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Current Status of High Definition Television Delivery Technology.

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Current Status of High Definition Television Delivery Technology.

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Summary

Over the coming years, all EBU members will need to take decisions about systems for HDTV broadcasting or for HDTV delivery by other means. One element of choice will be bitrate used for delivering the compressed HDTV video signal. This is a critical factor that affects both the quality the viewer sees and the transmission costs. It is important to take a well-informed decision about it. This report is intended to provide background information needed for this decision

All HDTV broadcasting planned to date in Europe will use MPEG-4-AVC video compression, but it will not be just a matter of buying an MPEG-4-AVC encoder from a supplier. The efficiency of MPEG-4-AVC encoders, and thus the quality viewers see for a given bitrate, depends on how the encoder has been designed and implemented. This is different from manufacturer to manufacturer, and equipment costs are different.

Part of the philosophy of the MPEG-family is that encoder manufacturers are allowed to include any compressions techniques they wish, provided the images are always decodeable by a standard MPEG-4-AVC decoder. This practice means that manufacturers can compete with each other for better products, and overall quality rises over time, while the public is always able to decode the images

In this report we examine the options for source formats and for encoding, and examine how this will affect the quality the viewer sees. This work has been done by EBU Project Group D/HDC, which was charged in 2007/8 with evaluating examples of the available MPEG-4-AVC HDTV encoders. D/HDC prepared this document as background to this work, and as a repository for general conclusions. D/HDC has also produced a second series of documents that give the results of tests on specific manufacturers encoders. This second series, one volume for each manufacturer's equipment tested, is only available to EBU members

This report includes, in three Appendices, background information on the methods used for evaluating the codecs. This used a compilation of HDTV test material in different formats, which is available to EBU members. The report also includes, as an additional Appendix, a note of explanation about the current situation regarding copy protection options for HDTV set top boxes and receivers. This is a complex situation, without currently a unified view across Europe about best practice.

1. System considerations

1.1 HD scanning formats

The EBU has identified and specified, in EBU document Tech 3299, **four HDTV production formats**: 720p/50, 1080p/25, 1080i/25, and 1080p/50. The 1080i/25 and the 720p/50 formats can also be used for broadcasting, or other forms of secondary distribution, whereas 1080p/25 is currently a production format only. However, for distribution, 1080p/25 can either be mapped into 1080i/25 as 1080psf/25 (**p**rogressive **s**egmented **f**rame, psf) or converted to 720p/50 by spatial down conversion combined with frame repetition. 1080p/50 is termed a '3rd generation' HDTV format, which some broadcasters consider may be used in future for production, and possibly distribution, purposes.

EBU studies suggest that, if the final quality seen by the modern HDTV viewer is taken into account, the most 'quality-efficient[1]' broadcast format of these four, seen on current HDTV consumer displays, is the 720p/50 format. 1080p/50 is also relatively quality-efficient and can be compressed to bitrates comparable to 1080i/25. No technical advantages have been identified to-date for the 1080i/25 format in the current broadcast environment, though there were advantages in the past in the all-CRT-based display environment.

Almost all HDTV displays sold in Europe today are matrix displays, requiring incoming interlaced TV signals to be deinterlaced. The progressive format is thus the natural match to current HDTV displays. Displays with the highest market penetration today are compliant with the 'HD-ready' or 'HD-Ready-1080p' specification of EICTA (see http://www.eicta.org/ for more details of these and other labels).

Some broadcasters in Europe are however choosing the production format 1080i/25 for other than technical reasons. This may be when, for example, older legacy equipment only supports 1080i/25, or when productions are commissioned in, or the customer may require, 1080i/25. Both are understandable reasons. But it is now technically understood that the interlaced footprint in the HDTV signal cannot be removed with standards converters. Consequently a chain with a progressive signal generated from an interlaced source will always have a potentially impaired quality compared to a full progressive chain

As a rule of thumb, for interlaced production, it is better to use one high quality professional de-interlacer at the playout point, rather than placing the burden of de-interlacing on the many (and less effective) consumer devices in the home. An additional advantage is that broadcast encoders can operate moderately more efficiently in terms of bitrate requirements with progressive signals derived from interlaced than with interlaced HDTV.

EBU tests suggest that, all other elements being equal, the advantage for 720p/50 broadcasting applies whether the viewer's display is one of the widespread Wide-XGA-panels (1366x768 pixel, also called HD-Ready) or a newer panel with 1920x1080 pixel (HD Ready 1080p), up to a diagonal size of about 52 inch.

HDTV broadcast encoder manufacturers usually provide optional signal processing functionalities which process the baseband input video signal. This normally includes selectable input filters that reduce the horizontal resolution of the video signals, in order to reduce the required bitrate in distribution, but with some quality trade-off.

Often this horizontal down-filtering is expressed as the number of pixels per line. Having lower horizontal resolution reduces the 'criticality[2]' of the scene, and thus makes compression easier. If a

[1] Subjective picture quality/transmission bitrate

[2] Technically, a function of the entropy of the picture, which relates to how difficult the picture is to compress without artefacts.

scene shows visible compression artefacts such as blocking, lowering the horizontal resolution can reduce these, though the sharpness potential of the image falls also.

In addition, the Sony HD-CAM and Panasonic DVCPROHD formats[1] record only 1440 samples per line (with camera scanning at 1920x1080i/25). There is arguably no point in broadcasting material derived from this format at more than 1440 samples per line (although on the HD-SDI interfaces, a 1920x1080i/25 signal is carried). A similar situation exists with the DVCPROHD format that horizontally subsamples (down-filters) the 1280 x 720p/50 format to 960 x 720p/50 (though on the HD-SDI interface, the signal is 1280x720p/50).

Newer formats from Sony (XDCAMHD 422) and Panasonic (AVC-I) and GVG/Thomson (Infinity J2K) do not use horizontal down-sampling for either 1080i/25 or 720p/50.

