White Paper

ATSC 3.0 and its Potential Impact on Video Quality Assessment

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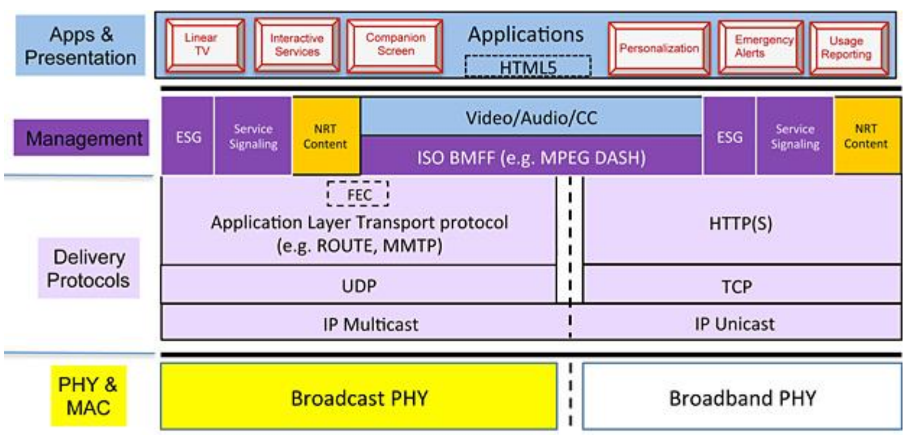
1. INTRODUCTION

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]
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). Moreover, with different users having different end requirements (display devices) 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 the need of the hour.

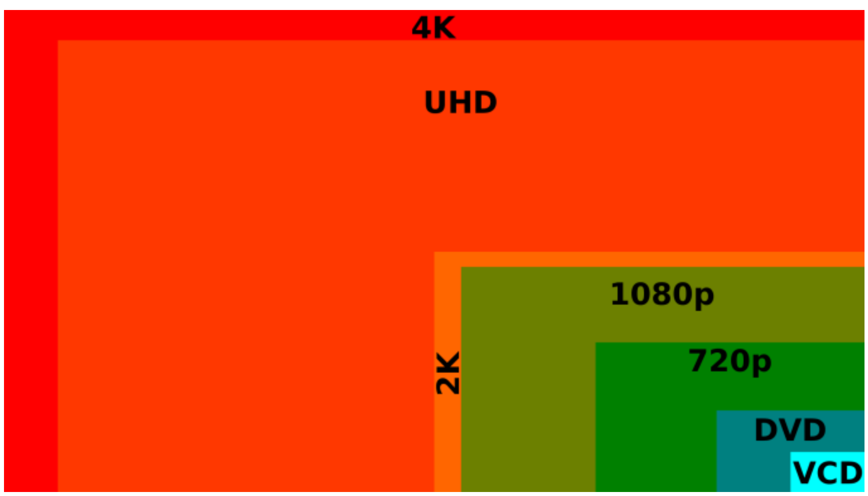
With these considerations in mind, we will first briefly discuss the UHDTV format below and follow it with a discussion on 4K content VQ issues.

2. UHDTV FORMAT – A BRIEF BACKGROUND

'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 two and a half 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) and the currently released H.265 (HEVC) standards. Along with VP9 from Google, HEVC is the latest standard geared towards handling higher video resolutions such as 3840 x 2160 (4K UHDTV) and even 7680 x 4320 ('8K'), 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 currently available capture/display formats (4K and below):



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

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]

Regarding the delivery of 4K content via streaming video*, YouTube and Vimeo allow a maximum upload resolution of 4096 × 3072 pixels (12.6 megapixels, aspect ratio 4:3).Currently, 4K content from both YouTube and Vimeo is limited to mostly nature documentaries and technology coverage. However, this is expected to expand as 4K adoption increases.[1b]

* In December 2014, Amazon announced that subscribers to its Prime Instant Video platform with at least 15Mbps of broadband speed can watch a selection of TV shows and movies in 4K Ultra HD resolution.

With this foundation, the section below will discuss some of the 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. 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 TOPICS THAT NEED TO BE REVISITED

a) Color Gamut

As discussed in some of the SMPTE 2014 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. In this case, color gamut issues include 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 proposed Rec2020 (UHDTV) color space (outer triangle), clearly illustrating the increase in the bit-depth / component requirement, as mandated by Rec2020:

