DECIDING TOMORROW'S TELEVISION PARAMETERS:

THE GOOD, THE BAD, AND THE EYESTRAIN...

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EBU TECHNOLOGY AND DEVELOPMENT
‘QUALITY OF EXPERIENCE’ FACTORS TO CONSIDER

- Static resolution and sharpness
- Dynamic resolution (judder, detail in moving objects)
- Flicker
- Colour fidelity (primaries, colour encoding)
- Dynamic range (bit/sample, transfer characteristic)
- Depth perception (depth cues)
- Audio object localization and fidelity
- Need: improving them with a significant step in a balanced, affordable, and comfortable way
- Backward compatibility can also be important.
SYSTEM ‘EFFICIENCY’ FACTORS TO CONSIDER.

- Video Compression
- Audio Compression
- Transport Layer
- Modulation systems
- Need: improving them in a significant step in a balanced and affordable way, in line with quality factors.
- Backward compatibility can also be important.
WHO DOES WHAT?

- Frameworks of parameter values – ITU-R.
- Modulation – DVB, ETSI, ATSC, ARIB, ETRI.
- Compression and Transport – MPEG, ITU-T.
- Content ecosystem – SMPTE
- Delivery ecosystem – IEEE/BTS
ULTRA-HD (UHD-1)
SUPER-HI-VISION (UHD-2)
S-3DTV
A-3DTV
3D-AUDIO
HYBRID
BROADCAST/BROADBAND ACCESS
GREEN
WHERE ARE WE WITH UHDTV?
ITU


- Available for download on the ITU website.

## PARAMETERS IN THE UHDTV SIGNAL FORMAT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect Ratio</td>
<td>16x9</td>
</tr>
<tr>
<td>Pixel Raster</td>
<td>3840x2160 (4k), 7680x4320 (8k)</td>
</tr>
<tr>
<td>Pixel aspect ratio</td>
<td>1:1 (square pixels)</td>
</tr>
<tr>
<td>Scan</td>
<td>Progressive</td>
</tr>
<tr>
<td>Frame Rate</td>
<td>120, 60, 60/1.001, 50, 30, 30/1.001, 25, 24, 24/1.001</td>
</tr>
<tr>
<td>Precision</td>
<td>10 bits</td>
</tr>
<tr>
<td>Code for Reference Black</td>
<td>64</td>
</tr>
<tr>
<td>Code for Reference White</td>
<td>940</td>
</tr>
<tr>
<td>Value for Reference Black (cd/m²)</td>
<td>unspecified</td>
</tr>
<tr>
<td>Value for Reference White (cd/m²)</td>
<td>unspecified</td>
</tr>
<tr>
<td>Non-linear coding</td>
<td>Linear+Gamma 2.2 (same as Rec.709)</td>
</tr>
</tbody>
</table>
WHAT HAPPENS TO QUALITY WITH INCREASING RESOLUTION?

Quality proportional to square root of resolution
QUALITY EVOLUTION OF TELEVISION FORMATS?

- **1990s**: Transition analogue to digital (SDTV to HDTV).
- **2004**: Legacy HDTV (1080i/25, 720p50) and Stereo 3DTV with two ½ HD images.
- **2011**: Transition to 1080p/50 (full HD) and HD Master Format (1080p/50 Progressive).
- **2016**: 4k (Ultra-HD) with higher frame rate, wider gamut, and higher contrast.
- **202x**: 8k (Super-Hi Vision) with 3DTV Multiview.