The HDTV baseband environment can be seen as comprising a number of quality format/levels, given that the compression system and bitrate are chosen to transparently deliver the original signal.

Though it is by no means a complete indicator of quality, a major indicator of quality of a moving picture system is its luminance-sampling rate. This is used in the table below to classify scanning formats. There are several factors in addition to horizontal resolution that relate to subjectively perceived picture quality, so the luminance sampling rate should not be taken as a singular or linear measure of potential quality

Scanning raster	**Luminance sampling Rate**
1920x1080p/50	148.5 MHz
1920x1080i/25	74.25 MHz
1920x1080p/25	74.25 MHz
1280x720p/50	74.25 MHz
	Equivalent luminance sampling rate with subsampling
1440x1080i/25	54 MHz
960x720p/50	54 MHz
1280x1080i/25	48 MHz
960x1080i/25	36 MHz

The lower the level in the above table that is used, the lower the bitrate needed to produce 'artefact free' images, for a given scanning algorithm, but also the lower the potential detail in the picture - which is important for the HDTV experience.

SDTV quality signals (720x576i/25, 13.5 MHz luminance sampling rate) can be 'up-converted' to any of the formats by the broadcaster prior to broadcasting. The quality available to the viewer in this case can be better that the quality obtained from up-conversion in the viewer's HDTV receiver, and may be improved in quality compared to normally seen SDTV - but is not 'HDTV'. This can become even more apparent to the viewer if he has the possibility of ‘zapping’ between SD-up-converted and native HDTV channels.

To avoid double up-conversion, once in the studio and once in the receiver, if an HDTV format is broadcast, it is best if 576i/25 source material is converted only once to 720p/50, using the best possible converter in the studio.

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[1] These have recently been superseded in newer formats from these companies, for example XDCAM422 HD and Panasonic AVC-I.

The 1080p/50 format will provide higher quality headroom for programme production, and will make a major contribution to programme production in the years ahead, when 1080p/50 production equipment becomes readily available. Today, however, no complete IT-based studio infrastructure is available for this format.

The 1080p/25 format is an excellent format for programme production where motion portrayal is not critical, as is often the case with drama (movie-look type programmes). This format fits into a 1080i/25 delivery channel as segmented frames (1080psf/25), and can provide very high picture quality for viewers with 1920x1080 displays (given that there is no overscan, but one by one pixel mapping, though which is not very often the case today), and a modest quality advantage for viewers with the more widely used WideXGA (1366x768) displays.

There may be a case for using any or all of the four formats, 1080p/50, 720p/50, 1080p/25,and 1080i/25 for programme production, and one or both of the formats 1080i/25 and 720p/50 for distribution. Broadcasters need to make informed decisions on formats, rather than decisions based solely on the advice of equipment manfacturers, who may be influenced by their own product line availability.

To respond to Members' needs, the EBU has asked production equipment manufacturers to make production equipment which is 'agile', and can support any of the three 74.25 MHz formats. If possible, the equipment should also support the 1080p/50 format (EBU R115). The information available to date (Spring 2008) is that current new generation mainstream HD production equipment made by most or all manufacturers can support any of the 74.25 MHz formats.

In 2005 the consumer equipment manufacturers association, EICTA, supported and encouraged by the EBU, agreed labels that can be used for HDTV displays and for HDTV receivers. These are the ‘HD-ready’, and ‘HD-TV’ labels. These labels mean that receivers and displays are able to interpret and display the 720p/50 and the 1080i/25 format, as well as SDTV.

Several manufacturers are also already making available 1920x1080 displays. Until recently, they have attached one of the many labels that are not clearly defined. However their meaning for the public was limited to indicating that those displays use a native 1920x1080 panel. It is neither an indicator of one-to-one pixel mapping (i.e. no overscan), nor of the signal formats accepted (e.g. 1080p24/25/50/60 for Blu-Ray) at its interfaces. These non-specified labels confused consumers and the industry, and should be avoided. Fortunately, in Autumn 2007 EICTA agreed new and defined labels for 1080p displays ('HD-Ready 1080p') and for integrated receiver-displays ('HDTV - 1080p'). This is a welcome move, and these labels should supersede the earlier labels.

European broadcasters can broadcast either 720p/50 or 1080i/25, or the horizontally downsampled versions of them, as well as SDTV, in the knowledge that all HDTV ready receivers will be able to decode and display them (provided any conditions needed for copy protection and conditional access needed have been met by the viewer).

It is reasonable for broadcasters to inform their viewers about the quality they have provided in their services. This is a sensitive issue, because many broadcasts today use ‘sub-sampling’ prior to broadcasting, to allow a lower delivery bitrate at the expense of some loss of detail in the picture. Strictly speaking, services that are not based on a 74.25 MHz luminance sample rate should not technically be labelled as 'HDTV'.

1.2 Distribution options

Broadcasters have to decide which delivery media to use for their HDTV services.

1.2.1 Broadband

The linear/non-linear medium of broadband (both wired and wireless) is available in some parts of Europe. However it should be noted that high-quality (unimpaired) HDTV-services need high data rates that can currently only be met by VDSL-technology. The more widespread ADSL2+ technology can be used, but with some drawbacks in quality and 'QoS'[1].

FTTH (Fibre to the Home) networks are being deployed in many countries providing a much higher data rate (100 Mbit/s) into the viewers home, using IP protocol. These services can provide 'transparent' quality for HDTV, provided the networks are managed to avoid packet loss for video services.

Broadband networks usually offer a certain bitrate that is not large relative to digital satellite, terrestrial, and cable capacities. In addition, zapping times and other quality of service parameters can be dependent on the number of broadband streams simultaneously watched by the viewers. Only few European Broadband networks today have the capacity to deliver a single channel of HDTV without impairment - that is with the bitrates of 12 Mbit/s or higher needed.

It is possible to deliver HDTV on the Internet by downloading or streaming. Peer-to-peer networks could deliver such services, but work remains to be done to establish the practicality of doing so.

