Technical Report 014

What follows HDTV?

A status report on 1080p/50 and ‘4k’

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EXECUTIVE SUMMARY

This document has been prepared by the EBU 'BeyondHD' Project that is part of the strategic programme on Future Television Systems. It is intended for EBU Members' senior management and provides a general technical overview about future TV formats.

Many broadcasters are still in the phase of implementing HDTV for all regular services and this activity will set the main focus in production and distribution for EBU Members for the coming years. The consumer and professional industries, however, are already promoting technologies beyond the current HDTV formats used in the broadcast domain. Very soon, new consumer and professional products will enter the market with resolutions clearly beyond that of current HDTV. The ultimate aim is to give the consumer a significantly enhanced viewing experience.

Broadcasters may wish to choose a future proof format, and may even be forced by competition to change their format. Whilst high frame rates offer better temporal resolution, which benefits sports and other content with high motion scenes, image formats with higher spatial resolution improve the imagery for genres such as movies, drama and documentary. The broadcasters' strategies, financial implications, theme and their viewers' interest should also be considered when selecting a 'next generation' format.

This first report of the EBU 'BeyondHD' project provides a high level review of the status and potential impact of two technologies; an evolutionary progressive HDTV format, 1080p/50, which incorporates the best features of the current HDTV formats, and a more revolutionary format, 4k, which has four times the resolution of 1080p/50.

The 1080p/50 standard is mature and may be applicable for some broadcasters as an immediate and enhanced HDTV format in the production environment to simultaneously increase image quality headroom and to reduce the number of HDTV formats, thus simplifying workflows. 1080p/50 converted to current HDTV distribution formats during play-out can also increase the image quality in the home. 1080p/50's deployment in distribution scenarios will require new types of encoder and receiver technologies, but these are partly being introduced now. The majority of new consumer displays with 1920 x 1080 pixel resolution can already handle 1080p/50 on their HDMI interfaces. The current downside to 1080p/50 in production is that the availability of 1080p/50 products is still limited and they are more costly.

4k will significantly increase the perceived image quality for consumers on large screens, thus enabling a more immersive experience by facilitating closer viewing distances. However, this format is just being developed for Digital Cinema applications, and further developments and standards for broadcast production environments are required. In distribution, 4k will require a new compression format called High Efficiency Video Codec (HEVC), which will come to market in 3 to 5 years. Consumer flat panel displays with 4k resolutions will percolate into the market as high-end models and they may potentially be well served with a 1080p/50 distribution format. Alternatives to linear broadcasting such as downloads, HbbTV and IPTV will allow native 4k delivery to the home.

EBU Members are advised to proactively participate in the relevant standards bodies and EBU initiatives to ensure that their requirements of future HDTV formats such as 4k are implemented before proprietary and potentially closed systems enter the market. Investigations should also include higher frame rates, dynamic range and enhanced colours.

The EBU project group 'BeyondHD' will create 4k test sequences that will allow EBU Members to gain experience of the format.

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Keywords: HDTV, 720p, 1080p, UHDTV, 4k, 8k,

1. Introduction

Many broadcasters have established HDTV productions and serve their audiences with at least one HDTV channel via Satellite, Terrestrial, Cable or IP networks to complement their regular SDTV distribution bouquets. It follows therefore that many broadcasters have established clear strategies to migrate all their production and distribution platforms to HDTV. This transition will undoubtedly form the clear focus of investment for broadcasters in the years ahead.

The professional and consumer industries, on the other hand, consider that HDTV is now state of the art, and are actively promoting new developments in very high definition products to provide enhanced media experiences to the consumer, not to mention securing their continuing revenue streams.

Consequently, broadcasters need to be informed about these proposed 'beyond HDTV' technologies, together with their possible impact on production, distribution and their relationship with the consumer.