**Immersive Quality**
KEY PARAMETERS

- Image format: 3840x2160 (UHD-1), 7680x4320 (SHV – “8K”)
- Bit depth and TF: 10, 12bit
- Frame Rate: 24, 24/1001, 25, 30, 50, 60, 60/1001, 120fps
- Color encoding: (Constant vs Non-Constant luminance)
- Color Gamut: Wider than Rec 709 and P3.
FRAME RATE: MAJOR ISSUE FOR UHDTV

A main issue today is the choice of image rate. Needs to take into account:
- Motion blur (aperture open for less than 5mS?).
- Judder/strobbing effects (frame rate more than 100Hz?).
- Flicker (frame rate more than 80Hz?).
- Compatibility with legacy equipment (100Hz, 150Hz, 120Hz)
- ‘Sense’ of reality improvement (?)
- Quality gain in moving to higher frame rate?
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UHD-2 8Mpixels 4x1080p Displays 2014?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>‘Movie’ Frame rates. 24,25,30 Hz</td>
<td>‘TV’ Frame rates. 50, 60, 60/1.001</td>
<td>Higher Frame rates. 100,120 Hz</td>
<td></td>
</tr>
</tbody>
</table>

Higher frame rate improves viewing experience

Similar to DCI movie format – content readily available
**UHDTV COLOR PRIMARIES**

<table>
<thead>
<tr>
<th>Chromaticity coordinates (CIE, 1931)</th>
<th>x</th>
<th>y</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red primary (R)</td>
<td>0.708</td>
<td>0.292</td>
<td>630 nm</td>
</tr>
<tr>
<td>Green primary (G)</td>
<td>0.170</td>
<td>0.797</td>
<td>532 nm</td>
</tr>
<tr>
<td>Blue primary (B)</td>
<td>0.131</td>
<td>0.046</td>
<td>467 nm</td>
</tr>
<tr>
<td>Reference white (D65)</td>
<td>0.3127</td>
<td>0.3290</td>
<td></td>
</tr>
</tbody>
</table>

Picture information can be linearly indicated by the tristimulus values of RGB in the range of 0-1.
The colorimetric values of the picture information can be determined based on the reference RGB primaries and the reference white.
The color primaries are on the spectral locus.
Color gamut comparison in the CIE u' v' chromaticity diagram

- **Rec.709 RGB**
- **D-Cinema P3 RGB**
- **UHDTV_PDNR 2011_RGB**
- **Spectral Locus**
COLOR DIFFERENCE ENCODING

- Converting R, G, B to Y’, R’-Y’, B’-Y’
- Human perception is less sensitive to resolution in color difference signals than luma signals
  - High frequency cut-off at around 60 cpd in luma, but at around 10-11 cpd in chrominance (R’-Y’, B’-Y’) signals
    (cpd - cycle per 1 degree of visual angle)
- We can sub-sample R’-Y’, B’-Y’ to save bandwidth
  - In storage and interfacing
  - In compression
- Sub-sample R’-Y’, B’-Y’ by a factor of two in each dimension. Resulting number of samples is ½ that of original RGB.
THE CONVENTIONAL WAY TO CREATE Y’, CB’, CR’ NON-CONSTANT LUMINANCE

The Cb’ and Cr’ signals contain some luminance information. If they are subsampled, there will be some loss in luminance resolution.
Y’ is now a pure luma signal; it contains no chroma information because it was made from linear RGB signals. This is called “constant luminance”, or “CL”. The color difference signals contain less luminance information and can be down sampled with much less effect on the luminance resolution. The Cb’, Cr’ signals can be created using slightly different schemes.
BENEFITS OF CONSTANT LUMINANCE ENCODING

- Luminance resolution is less affected by down-sampling the chroma signals
- Detail and edge information is more accurately maintained
- Lower correlation between Cr’, Cb’ and Y’
- Better compression efficiency
- Chroma information survives compression better
ADVANTAGES OF NON-CONSTANT LUMINANCE

- Same results for color mixing between R’G’B’ and Y’Cr’Cb’
- We have been doing NCL for 60 years
- Tried and true
- No-risk involved, no surprises lurking
- Why change something that works?
The impact of the maintenance of lightness on image sharpness

**Non-Constant Luminance Signals**

- Significant lightness discrepancies in the right-side four dark pixels after 4:1:0 sub-sampling
  - Blurred boundary (white box)
  - Smeared black stripe line (green box)

**Constant Luminance Signals**

- The lightness values are almost maintained in the right-side four dark pixels after 4:1:0 sub-sampling
  - Original sharp boundary (white box)
  - Apparent black strip line (green box)
WHO IS INTERESTED IN UHDTV?