1.2.2 Factors affecting delivery bitrate

When deciding a delivery bitrate, it must be remembered that the digital capacity needed to deliver HDTV depends on a number of factors. They include the following:

a) The HDTV scanning format used.

b) The type of compression used.

c) The degree to which picture impairments are acceptable.

d) Whether the compression has to be done as the programme unfolds -'on the fly'- or not.

e) Whether the HDTV signal is part of a 'statistical multiplex'.

f) The performance of the particular manufacturer's encoding equipment.

All European broadcasters that have to date announced plans to broadcast HDTV will use **H.264/AVC** (MPEG-4 Part 10) compression, although some European HDTV services still use MPEG-2.

Satellites have generally adequate data capacities for HDTV channels, though current satellite bands are filling up.

Introducing HDTV in the terrestrial frequency bands is less straightforward, mainly because terrestrial spectrum is a more scarce resource.

[1] Related to error free transmission time

1.2.3 Satellite delivery

The digital satellite transponder is essentially a container that can carry digital signals of any form, and there is considerable airwave capacity available in DTH bands.

The DVB-S2 digital multiplex capacity will be typically about 50 Mbit/s. If this is used as a single statistical multiplex of HDTV services with diverse types of content, with mature encoders, the multiplex should be able to accommodate three to five HDTV AVC channels.

1.2.4 Terrestrial delivery

Frequency planning for the digital terrestrial television environment is based on using the same channel widths that are used today for analogue television broadcasting. This means that any digital terrestrial television (DTT) service, including HDTV terrestrial services, will be based on conventional radio frequency TV channels, with the consequent limitation on the size of digital multiplexes.

The DVB-T digital terrestrial television system (DTT) is essentially a 'container' with a capacity of between 12 Mbit/s and 24 Mbit/s, depending on the error protection level and modulation scheme used, for a 7/8 MHz (Band III) or 8 MHz (Bands IV and V) channel.

Work is underway in the DVB Project on a new digital terrestrial broadcasting format, DVB-T2. The first specification of this should be available later in 2008. DVB-T2 should offer, in its first profile, a 50% gain in channel capacity compared to DVB-T. Though there are many parameters affecting capacity, a typical maximum channel capacity for DVB-T2 may be 36 Mbit/s. DVB-T2 receivers however will not be available for several years.

European nations, Africa and the Middle East, have a spectrum usage plan for digital broadcasting in Bands III, IV and V (the 'GE-06' conference plan). This will define future HDTV service available to broadcasters.

Though the allocation arrangements are complex, this is likely to result in about 6-8 'layers' or multiplexes, depending on transmission and reception conditions being available for digital terrestrial broadcasting, in each European country. These could be used to provide, after analogue switch off, for example, services with near universal digital television coverage - equivalent to today's analogue television - for all multiplexes, but the precise arrangements will be decided by individual national administrations.

After analogue switch-off, for those who have already started DTT, more spectrum capacity may be available in some countries for additional multiplexes or other services. This will depend on decisions taken by individual national administrations about the extent and quality of the desired coverage.

The analogue switch-off date will vary from country to country, as will the way that any additional spectrum capacity is used, but is likely to occur before 2012 in most European countries.

1.3 Licence Fees for MPEG-4-AVC

A factor affecting decisions on the use of technologies is the licensing costs of using them. A technology of particular importance for HDTV delivery is compression technology.

In November 2003, MPEG-LA announced participation fees for over-the-air free to air broadcasts using MPEG-4 AVC.

- No royalties for markets of 100,000 or fewer households
- For markets of greater than 100,000 households, $10,000 per year per local market service.

EBU members expressed concern about these charges, and MPEG-LA also offered the option of a one-time fee of $2500 per professional encoder

In 2008, there are two options for free to air broadcasters:

- one payment of $2,500 per encoder
- Payment of $10,000 each year for any number of encoders per legal entity.

The less expensive option depends on the way the individual broadcaster operates.

1.4 Interactivity services and Teletext

Broadcasters may also want to add interactivity to their HD broadcast services

Teletext already allows for limited local interactivity (with SDTV resolution only) , whereas the DVB developed system, the Multimedia Home Platform MHP (and other systems) can provide the full range of interactive content (declarative and procedural). The MHEG API used in the UK currently provides for declarative content.

The MHP 1.1.3 specification has been extended to support HDTV, i.e. the resolutions of 1280x720 and 960x540 as mandatory formats, and 1920x1080 as an optional format in addition to an SD resolution of 720x576.

Both mandatory resolutions of 1280x720 and 960x540 are 'exclusive', which means that applications can only use one of these resolutions at a given time. In most cases, a broadcaster will need to align the resolution of the HD MHP graphics plane with the resolution of the video content. Where several applications share a graphics plane, these need to agree on the same resolution.

If unbound applications provided by a network operator are active at the same time as applications provided by a broadcaster, the parties need to agree on a graphics resolution that is commonly used by their applications.

At the current time however, the EBU Technical Committee has withdrawn its recommendation for MHP because of lack of information on licensing, and is developing requirements for future systems.

1.5 Dynamic switching of HD and SD resolutions

The display (or other downstream device) following the receiver, whether connected through analogue or digital (HDMI) interfaces, needs to follow resolution changes without picture break up, frame roll or freezing, and without on-screen display indications, unless a fixed output format is configured at the receiver output. The use of such fixed output format is less advantageous for overall signal quality.

1.5.1 Dynamic switching between SD and HD

The new DVB guidelines for receiver implementation, ETSI TS 101 154, identify four separate categories of receivers in the 50 Hz world:

- Receivers based on MPEG-2 and supporting SDTV,
- Receivers based on MPEG-2 and supporting HDTV,
- Receivers based on MPEG-4 H.264/AVC and supporting SDTV
- Receivers based on MPEG-4 H.264/AVC and supporting HDTV

These categories are not mandatory backwards compatible, and at least in principle, receivers could be made that are capable of decoding MPEG-4/AVC in HDTV, but do not support either SDTV, or MPEG-2 services in either resolution.