The objective of this document is to provide general information about two technologies that are currently being developed by the industry that go beyond the current HDTV experience. The first of these is the evolutionary 1080p/50 format, which combines the best features of the current HDTV formats. The second format is the newly proposed "four times HD resolution" format, abbreviated as "QuadHD" or (more imprecisely) "4k". This "four times HDTV resolution" format (3840 x 2160 pixels) corresponds to the Level 1 (format) of NHK's Super High Vision system (Level 2, with 16 times HDTV resolution is also being developed in Japan). For the purpose of this document we use the term 4k although the reader should be aware that there is a broad family of slightly different image formats. See § 4.3 for more detail.

Stereoscopic television (3DTV) is not considered in this document as it represents a different genre of programme. However, the 2D image formats discussed in this document can likely be applied to 3DTV.

2. Consumer market and consequences for broadcasters

Three significant trends have been observed that will increase the consumers' expectations of image quality:

- **First trend: Marketing of new Flat Panel Displays in the home**

The most important "Wow" factor in the consumer industry and one that primarily drives customer interest is undoubtedly the display. Since the recent mass penetration of flat panel displays in the consumer market, a clear preference for increasingly large display sizes has become evident.

Also from the point of view of display resolution, whilst 1920 x 1080 pixel displays are today's state-of-the-art ("1080p", "Full HD"), the consumer industry already has Quad-HD resolution displays on offer.

This increase of resolution coupled with other features such as "more and better colours", cinema-like aspect ratios (e.g. 21:9), higher display frame rates etc. will stimulate new consumer investments in displays.

At the Consumer Electronic Show, CES 2012, so-called "4k" displays were shown by Sony, Toshiba (which is also a glasses-less 3D display), Samsung, Sharp (also in 8k resolution), LG, Panasonic and others.

Toshiba has already started consumer market deployments of its 4k display in the UK and other territories.

Figure 1 Example: Toshiba 55ZL1G consumer display with 4x HDTV resolution and 3D capability without the need of 3D glasses

- **Second trend: TV programmes made available through new distribution media.**

In the near future new distribution channels (non real time download of high quality material from the internet, packaged media, HbbTV, connected TV, IPTV) could provide bit rates that are much higher than those defined in current DVB specifications. As an indicator of this trend, content aggregators are already preparing to deliver higher quality content via these channels. As an example, Apple's iTunes requires that HDTV content be delivered in contribution with ProRes 422 HQ (220 Mbit/s VBR)[1].

Telecommunications and satellite operators may use their available bandwidths to provide content in higher resolution than today's HDTV.

- **Third trend: Consumers are increasingly accustomed to high quality electronic pictures**

In the past the only quality reference available to the typical consumer was the TV picture they saw at home. Usually the broadcast image format represented the state of the art on quality and technological advances. With the introduction of the Blu-ray, and high quality downloads this is no longer necessarily the case. Downloads or streaming of various image formats, and real time image processing by graphic engines in home computers, game platforms, set-top boxes and displays can produce very immersive images, many times better than those seen in broadcasts. Graphic engines will permit the technical image formats used in production, distribution and at the consumer premises (flat panel display, second screen, etc.) to differ substantially.

The benefit of this situation is that broadcasters can apply new HD formats in production first without the need to change their distribution platforms. The principle of oversampling at the source (camera and production) will result in higher quality headroom and better images in the home even if current HD distribution formats are employed.

In addition, the consumer industry is about to launch camcorders with 4k resolution to market, good photo cameras (e.g. DSLR) can already easily capture 4k resolution and 4k YouTube clips are not unknown.

Figure 2 Example: JVC 4k camcorder introduced at CES 2012

[1] iTunes Package Asset Specification 4.3, (March 2012), Apple inc.
http://images.apple.com/itunes/lp-and-extras/docs/iTunes_Package_Asset_Specification.pdf

- **Consequence for broadcasters**

The new trends described above will pose questions for the longer-term technology investments of broadcasters:

- How long will present HDTV broadcast signals provide sufficient image quality to the home, particularly if competitors' and consumer equipment moves to 4k?
- Broadcasters considering their next investment cycles may be confronted with questions on what is a safe investment for current HD formats in production or whether there might be an alternative in the short to medium term?

These issues will now be discussed in terms of 1080p/50 and 4k formats. In addition some background information to each of the formats will be provided.