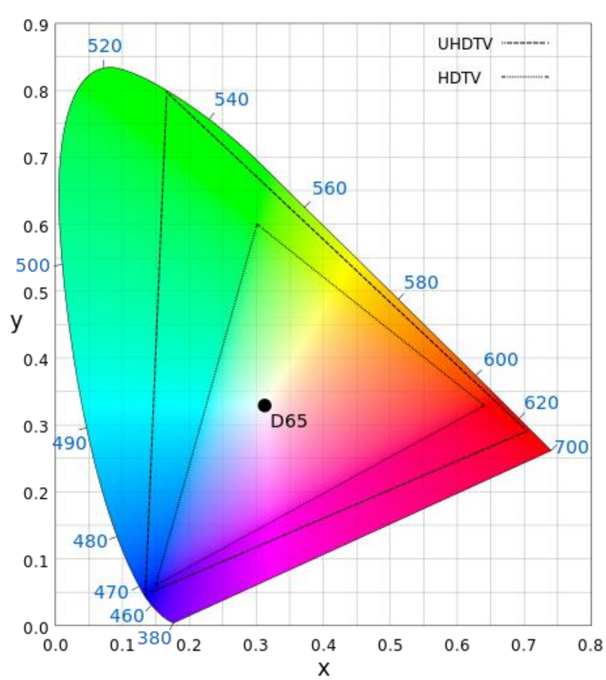


Diagram of the CIE 1931 color space showing the ITU Rec. 2020 (UHDTV) color space in the outer triangle and Rec. 709 (HDTV) color space in the inner triangle.

b) Block Error / Dropout Geometries

As we pointed out earlier in our *Interra Systems* SMPTE 2013 presentation, newer geometries of block / tile errors will have to be addressed(as in HEVC, which along with Google's VP9 will likely be 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'

Currently, true HD content is somewhat limited to content such as "House of Cards" and "Breaking Bad" 4K streams from Netflix, a few random clips available on YouTube or dedicated 4K/UHD download sites, and the new Ultraflix platform. *So in the near / mid-term*, a great deal of current content delivered in the guise of 4K might well 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

Keeping in mind the *larger* 4K 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 (H.265 / VP9) also makes the perceptual VQ for the end user more susceptible to Packet Losses (PL), as discussed and analyzed in the *Interra Systems* SMPTE2014 presentation.[8]

- 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]

b. Down-converted native 4K content -to HD and below

The down-conversion of native 4K to be viewed at a lower resolution, mandated either due to legacy/backward compatibility of the end user or due to bandwidth considerations, has its own set of VQ issues *if not done carefully* – i.e., in addition to the loss of color gamut/banding as mentioned in Section 3.1*a*, there also arises the possible issue of aliasing.

The above is an initial assessment of the impact of 4K on a handful of VQ issues. This assessment may evolve based on some of the global issues pertaining to 4K that become clearer over time. An initial outline of these issues follows.

4. SUMMARIZING THE 4K 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:

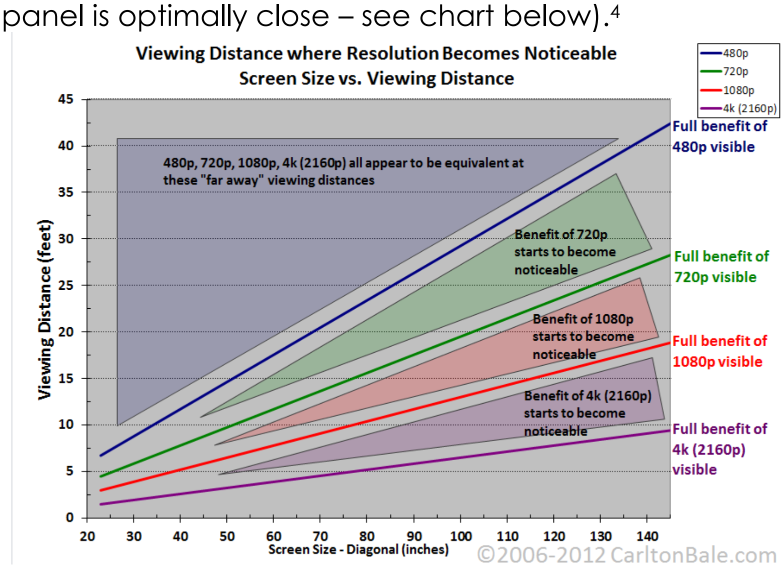
- ***Bandwidth*:** Questions remain over how fully the new UHD/4K content services offered will deliver on the true picture potential of the UHD/4K format, especially if there are bandwidth constraints mandating heavier compression.[3b]

  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 4K 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 4K' 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.

5. ABOUT INTERRA SYSTEMS

Interra Systems provides software and services for the digital media industry. The company's solutions include Baton, an automated verification system that ensures media content readiness, Vega, a family of audio/video analyzers that accelerate media product development and Orion, a real-time content monitoring solution. Interra Systems is headquartered in Cupertino, CA. For more information, please visit http://www.interrasystems.com.

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