However, most receivers in free-to-air markets will support both HD and SD resolutions, and often MPEG-4/AVC and MPEG-2 video coding. A requirement to support more than one of these categories should be specified in receiver guidelines.

Where a receiver supports more than one category, the broadcaster might wish to dynamically switch between an HDTV and SDTV event by event in order to optimize the use of a broadcast channel. Receivers should follow such changes without any action by the user, without any on-screen indication, and with a minimum of service interruption comparable to a channel change.

Since such near-seamless dynamic switching is not explicitly specified by DVB, a broadcaster who wishes to do so should make this an explicit requirement, and might also decide to provide test signals on air to check this feature. This approach would help to establish a receiver population supporting all these operational modes, even if such features are not used from the start of any HD broadcast services.

1.5.2 Dynamic switching of HD resolution and HD formats

In the same way as switching between HD and SD resolutions, a broadcaster might wish to dynamically change the horizontal resolution, e.g. between 1920 and 1440 pixels, for a give vertical resolution, or might wish to change between 1080i and 720p formats. Such switching could help to avoid cascaded conversion processes in a broadcast chain.

In the same way as for dynamic switching between SD and HD, it is recommended that prior to regular services using this feature, test signals are provided on air, and inclusion of such features in the related receiver specifications.

1.5.3 Dynamic switching of channels and transponders

It may be useful for broadcasters to be able to provide HD versions of programmes on a different channel to SDTV versions, and to trigger set top boxes to switch to HD versions of programmes when they are available. This approach is used by TPS in France, and uses signalling in the DVB-SI, in 'private data' to signal the existence of an HDTV version of a programme, and its location (transponder, multiplex, SI). If such a feature were valuable to several broadcasters, a standard could be developed.

1.5.4 Signalling of aspect ratio

MPEG-4/AVC signals include the 'pixel' aspect ratio as an optional parameter in the bit-stream, whereas for MPEG-2 signals, the aspect ratio is mandatory information

At the time of writing this report, not all AVC encoders include this optional information, and there is also a minor inconsistency between the ISO/IEC MPEG-4/AVC specification and the corresponding DVB document.

However, all professional broadcast encoders should include this information in the broadcast stream.

2. Compression State-of-the-art

2.1 Current HDTV Bitrates

The bitrate used for current HDTV services is constrained by commercially available encoder performance. EBU investigations in 2005 showed that some MPEG-4 H.264/AVC hardware encoders did not show any bitrate advantage over MPEG-2 and in some cases even performed less well than MPEG-2 encoders. This situation improved by September 2006, and continued to improve in 2007 and 2008.

For the World Cup in summer 2006, European broadcasters used 19 Mbit/s (German Pay-TV operator "Premiere"), 20 Mbit/s (BBC, SVT), and 10.5 Mbit/s (TF1). These 1080i/25-services were encoded as constant bitrate.

By the end of 2006, encoder performance was such that if statistical multiplexing of 2 or 3 HD services were used, they could each be set to operate with the bitrate limits adjusted to 6-20 Mbit/s with unimpaired picture quality for the higher bitrates (i.e. >16 Mbit/s).

In 2008, a range of bitrates are used for HDTV broadcasting, including, for example, about 13 Mbit/s by the SRG for their 720p/50 service for Switzerland.

Bitrates used evolve depending on encoders' evolving performance and other factors, and thus up to date information should be obtained directly from the broadcaster concerned.

3. Broadcast issues

3.1 Encoder performance

3.1.1 Encoders

Encoders for MPEG-4 H.264/AVC have been developed by several established broadcast equipment manufacturers, but also by manufacturers generally known for Internet applications, or from the merging IPTV market.

For head-end implementation, most encoders already provide both DVB-ASI and IP/Ethernet interfaces, as typical interfaces for these areas.

3.1.2 Current quality of H.264 compared to MPEG-2

The quality of MPEG-4 H.264/AVC encoders has improved significantly in recent years. An evaluation of sample encoders has been carried out in the EBU project D/HDC. This quality evaluation was based on initial PSNR calculations followed by subjective adjustment, using methodology as described in the Appendixes to this document. The results of the evaluation are given in separate reports available for each manufacturer, to EBU members only.

3.1.2.1 Preliminary conclusions on encoder quality

The following initial conclusions can be drawn from this evaluation:

- Coding efficiency has significantly improved during 2006/7. Practical broadcast implementations of MPEG-4 H.264/AVC now show a clear advantage over established MPEG-2 encoders.
- Some implementations of MPEG-4 H.264/AVC encoders now allow a saving of about 40-50%

bitrate (depending on Content criticality) compared to MPEG-2 .

- 1080i/25 is generally more difficult to compress than 720p/50. The advantage of 720p/50 over 1080i/25 varies for different implementations. Current, but ongoing, investigations indicate about 20% bitrate savings for critical content with 720p/50.

3.1.3 Delay issues between audio and video

In HDTV systems that use sophisticated compression and scaling, the major sound vision synchronisation issue is the extent to which the sound runs ahead of the vision due to the image processing, which causes a delay, which in turn can be much greater that the delay caused by the audio processing.

The human senses are much more sensitive to sound ahead of the picture than to sound behind the picture, because having sound arriving later than the image is quite normal when we converse with people who are far away. Unfortunately, sound running ahead of the image, to which we are particularly sensitive, is the usual form of lack of synchronisation in HDTV broadcasting.

The situation is complex because the delay in the display itself can depend on whether the incoming picture is interlaced or progressively scanned, because of the need to deinterlace the interlaced image in the display.

The threshold of perception of sound running ahead of the picture in critical conditions is very small - about 10ms, and the threshold for sound running after the picture is about 20ms. In normal circumstances, in Europe we consider however that for SDTV these can be relaxed to 40ms and 60ms for the end-to-end chain (EBU R37)

To apportion this to different parts of the broadcast chain is somewhat arbitrary, but ideally, the delay should be arranged in the encoder/decoder combination to be less than 5ms, to allow maximum freedom for delay in production and home display.