3. Candidate 1: 1080p/50

The following figure illustrates the significant differences between current (legacy, 1080i/25 and 720p/50) HD formats used by broadcasters in production and distribution in relation to the 1080p/50 HDTV format.

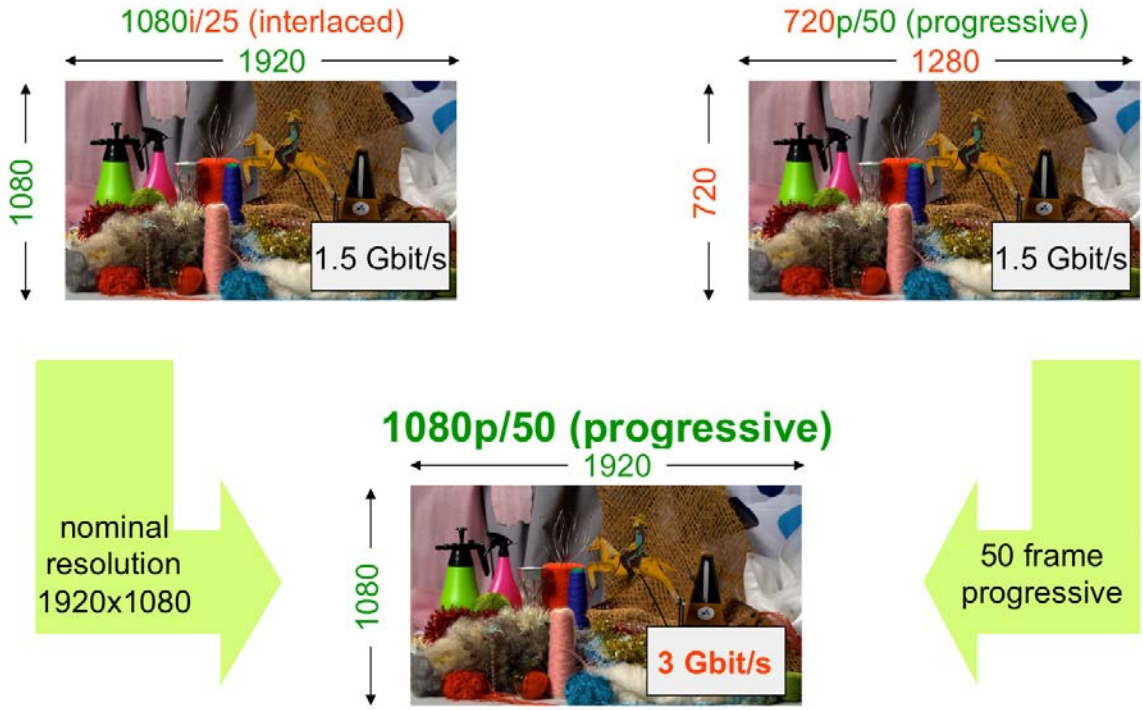

Figure 3: The 1080p/50 format reaps the benefits of 720p/50 and 1080i/25

Significant features of 1080p/50:

- By avoiding interlaced scanning, a number of production processes can be simplified and their quality improved.
- 1080p/50 employs the good spatial resolution of 1080i/25 as well as the good temporal resolution of 720p/50. Thus it combines the best features of the current HD formats.
- The drawback of 1080p/50 is that the uncompressed bit rate is double that of 1080i/25 and it therefore requires the use of 3G SDI infrastructures.

3.1 Analysis: 1080p/50

3.1.1 For use in production

- 1080p/50 is technically mature and fully standardized.
- Broadcasters' deployment of 1080p/50 is very limited today. Nevertheless many have prepared basic infrastructures (cables, routers, switchers) with potentially longer economic lives for use with 1080p/50. Additionally, some broadcasters will renew their studio infrastructures to be fully compatible with 1080p/50 when their next investment cycles happen.
- Mainstream 1080p/50 HD production equipment is still expensive.
- 1080p/50 in production will provide higher quality headroom even if the distribution uses current HD formats such as 1080i/25 and 720p/50.
- Standards conversion for programme exchange will be simplified (an inherent benefit of the universal use of progressive signals)
- 1080p/50 is an evolutionary HD production format, and it will require higher bit-rate with studio compression formats (as already tested by the EBU), thus more storage, and increased network loads.
- Several contribution codec manufacturers include 1080p/50 as an option

