR panel for backwards compatibility. On the other hand, in a multi-layer approach such as the one proposed by Dolby Vision (Dolby Labs), an SDR version of the HDR content is decompressed for legacy viewing, wherein the associated metadata containing HDR related information is ignored. For HDR viewing, the associated metadata is used in a subsequent (post) processing stage to achieve the tone rendering for targeted HDR performance.

Both these approaches use extended metadata for image reconstruction; SDR rendition in case of single layer and HDR in case of multi-layer. With each approach the adequate and appropriate usage of metadata for image reconstruction within the allocated dynamic range is crucial. Moreover, issues with out-of-gamut color mapping or localized contouring due to tone mapping may need to be factored into Video QC when scalable approaches are implemented.

c. *Consumer Viewing Environment and Potential Hazards*

The UHD experience is best achieved in an immersive viewing setup. With the implementation of HDR, prior issues like Photo-sensitive epilepsy[16], wherein there is a potential of flashing images to trigger seizures has been well studied for SDR imagery. However, the specifications / restrictions that resulted from the study on flashy content creation and delivery may have to be revisited for an immersive viewing environment with HDR; and this in turn will impact the current Video QC in this regard

The above is an initial assessment of the impact of UHD formats delivered via ATSC 3.0, on a handful of basic VQ issues. This assessment may evolve based on some of the global issues pertaining to UHD that become clearer over time. An initial outline of these issues follows.

4. SUMMARIZING THE UHD ECOSYSTEM– '*THE BIGGER PICTURE*'

At this juncture, we now take a quick overview of the current state of the art and in particular, how it ties in with the VQ issues discussed in Section 3 and the subsequent planning to address these issues in the near future:

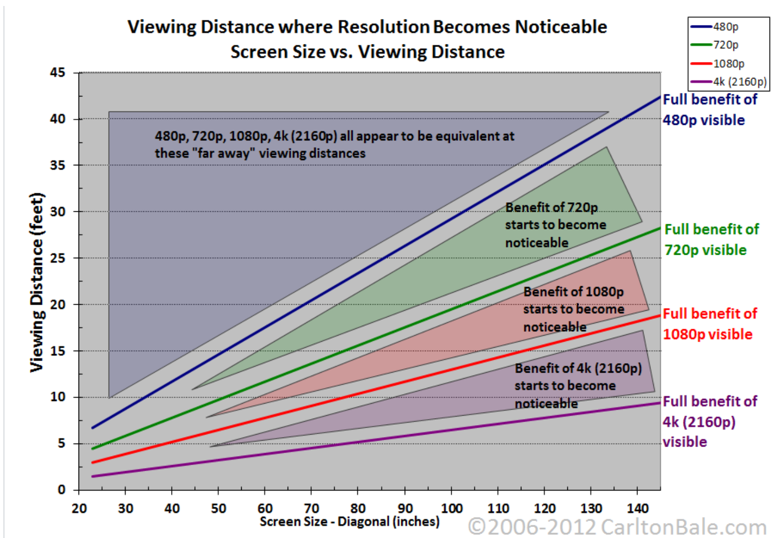
- ***Bandwidth*:** Questions remain over how fully the new UHD content services offered will deliver on the true picture potential of the UHD format, especially if there are bandwidth constraints mandating heavier compression.[3b]

  Since a severe constraint on the bandwidth invariably leads to heavier compression, then as discussed in 3.2a, the issues of PL, blocking and banding become more critical to perceptual VQ.

- ***Optimization with the end user*[9]:** For delivering UHD content it will be assumed that the computer/display can handle the native format, provided that the higher volume of internet traffic is manageable without hiccups, stuttering, freezing, etc. However, in the case of a mobile device (i.e., smartphone, tablet), transmitting a native 4K (compressed) file might not always be feasible, not merely from the standpoint of the screen resolution but also of the device processing power. For this type of device a lower image resolution will suffice, leveraging the fact that the layered coding technology is designed to distribute the same content at variable quality.

  In conjunction with the above, we need to note that this down-conversion of (native) 4K to a lower resolution to meet bandwidth/low res *requirements has its own set of VQ issues, several of which have been mentioned earlier in 3.2b.*

- ***Problem of Motion Blur*[5]:** All LCDs suffer from motion resolution (motion blur) problems, in many cases impacting up to 40 percent of their visible resolution in regions where there is significant spatio-temporal activity. Moreover, without motion interpolation, even higher refresh rates do little to fix this motion blur, which can be accentuated while viewing a big screen display (especially since the 'true UHD' experience is best achieved when the viewing distance from the panel is optimally close – see chart below).[4]



Viewing distance versus panel resolution

Therefore, motion blur detection – related to Section 3.1d, might prove to be another critical VQ issue for 4K - from an end viewer standpoint.

These are a few of the global issues that initially come to mind, that in turn draw upon items mentioned in Section 3. Thus, the items described in Sections 3 and 4 (Ecosystem overview) highlight some of the issues that merit further consideration in the near to midterm, in order to establish and maintain viable UHD VQ capability. Such a capability would certainly be the expectation, moving forward, by quality-conscious ATSC 3.0 compliant broadcasters.

About Interra Systems

Interra Systems is a global provider of enterprise-class solutions that streamline the classification, quality control (QC) process, and monitoring of media content across the entire creation and distribution chain. Relying on Interra Systems' comprehensive video insights, media businesses can deliver video with high quality of experience, address new market trends, and improve monetization. The company's industry-leading solutions include BATON, an enterprise-class automated file-based QC system that ensures high quality content at every stage; BATON Captions for efficient video captions creation and distribution; BATON Lipsync for automated audio video sync detection; ORION-OTT for quality assurance of ABR streams, allowing flawless delivery of live and VOD content; ORION for 24x7 confidence monitoring of linear/live video delivery; WINNOW for content classification and compliance; VEGA for in-depth media analysis, offering content debug & compliance; and BMP, a powerful industry grade media player.

Interra Systems is headquartered in Cupertino, CA. For more information, please visit http://www.interrasystems.com.

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