3.2 Recommended Configurations

3.2.1 Quality for broadcasting

Bitrates should be chosen such that there are acceptable (just perceptible or imperceptible, for virtually all average programmes) compression artefacts at 3H viewing distance, on scenes which are 'critical for advanced compression systems but not unduly so', on a given target display (up to 50”). This means using scenes that have high entropy (scenes full of non identical detail and non uniform movement) but which could still be conceivably part of a normal programme.

For an HDTV service to have a public value, it is necessary to provide and maintain high quality, and the presence of artefacts must not diminish the value of the high definition. The service must be essentially artefact free, in order to provide the added value compared to an SDTV service.

The bitrate needed depends on many factors, explained in Section 1 of this report.

The EBU has conducted a series of evaluations of current commercially available professional encoder performance, which, as explained earlier, are available to EBU members only, on request.

4. Receiver Content Protection

Information on the current Content protection options is given in Appendix 4 to this report.

5. General conclusions on HDTV delivery

In principle, the highest quality for the viewer will result if the highest quality is used for programme production, and the most efficient format used for compression for broadcasting, bearing in mind viewer's display capabilities.

The highest quality HDTV can be provided for normal viewers using display sizes up to about 50 inch, if programme production is in the 1920x1080p/50 format, and broadcasting is in the 1280x720p/50 format.

If 1920x1080p/50 format production is not available (as is the case today), the highest viewer picture quality will be achieved for scenes with motion critical content by 1280x720p/50 programme production and 1280x720p/50 delivery. This will deliver the best quality for 'events' HDTV television, and the best trade-off between bitrate required and quality delivered to the home.

If 1920x1080p/50 format production is not available, and the programme content has very little movement (i.e. with movies), the highest potential viewer quality will be achieved for viewers with 1920x1080p/25 production and 1920x1080psf/25 delivery. This will deliver the best quality for 'drama'.

If 1440 or 1920x1080i/25 programme production is used, conversion to 720p/50 for broadcasting will not significantly improve the picture quality, because the efficiency gains of progressive scanning for compression will not be available, although professional standards converters can improve quality. The viewed picture may be slightly better because of the improved sophistication of the interlace-to-progressive conversion. It is better to use professional, high quality interlaced-to-progressive converters at the broadcaster's premises than to place the de-interlacing task on consumer displays or set-top boxes.

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Appendix 1: Evaluation Method 1 - Basic principles

PSNR plus Expert Viewings

There are many methods for picture quality evaluation, among them the subjective methods proposed by the ITU, methods proposed by the EBU SAMVIQ group, or other methods such as the JND metric implemented in products available on the market for SD quality evaluation (PQA 200/ Tektronix).

It is well known that automated methods do not correctly reflect the subjective quality but that a full subjective assessment is costly and time-consuming. So-called “Expert viewings” are a method used to reduce the resources required for subjective testing, but the result is not backed up by statistical data.

Therefore, the codec performance can be evaluated in a dual-step approach that combines:

- an automated PSNR measurement, with
- a correction of the PSNR figures by subjective assessment during an experts’ viewing. This stage of experts' viewing aims to identify sequences of similar quality rather than trying to estimate the differences in quality of sequences, and is thus more reliable.

The method also allows the evaluation of sequences longer than the 10s sequences normally used for subjective evaluations.

For subjective adjustment and confirmation of the PSNR results, two selected streams from the set of recordings were simultaneously presented to experts on two displays that were mounted side by side in a viewing room with controlled lighting conditions. The ‘expert viewers’ were able to select and play any of the recorded streams for direct comparison.

The method used to interpret the results of the PSNR calculations in light of the experts’ subjective assessment is described below.

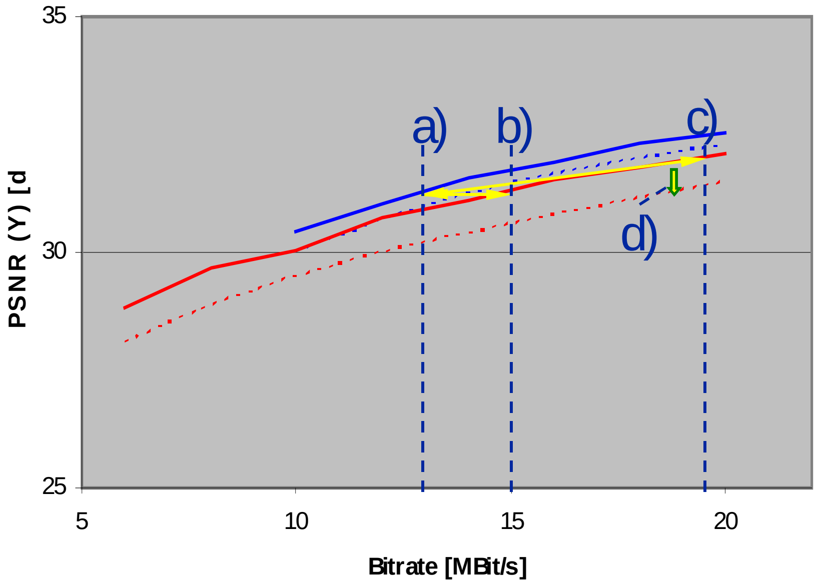

Fig. 1: Example for subjective adjustment of objective PSNR figures

A sample result of the PSNR calculation from two different encoders is shown in Fig. 1 as the blue and red curves. In the case that the objective PSNR figures directly correspond to the subjective evaluation, sequences with the same PSNR, e.g. the “blue” (reference) encoder at bitrate a) and the “red” encoder under test at bitrate b) should give identical subjective quality when played and compared side by side on the two displays. If the subjective quality impression did not match, the comparison was repeated at different bitrates until the subjective quality was estimated to be identical. In Fig. 1, this is assumed for bitrate c) for the “red” encoder.