Terrestrial
- Korea have UHD-1 DVB-T2/HEVC trials on air.
- Korea plans UHD-2 terrestrial trials in 2008
- CSA in France interested in UHD-1 for use in DVB-T2/HEVC transition.
- RAI in Italy may consider UHD-1 as part of DVB-T2/HEVC if easy to do.
- Sinclair in the USA plan tests
- RTVE in Spain have made tests

Satellite
- Sky Deutschland says UHD-1 services are at least 2 years away
- SES says ‘they are waiting for UHD-1 orders’. Already test broadcasts.
- Eutelsat says ‘they are waiting for UHD-1 orders’. Already test broadcasts.
- NHK plan UHD-2 broadcasts before end of decade.
QUO VADIS 3D AUDIO?

- Channel based (e.g. 22.2, 10.2, 7.1, 5.1)
- Scene Based (e.g. Ambisonics 4-channel)
- Object Based (e.g. ATMOS)
WHAT IS THE EBU DOING?

- EBU FTV BEYONDHD Group
  - Generation of UHD-1 Test Material for experiments.
    - UHD-1 Test material shot in JUN’12.
    - UHD HFR Test material shot in JAN’13.
  - Active participation from industry welcomed
WHAT IS DVB DOING?

- Defining a UHDTV broadcast profile.
  - Identify market demand per platform/service type
  - Identify/collecting commercial requirements for UHDTV services.
SMPTE

- Mainly focusing on the production workflow and integration of UHDTV.
- First UHDTV standard set published in 2006
  - SMPTE ST 2036-1 :
  - SMPTE ST 2036-2 : Audio characteristics and mapping.
  - SMPTE ST 2036-3 : Mapping of UHDTV in 10Gb interface
- Study group on the full UHDTV Ecosystem 24TB
- Output report on current status of technology and missing standards for professional workflows
- Tackling the professional interface problem for Higher data rate content :
  - 32NF Multi-link SDI interfaces.
Theoretical parameter set for UHDTV audio and video

ITU-T SG6 WP6c

ITU

Investigating missing standards for full UHDTV ecosystem.

SMPTE

24TB – SG on UHDTV Ecosystem

32NF – Multilink 3G SDI

UHDTV

Consumer Electronic Labels

CEA / DE

Experiments to assess best parameters for UHDTV vs HDTV – no audio

FTV - BeyondHD

FAR – 3DAudio

Defining requirement for a UHDTV broadcast profile

CM - UHDTV

CM/TM - AVC

MPEG

HEVC

3D Audio

Investigating the most efficient compression technologies
WHO DOES WHAT (SUMMARY)?

ITU-T SG6 WP6c
ITU BT 2020
ITU BT 2246-1

ITU

ITU

SMPTE

SMPTE 2036 – 1: image parameters for UHDTV
SMPTE 2036 – 2: Audio characteristics and audio mapping
SMPTE 2036 – 3: Mapping of UHDTV in 10Gbps interface

24TB – SG on UHDTV Ecosystem

MPEG

MPEG

DVB

CM - UHDTV
CM/TM - AVC

EBU

FTV - BeyondHD

CEA / DE

CM - UHDTV

UHD-1 Test material
UHD-1 vs HDTV
Frame rate issues?

32NF – Multilink 3G SDI

3D Audio

Main profile
Main 10 profile

08.03.2013
WHERE ARE WE WITH 3DTV?
PERCEPTUAL CUES

- Focus
- Vergence
- Binocular parallax
- Perspective (vanishing point)
- Relative sizes
- Light and shadow
- Interposition (overlap)
- Texture gradient
- Fog, dust, and haze
- Motion parallax

- Neither 2D or 3D
- 3D only
- 3D only
- 2D and 3D
- 2D and 3D
- 2D and 3D
- 2D and 3D
- 2D and 3D
THE MAGNIFICENT EIGHT!