3.1.2 In distribution and the home

- In the consumer domain almost all new flat panel displays with HDMI 1.3 interfaces and the HDTV 1080p label can display 1080p/50. However, there is an open question regarding sources, because there are no 1080p/50 broadcasts via DTT, SAT, IP etc. today.
- DVB has included the 1080p/50 format in its DVB specifications for H.264/AVC and SVC (since DVB specification TS 101 154 V1.9.1).
- With high performance H.264/AVC encoders being used, about the same bit-rate as that used for 1920 x 1080i/25 broadcasts will be required, and a better image quality will be delivered to the home (there is better coding gain with progressive signals, and no de-interlacing at the display will be necessary).
- A really significant perceptible image quality improvement in the home will only be perceived with increased display sizes at the same or shorter viewing distance (>46" for a 1920 x 1080 display, see BBC white paper 092). Only then, higher resolutions and better image quality delivered to the home will be positively perceived.
- Only a minority of set-top boxes and integrated receivers are able to decode 1080p/50 today. Upcoming STB and integrated receivers, which also target better stereoscopic 3D quality, will include 1080p/50 decoding capabilities after a transition phase.
- 1080p/50 and 1080p in general is penetrating the consumer environment via camcorders (e.g. Panasonic HDC-SD707, Sony HDR-CX130), but also via games consoles such as Sony's PlayStation 3 and Microsoft's Xbox 360. Also, smartphones such as the Apple iPhone 4S are capable of recording in 1080p HD video (but only at 24 - 30 Hz frame-rates). In general, the performance of consumer equipment cannot be compared to professional production equipment.
- The successor to H.264/AVC (the current compression format for HDTV distribution) called HEVC (high efficiency video coding) is under standardisation at ISO/MPEG and ITU-T. Products are expected to be commercially available some time around 2015. It will provide additional savings in bit rate (the goal is up to 50% savings compared to H.264/AVC), thus it will be an ideal candidate for 1080p/50 or even higher resolution formats such as 4k.

- An informative publication on the 1080p/50 format is also available from the UK Digital TV Group (DTG): *"1080p50: Delivering the Benefits of the Progressive Format over Interlace in Broadcast Television Through Acquisition, Production and Encoding"*.
  See http://www.dtg.org.uk/publications/books.html
- Introduction of a new format (1080p/50) as addition to an existing one (720p or 1080i) may require simulcasting the same service at two different formats. In such a scenario a reduction of channel cost is desirable. In principal two methods are possible:
  - (A) Using H.264/AVC High Profile for the base layer at 720p/1080i and Scalable Video Coding (SVC) at Scalable High Profile Level 4.2 for the enhancement layer at 1080p/50, or
  - (B) H.264/AVC High Profile for the base layer at 720p/1080i and HEVC for the enhancement layer at 1080p/50.

  For both methods (A) and (B) a channel rate reduction of about 20 - 30% compared to the simulcast case (using 720p/1080i & 1080p H.264/AVC High Profile for both) can be assumed.

  Equipment is currently only available for method (A), and it should be noted that the H.264/AVC licensing of the High Profile also includes the Scalable High Profile for SVC.

3.1.3 Conclusions on 1080p/50

1080p/50 is a useful intermediate format to replace current HDTV formats in production.

Broadcasters planning to invest in the near future in mainstream HDTV production equipment should carefully assess 1080p/50 as a viable option, but they should also be aware of increased costs and limited availability of equipment. Attention should also be given to the impact of the increased bit rates on storage and networks. 1080p/50 would facilitate a useful increase in production quality headroom, whilst a 1080p/50 production environment with conversion to current HDTV formats in distribution will offer many advantages too.

1080p/50 used in distribution will require no more bit-rate than that used with today's 1080i/25 format (with MPEG-4 AVC/H.264 codecs). In a few years, with the deployment of HEVC in broadcast encoders and domestic receivers, 1080p/50 will require much less bit-rate than today's HDTV broadcasts.