As a consequence, a vertical correction of the “red” curve (d) towards lower PSNR figures can be identified and the objective PSNR diagram can be converted to a diagram representing subjective quality (Fig. 2). The Y-axis of the new diagram does no longer represent pure absolute PSNR figures. However, a relative “visibility threshold” corresponding to 0.5-0.7dB could be identified which closely matches figures that are known from literature.

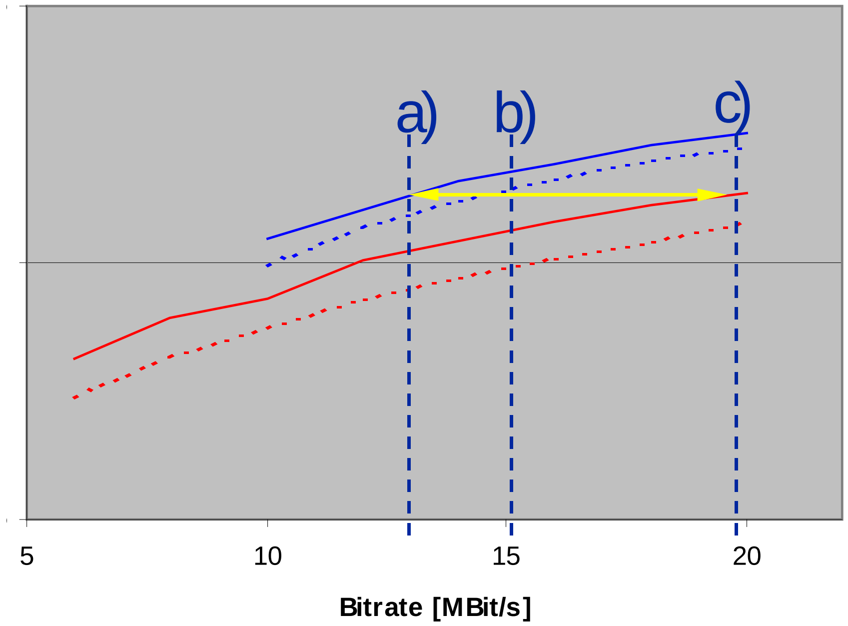

Fig. 2: Diagram after subjective adjustment

This subjective adjustment was carried out for each encoder under test against an MPEG-2 based reference encoder. Moreover, the adjustment offset was confirmed for each encoder at various bitrates, e.g. to confirm that a pure vertical offset does really reflect the subjective assessment. As a final verification, direct cross-checks were applied between two “adjusted” encoders, e.g. between two different H.264 encoders in order to confirm that the correcting offsets separately identified for these two encoders lead to consistent results when these two encoders are compared directly.

Appendix 2: Evaluation Method 2 - Basic principles

Triple Stimulus Continuous Evaluation Scale (TSCES)

A new method for subjective video quality assessments, particular suited to HDTV, is proposed here. The Triple Stimulus Continuous Evaluation Scale (TSCES) method allows the evaluation and ranking of the performance of different television formats by rating the format under test with respect to two reference pictures; a defined lower quality anchor and a higher quality anchor.

The method

Assessors are presented with three monitors one above the other, as shown in Fig. 3. The identical displays are mounted such that a reference viewer can sit at an eye-distance of three times picture height (3h - the 'design viewing distance' for HDTV) to all three displays. Furthermore, at a typical (seated) eye-height of 1.2 m, the viewer views each of the monitors normally (i.e. at 90° to the plane of the screen). Having the monitors mounted above one another, the observers quickly grasp what needs to be done to compare images on all three screens. The arrangement particularly suits widescreen displays as up to three viewers can simultaneously assess images using the arrangement. ITU-R BT.500-11 viewing conditions are recommended. The top display is used as an upper reference, providing a high-quality anchor and the bottom display as the low anchor with a defined impairment. The type of impairment used for the bottom anchor should be similar to those in the scenes under test, which are shown on the middle display. All three displays show the same scene content at the same time.

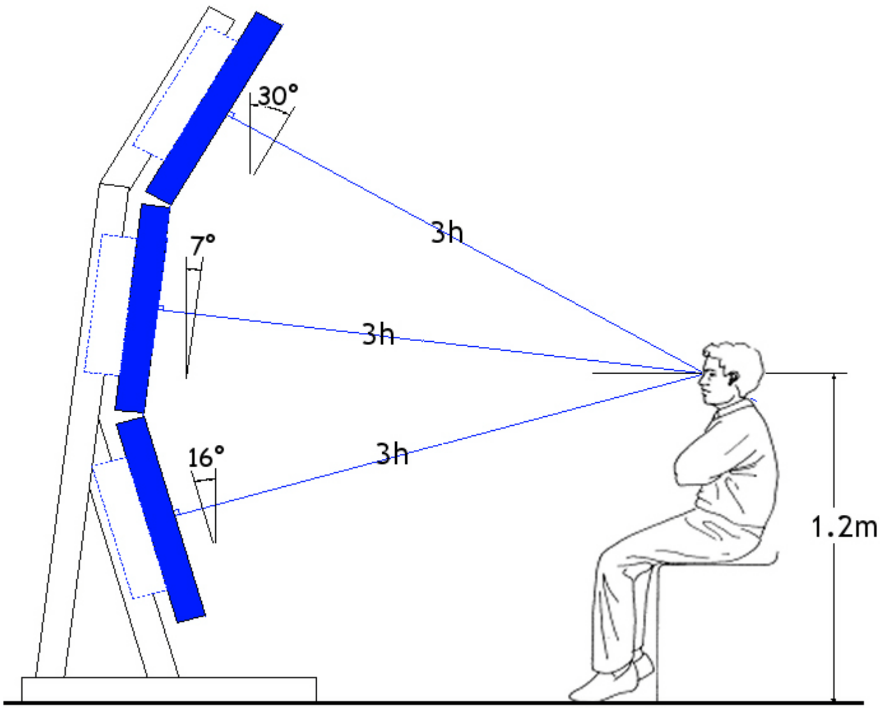

Fig. 3: the set up configuration for the three displays

Presentation and voting: First a training session and explanation is given. Each test sequence has a length of 10s and is repeated four times before voting. The middle display test sequences are shown in randomised order, and the test sequences include the upper and lower anchors to verify the consistency of the assessors. Assessors are given a continuous 100 mm line (Fig. 4) to make the assessment. The top of the line represents the quality of the top monitor and the bottom of the line represents the quality of the bottom monitor. The assessors mark where the overall quality of the central monitor falls between the top and the bottom.