DVB 3DTV Frame Compatible Formats

- 720p@50, 60 - Top and Bottom
- 1080i@50, 60 - Side by Side
- 1080p@24 - Top and Bottom
- 720p@50, 60 – Side by Side
- 1080p@24 - Side by Side

- Why so many? There are circumstances where each of them will produce the highest quality results for the viewer
<table>
<thead>
<tr>
<th>Conventional HD Service Compatible (CSC)</th>
<th>Conventional HD Frame Compatible (CFC)</th>
<th>Conventional HD Display Compatible (CDC)</th>
<th>Multiview Profile 2\textsuperscript{nd} Gen 3DTV</th>
<th>Object Wave Profile 3\textsuperscript{rd} Gen 3DTV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 3</strong></td>
<td><strong>Level 2</strong></td>
<td><strong>Level 1</strong></td>
<td>Plano-Stereoscopic Profile 1\textsuperscript{st} Gen 3DTV</td>
<td>Multiview Profile 2\textsuperscript{nd} Gen 3DTV</td>
</tr>
<tr>
<td>2D compatible 2D HD + ‘top up’.</td>
<td>Frame compat. side-by-side or top-and-bottom.</td>
<td>colour anaglyph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D HD + ‘top up’</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CSC/FC + depth maps
THE SITUATION TODAY

- S-3D TV displays widely available – using either polarization plane or shutter glass viewing.
- Most used broadcast system today is the DVB ‘Frame Compatible’ (FC) system.
- Blu Ray system is a ‘Service Compatible’ (SC) system with an MVC ‘top up’ signal.
- Some use of a ‘Dual Stream’ (DS) system with independent L and R images.
- Future probably lies with an A-3D TV system, using Ultra-HD displays that display multiple images, with screen coating that directs the viewers’ eyes to one pairs of images.
AUTO-STEREOSCOPIC 3DTV

- Ultra HD display used for both Ultra-HD and A-3DTV
- Screen display has contiguous ‘slices’ that collectively constitute images.
- Screen coating is arranged so that each eye sees one of a pair of pictures.
- Horizontal resolution is proportional to the total resolution divided by the number of views
- Probably 8-10 views
- Resulting quality is HDTV-like
- Issue 1: Does the screen coating affect 2D quality
- Issue 2: Should the multi-views be derived from L and R images alone, or will help be needed?
3D TV ROADMAP

- Frame Compatible AVC (2010)
- ?
- Auto-stereoscopic (with helper?)
- HEVC (2020)
THE 3DTV ROAD MAP

L and R Images

- FC format
- SC format AI+MVC
- SC format AI(AVC)+HE VC
- DS format L(AVC)+R(HE VC)
- Tile Format (AVC)
- Tile Format (HEVC)

- FC(+AVC)
- FC(+HEVC)
- DS format L(HEVC)+R(HE VC)

- Autostereoscopic 3D display (UHD-1 display)

L, R, plus helper.
3DTV OR UHDTV – WHICH IS BEST?

- 3DTV suits certain types of programme content. Benefits where you can get cameras physically close to the action, and where there is limited action.

- UHDTV suits certain types of content. Benefits come when there is a ‘large canvas’ event with lots of detail and motion.

- Both 3DTV and UHDTV have strengths!
CONCLUSION

- What should be the ‘step’ between FC and AS for 3DTV?.
- Can AS be made to work with L and R alone, or will helper signals be needed? Will set makers cooperate on this?
- Which UHD-1 frame rate(s) – movie, TV, or higher?

What do I think?
- UHDTV is likely to be more relaxing to watch than 3DTV, with less eye-brain activity, and wider range of production grammar, so it may become the more dominant media.
- 3DTV is unlikely to disappear – its recurrence every few years suggest a public demand.
- We need to think about how long the life of UHD-1 may be.
- Do we need a DVB-T2+ for UHD-2?
Thank You!

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