3.1.4 Further work on 1080p/50 in relation to new 4k consumer displays

An investigation should be started amongst EBU Members as to whether 1080p/50 in distribution would also serve 4k displays with good image quality (and under what conditions, such as display size, viewing distances and bit-rates). This could allow EBU Members a migration scenario when the penetration of 4k displays reaches 15-20% of the market in few years time. The test should be done in comparison to a full 4k chain.

4. Candidate 2: 4k

The 4k format has about 4 times the resolution of 1080p/50. It is a fully progressive format, and it is initially targeting Digital Cinema applications (with frame rates of 24 and 48 Hz) and it might later impact broadcasting with frame rates between 50 Hz and 120 Hz[2].

Figure 4: Evolution of image formats from SD, to HDTV, to 4x HDTV (4k)

4.1 Analysis: 4k

4.1.1 4k Terminology confusion

There are a number of image formats that can more or less be associated with the terms 4k and Ultra High Definition TV.

4k formats have their origins in Digital Cinema. The 4k Digital Cinema format has a resolution of 4096 x 2160 pixels with a cinema style aspect ratio (SMPTE ST 428 1:2006).

The term "QuadHD" is undefined but is used to suggest four times the resolution of HDTV, which is 3840 x 2160 pixels with an aspect ratio of 16:9.

A more precise and correct definition can be found in ITU-R BT.1769 and SMPTE 2036 1:2009 which defines Level 1 Ultra High Definition (UHDTV) as having 3840 x 2160 pixels and Level 2 corresponding to the so-called "8k" system (called Super High Vision by NHK Japan) with 7680 x 4320 pixels resolution.

UHDTV was revised in ITU-R in April 2012, to include wider colour spaces, and higher frame rates up to 120 Hz[2].

4.1.2 Status of 4k in production

- There is no significant broadcast content available today.
- The major use of 4k is in Digital Cinema. In 2011-12, the first movies such as "*The Hobbit*" were shot in 4k and even at 48 Hz frame rate. It is safe to assume that technology deployed in Digital Cinema will migrate to the broadcasting industry (as has always happened in the past) over time.
- For broadcast production some products and prototypes have been shown at NAB 2012. Sony for example has shown typical TV content and workflow in 4k resolution created with

[2] Frame rates up to 120 Hz for 8k UHDTV were standardised in ITU-R in April 2012.

the F65 camera; other manufacturers are promoting new compression formats (e.g. AVC-ULTRA by Panasonic), DSLR cameras (Canon) or even prototypes of reference monitors (Canon).

- A good overview of current standards for UHDTV is provided by the following SMPTE documents:
  - **ST 2036 1:2009** *Ultra High Definition Television - Image Parameter Values for Program Production*
  - **ST 2036 2:2008** *Ultra High Definition Television - Audio Characteristics and Audio Channel Mapping for Program Production*
  - **ST 2036 3:2010** *Ultra High Definition Television - Mapping into Single-link or Multi-link 10 Gbit/s Serial Signal / Data Interface*
- High quality and expensive broadcast productions (i.e. with cameras, multilink interfaces, and special recorders) are possible today, but many technological challenges have to be addressed before 4k can be made ready for mainstream broadcast applications.
- There are some challenges to implementation of a true 4k resolution in cameras if the market wants to maintain a 2/3" form factor that allows continued support of large zoom lenses used in sports or other large venue productions.
- NHK's 8k Super High Vision includes 4k in its hierarchy.
- The increase of spatial resolution to 4k will provide a significantly improved viewing experience on large (>50" native 4k displays) with more static images. The question remains as to whether dynamic genres such as sport at higher "BeyondHD" resolutions will also require an increase in frame rates beyond 50 Hz to avoid motion blur effects.