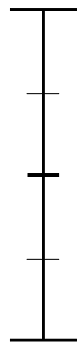

Fig. 4: Scale for voting on paper-original 100 mm length

Reporting of results: The viewing conditions are specified and the precise instructions and voting procedure are documented. The statistical analysis of the results including assessors' screening can follow ITU-R BT.500-11. The display conditions, upper anchor signal, the impaired signal, and how the lower anchor signal was generated in particular need to be clearly documented.

References:

Hoffmann, H.; Itagaki, T.; Wood D., Hinz, T., Wiegand, T., 2007. *A novel method for subjective picture quality assessment and further studies on HDTV formats*. IEEE Transactions on Broadcasting, March/2008

Appendix 3: Evaluation Method 3 – Basic Principles

Methods used within the D/HDC-Group for current encoder evaluations.

1. **H.264/AVC quality was compared to MPEG-2 quality at double the bitrate, to investigate the claimed bitrate saving of 50% for H.264/AVC over MPEG-2.**

The method:

For 720p/50, H.264/AVC with low* bitrate (e.g. 6 Mbit/s) was compared to double the bitrate (e.g. 12 Mbit/s) for MPEG-2. Viewing was performed in split screen.

For 1080i/25 (with 1920x1080i/25 and 1440x1080i/25), H.264/AVC with low* bitrate (e.g. 8 Mbit/s) was compared to double the bitrate (e.g. 16 Mbit/s) for MPEG-2. Viewing was performed in split screen.

Note: this low bitrate was chosen because it is claimed by some encoder suppliers to be sufficient for HDTV

The Content:

Content with different criticality was used, representing content which is "critical but not unduly so (ITU-R BT.500-11)".

Results:

Comments are noted describing the artefacts (e.g. noise, loss of resolution or blocking) observed and whether the claimed bitrate saving is achieved.

2. **Threshold test using a high bitrate MPEG-2 anchor (e.g. 24 Mbit/s).**

This method is used to identify the H.264/AVC bitrate needed to achieve the same quality as with the MPEG-2 encoded anchor. The required H.264/AVC bitrate will depend on the sequence used.

Results:

The sequence and the bitrate are to be noted. Additional comments on the artefacts can be listed.

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Appendix 4: Digital HDTV broadcast security elements

The current situation suggests that EBU members have **different circumstances and different needs** for HDTV broadcast security. A number of different scenarios will therefore need to exist among EBU members.

- A 'common EBU position' may amount to an acknowledgment that different scenarios exist, which may each suite different members best, depending on their local circumstances
- There are five different scenarios in use by different broadcasters in different countries.

The elements determining broadcast security

There are two main elements of the broadcasting path to consider:

- the signal on the broadcast path **from the transmitter (e.g. via satellite) to the receiver** in the home, which is usually a set top box.
- the signal on the path in the home **from the set top box to the display**.

The signals in each case can be 'in-the-clear' or 'scrambled'. If the signal is 'scrambled' the picture will not be viewable unless it is 'descrambled'.

For the first element of the broadcasting path, e.g. from a satellite to the receiver in the home, '**geolocation**' (limiting coverage to certain geographical areas) may be applied to limit coverage.

Broadcast coverage areas can, in principle, be limited by two means:

- The first may be called '**physical geolocation**'. In this case the coverage beam or a combination of the coverage beam and the error correction system used on the satellite delivery path are arranged to ensure that only viewers in a given area can watch the broadcast. This may or may not be possible depending on factors such as which satellite beams are available. This is done, for example, by the BBC and ITV in the UK to constrain coverage of their digital satellite services to the United Kingdom.
- The second may be called '**electronic geolocation**'. In this case, the broadcast signal is scrambled and is only available to those who have a receiver that accepts smart cards, and have a particular smart card. This is done, for example, for SDTV services by the SRG in Switzerland, who provide the necessary smart card only to those who have paid the annual broadcast license, and are normally resident in Switzerland. There are scrambling methods available, such as the DVB algorithm, but there is no EBU recommended scrambling method specifically for this application.

The reason geolocation is applied to broadcasting is usually because rights have not been obtained for viewers outside a constrained area

For the second element of the broadcasting path, the path from the set top box to the display, '**content protection**' may be applied to prevent copying and redistribution of the signal

If simply signalling that the material should not be copied is not enough, the signal on the link can be scrambled (though with a new system which is separate from that used on the broadcast path). The signal will be viewable on the display if it is an 'authorized' display (subject to authentication or revocation between STB and Display), because it will contain the descrambler. There is a standardized method of scrambling and descrambling on this link called '**HDCP**' (High Bandwidth Digital Content Protection).

The HDCP scrambling can be set to be 'on' or 'off' by default, which will be the status of the equipped devices when purchased. It is possible in principle to switch either at any time, or per content. This requires, however, that broadcasters insert a flag in their signal to activate or deactivate the appropriate mode, respectful of the original default mode. This flag however requires a particular protected transport that is usually not available for FTA broadcasts.

The DVB Project has developed a signalling system that can be used to switch the HDCP scrambling on and off. This DVB signalling is intended for use in general for Content Protection and Copy Management (DVB-CPCM). It contains a flag called 'Do Not Scramble' that could be used to control HDCP. This signalling could be implemented and used before consumer electronic products implement the DVB-CPCM solution as a whole

The total broadcast security system is defined by the **combination of methods used on the two parts of the signal path**. There is a link between the two elements to the extent that security may need to be balanced in both parts - both high and both low. However, there may be circumstances when this does not apply.