4.1.3 Status of 4k in distribution and the home

- Today, there is no distribution of 4k via SAT, DTT and cable. YouTube has provided some clips, but with a limited frame rate (non TV frame rates).
- Again, the final standardisation and deployment of the successor to the H.264/AVC compression standard called HEVC will be essential for the success of 4k in reducing the bit rates required.
- 4k is not yet included in the DVB standards.
- Some 4k flat panel displays (and projectors) will enter the market in the high-end segment; however home infrastructures (e.g. new HDMI versions) still need to be developed.

4.1.4 Conclusion on 4k and what EBU Members should do

It is safe to say that large scale, mainstream, 4k broadcast production infrastructures will not be available for the next 3 - 5 years. Developments and standards efforts for 4k will likely increase for Digital Cinema and will also impact typical broadcast applications.

Commercial broadcasters and satellite operators have already started to investigate and experiment with 4k as a premium product. Depending on the related business models, the market impact of 4k could be significant. The consumer industry will use "Beyond HD resolutions" (cf. Apple iPad 3 and 4k flat panel displays) as a marketing vehicle to stimulate the content creation industries.

EBU Members should pay close attention to these developments and should proactively participate in related EBU projects. The window of opportunity available to significantly influence standards and industry developments is opening now. Gathering first experiences with premium productions may be a useful option. The EBU project 'BeyondHD' is creating 4k test content for EBU Members. Overall, EBU Members should consider 4k in mainstream production as a longer term development, where many parameters can still change.

5. A note on audio developments

Any new TV systems that seek to deliver a significantly improved visual experience should also take into account the need for a significantly better audio experience. Human hearing is more acute than is visual acuity. One can hear depth, height, width and front-to-rear positioning with great range in detail and dynamic range. But thinner and yet thinner displays leave no room for decent loudspeakers and a new approach to "Audio-fidelity" should be communicated to the consumers.

Some examples that could form part of the future:

a. **Channel based**. This is the conventional approach that feeds audio signals to discrete loudspeakers dispersed around the viewing environment (e.g. front left, centre, front right, surround left, surround right and LFE). A known and mature technique, but with considerable practical limitations, not least that most homes have difficulty correctly locating and cabling 2 speakers, let alone 5.1 (or 22.2). There are speaker technologies that mitigate though including phased-array speakers and wave field synthesis but these have not become mature enough for widespread consumer use.

b. **Scene based**. Using techniques that capture (e.g. using the Sound Field Microphone) and present (e.g. using Ambisonics) the whole sound field could also be an important future element. They have the advantage of bandwidth efficiency (especially at lower orders), backwards and forwards compatibility (working well with mono or multi speaker reproduction) and offer some opportunity for creative sound field manipulation. They do however have limitations especially when the sound field cannot be described at a single point (i.e. when 'multi miking' is required or there is a need for creative sound design).

c. **Object based**. These techniques are starting to emerge and could well be significant. Both Dolby Atmos and the Fraunhofer Intelligibility technology use object coding. Practical implementations are still in their infancy and much work needs to be done but this technology has the feeling of something very significant about it.

d. **Binaural**. Commonly known as 'dummy head recording', the result is a two channel signal that is typically reproduced through headphones.

This is not a new technology but it is being revisited with enthusiasm partly because it is easy to deliver to an audience that, with mobile devices, is well used to using headphones. Not only could headphone listening become as immersive as speaker listening but binaural techniques are also being employed for loudspeaker reproduction too.

Neumann KU100 binaural microphone

Annex 1:Technical Details

A.1 The 1080p/50 format

A.1.1 Does 1080p = 1080p/50?

Not necessarily. When reading press or product information that refers to "1080p" but which does not clearly describe the frame rate, it is important to realise that this usually means 1080p for cinema/drama with frame rates of 24 Hz, 25 Hz, up to 30 Hz, and thus not suitable for typical broadcast genres. One should always critically ask what frame rate is meant with "1080p". European TV broadcasters usually require 50 Hz for sports genres.

A.1.2 Does 1080p = 2k?

1080p/50 has a close relationship in resolution to the so called 2k format (2048 x 1080), which is the predominant Digital Cinema format in content creation and presentation in cinemas. All Digital Cinema formats use progressive scanning formats, exactly like 1080p/50, but they have only 24 frames per second (compared to 1080p/50's 50 frames per second which allows its use with sport and other fast action genres). However, within the near future Digital Cinema formats will also include 48 frames per second (or higher).

A.1.3 Do we need the same image formats in production and emission?

No. HDTV has already shown that using "oversampling" in production and a lower resolution image format in distribution can provide very good results in the home. It also optimizes the use of bandwidth in distribution.

In addition more and more consumer devices have advanced graphic engines to render the incoming image format to the required resolution of the display. It is a clear advantage to avoid interlaced signals in distribution.

Whilst it would be ideal to have 1080p/50 in production and emission, it is easy and inexpensive to convert from 1080p/50 to the existing emission formats (1080i/25 or 720p/50).

A.1.4 Will 1080p/50 be the only production format?

No. 1080p/50 can be a common denominator and replace 1080i/25 and 720p/50, and it might also be a signal master format for archives. For creative reasons, many European producers will still continue to produce drama genre programmes with 25fps.

It is important to note that the 1080i/25 and 720p/50 formats as well as 1080p/25 can be easily derived from a 1080p/50 master whilst preserving the picture quality.

A.1.5 EBU work and documents on 1080p/50

The EBU has already performed a live demonstration of end-to-end 1080p/50 contribution from ARD Frankfurt to Geneva and to IBC Amsterdam in 2011. The aim of this demo was to show a live 1080p/50 contribution quality link using the same bit-rates in satellite and fibre connections as those used currently for 1080i/25. In addition to the prototype production equipment used, a prototype STB for 1080p/50 was used to simulate a real 1080p/50 broadcast. Results were observed at IBC 2011 on two reference monitors indicating for 1080p/50 the same or better quality than 1080i/25 at the same bitrates.

- EBU Studio Compression Analysis for 1080p/50 acquisition/studio and NLE codecs:
  - BPN 097 - HDTV Studio & Acquisition Compression Analysis: Avid DNxHD codec
  - BPN 098 - HDTV Studio & Acquisition Compression Analysis: Panasonic AVC-I 200 codec
  - BPN 099 - HDTV Studio & Acquisition Compression Analysis: Sony SR-Lite codec
- EBU findings on 3G SDI infrastructures for 1080p/50
  - See EBU Technical Report 002.

A.2 Viewing benefits for 4k, 8k

The ITU has published a document that describes the viewing angle between the different image formats – HDTV, the 4k and 8k formats. As shown below 4k has a clear benefit over current 1920 x 1080 displays.

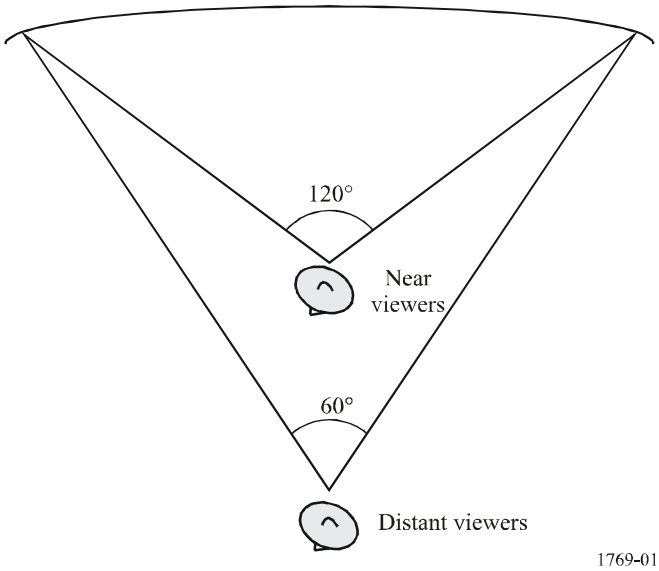

Figure 5 from ITU-R BT.1769

System	1920 x 1080	3840 x 2160	7680 x 4320
Viewing distance (relative to picture height)	3	1.5	0.75
Viewing angle- horizontal (degrees)	33	61	100

These values are calculated, assuming a distance at which scanning lines just cannot be perceived by people with a visual acuity of 1.0.