Scenario 1: Free to Air Scrambled (FTA/S) with HDCP default set to 'on in the set top box or receiver

1.1 The digital HDTV signal over the broadcast path is scrambled. The purpose is not to enable payment systems, it is usually to ensure that only viewers in given geographical areas are able to watch the programmes ('geolocation') when and if viewing rights restrictions call for it.

1.2 The digital HDTV signals can only be received on 'authorized' receivers, in the sense that the receivers conform to a specification that includes a descrambling process and the receiver needs a smart card.

1.3 Part of the descrambler is included in a smart card that needs to be inserted into the receiver. Smart cards can be available at no cost to the user at the point of sale of the receiver or in some other convenient way, but only in geographically authorized locations. They could be available subject to proof of payment of a TV license

1.4 There are several elements of additional costs associated with this scenario, compared to a free to air unscrambled scenario. The set top boxes need additional complexity and they will cost more. The smart cards have to be made and provided. Broadcasters have an additional burden associated with the scrambling process.

1.5. The burden of the additional costs to be born by the viewer can be light to the extent than volume production of receivers inevitably reduces the cost of features in a receiver. The cost of the set top box is determined more by the volume made than by the cost of the components in it

1.5 The burden of the costs to be born by the broadcaster in the arrangements for the smart card is large if born by a single broadcaster, and could have a significant impact on broadcasters. The burden of costs would be reduced if born collectively by a group of broadcasters. A smart card system has been in operation in Japan and the cost of management of the smart card has proved to be higher than anticipated

1.6 The scrambling between the set top box and the display is set to 'on' unless otherwise instructed. Authorized displays (e.g. those which have the 'HD ready' label) are able to descramble the signal and display it. Older displays which do not have an HDCP-descrambler built in (and thus no HD-ready label) are not able to display the digital signal, but may be able to see a marginally inferior analogue HDTV picture.

1.7 Programmes that need to be scrambled for ‘geolocation’ reasons are likely also to be subject to restrictions on copying and transfer to other media such as Internet. Once the obligation of distributing content within a geographical area has been fulfilled there may however be no reason why content could not remain in the clear after acquisition within the home.

1.8 If broadcasters use HDCP actively this will mean they have the responsibility of distributing the ‘black list’ of devices which should not be served because they are known to allow piracy in some way - the so-called ‘revocation list’. Furthermore, if a device is on the revocation list because of its insertion by a Pay TV operator, the same revocation will apply to free to air services, whatever the public service mission of the operator of the free to air services.

Scenario 2: Free to Air Unscrambled (FTA) with HDCP default set to 'off''

2.1 The digital HDTV signal over the broadcast path is in the clear. Other means of physical geolocation may be used.

2.2 The digital HDTV signals can be received on any receiver, and no smart card is needed.

2.3 Old HDTV and new HD-ready displays are able to view the digital HDTV signal

2.4 Given that a signalling system is standardized in the DVB Project, and that receivers recognize it, it will be possible for the broadcaster to switch the HDCP scrambling off remotely. This could be important if there are set top boxes on the market which have HDCP enabled by default and if manufacturers are obliged to implement HDCP devices with this switching function

2.5 This configuration prevents revocation from impeding reception.

Scenario 3: Free to Air Unscrambled (FTA) with HDCP default set to 'on'

3.1 The digital HDTV signal over the broadcast path is in the clear. Other means of physical geolocation may be used.

3.2 The digital HDTV signals can be received on any receiver, and no smart card is needed.

3.3 The scrambling between the set top box and the display is set to 'on' unless otherwise instructed. Authorized displays, those that have the 'HD ready' label and thus have an HDCP descrambler, are able to descramble the signal and show it to the viewer. Other devices that are not authorized cannot. This acts as a deterrent to the redistribution of the programme. Older displays which do not have the HD-ready label are not able to display the digital HDTV signals, but may be able to see a marginally inferior analogue HDTV signal, although the trend is to abandon such analogue interfaces on the mid to long term.

3.4 If all devices are HDCP compatible, free to air programmes would flow transparently to the display. If the device is shared with other service providers such as Pay TV broadcasters with stronger security constraints, and if Pay TV broadcasters were required by content providers to revoke certain devices, the screen would go also black for FTA content as HDCP revocation is per device and not per content. This is one of the drawbacks of HDCP "on" by default.

Scenario 4: PayTV Scrambled with HDCP default set to 'on'

This is the most likely scenario for Pay TV services.

As mentioned above, the use of revocation per device may have repercussions for the reception of FTA content.

Scenario 5: PayTV Scrambled with HDCP default set to 'off'

This is the second scenario for Pay TV services

The digital HDTV signal over the broadcast path is scrambled but the default setting of HDCP scrambling between the set top box and the display is set to 'off'.

Pay TV services use their proprietary scrambling systems on the broadcast path to switch HDCP scrambling 'on' if this is required for some content by the owners.

Available information suggests that German Pay TV broadcaster Premiere uses this scenario.

Current situation in Europe

Available information suggests that:

France Television believes that Scenario 1 is necessary for the French environment, including public service broadcasting. The dominant factor is the critical need for content that is only available if there is guaranteed geolocation and copy control.

ARD, ZDF, and SRG believe that Scenario 2 is necessary for their environments in Switzerland and Germany. The dominant factor is the national policy for public service broadcasting to be in clear.

The BBC and ITV believe that Scenario 3 is necessary for the UK environment. The dominant factor is a combination of the national policy for public service broadcasting to be in clear, coupled with the wish to take some steps to deter redistribution of content. Though not 'watertight' measures, they would act as a deterrent to unauthorized redistribution.

Information available is that Scenario 5 is used by Premiere for Pay TV services, and 4 is used by Sky Italia and Sky UK for Pay TV services, and by Canal plus/TPS for Pay TV services. The reason for the different approaches has not been established.