EBU – Recommendation R132

Signal Quality in HDTV Production and Broadcast Services

Guidelines for technical, operational & creative staff on how to achieve and maintain sufficient technical quality along the production chain

Recommendation

Geneva
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All text is normative except for that in the Introduction, any section explicitly labelled as 'Informative' or individual paragraphs that start with 'Note:'.

Normative text describes indispensable or mandatory elements. It contains the conformance keywords 'shall', 'should' or 'may', defined as follows:

'Shall' and 'shall not':	Indicate requirements to be followed strictly and from which no deviation is permitted in order to conform to the document.
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Signal Quality in HDTV
Production and Broadcast Services

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1. The Quality Principle

1.1 Definition of High Quality

As far as television signal quality is concerned, 'High Quality' means a quality that is transparent to the intention of the programme maker and without visible artefacts, insofar as it is reasonably economic and technically practical to achieve.

1.2 Consumer Expectations

Technical quality becomes an issue for the home audience when there are evident variations in the quality of different sources available to him. It is self evident that TV channels presented in an inferior quality will be judged disfavourably to those presented in a higher quality. More than this, broadcast channels are now being judged in the light of sources such as Blu ray disks that can provide an excellent audiovisual quality, far exceeding what is currently possible by most broadcast systems.

It must also not be overlooked that as the price of larger sizes of consumer flat panel displays becomes more affordable, the expectation for enhanced picture quality in the home accordingly rises.

1.3 Broadcaster Obligations

Broadcasters must first be mindful of the quality of the audio and video that they generate in their production systems or the material they buy-in. Particular attention must be paid to how their entire programme chain operates and what impact this has on the signal quality as it passes through the programme chain.

Decisions and choices that are made about production equipment and its quality impact must be governed by the final quality that the viewer can see at home, not (only) by the quality achievable in the studio.

International standards must be adhered to for content from studios and in archives.

Note: EBU R112 recommends the 720p50 picture format for HDTV emission.

Proper monitoring, control and maintenance must be established in the full production process and also in the distribution to the home.

1.4 Quality impact of different distribution platforms

Distribution channels with limited bit rate capacities will significantly reduce the technical quality that is achievable. Therefore the technology and parameters used in distribution channels should be carefully selected for HDTV content.

Digital technology allows a great deal of flexibility when it comes to the number of programme channels that can be accommodated in a distribution multiplex of a given bit rate capacity. There is an inverse relationship between the number of programmes and the bit rate of individual programmes (and therefore signal quality) in a multiplex. Techniques such as statistical multiplexing can somewhat increase the number of programmes that can be fitted into a multiplex for a given subjective programme quality. This inherent flexibility of digital technology should not be exploited to increase channel choice at the expense of picture quality.

It must be noted that the adoption of newer transmission technologies can increase the capacity of distribution platforms. Examples of these technologies are DVB-T2 and DVB-S2 as opposed to the older DVB-T and DVB-S, respectively.

As alluded to above, the audience's ability to perceive inadequate technical quality is increasing with the size of the flat panel displays that they are becoming able to afford.

1.5 Informed staff

All modern digital studio and broadcast systems now use 'compression'. Creative, technical and operational staffs need to be trained to understand the impact of compression on their signals and how picture quality is affected by processing in acquisition, contribution, production and distribution. It should be borne in mind, for example that there are major differences in performance (and cost) between different manufacturers of MPEG compression equipment.

Staff must understand the consequences of their choices of resource used, e.g. the compression variant used for post production or the choice of data rates when booking SNG links.

Compression technology also continues to evolve. Typically there are major upgrades in technology about every 6-9 years, with incremental improvements, often done in firmware or software, being made by individual manufacturers in their equipment between such upgrades.

At a management level, it is necessary to make technically informed choices of compression equipment and to understand the relationship between bit rate and quality for the equipment chosen. It is also recommended to only use open and standardised compression formats.

Note: See EBU Technical Review 2008 Q3. "HDTV production codec tests".

2. Quality maintenance in HDTV Programme Production

2.1 General

Maintaining high quality in programme production will always pay dividends in the final quality the viewer sees at home. Production quality should be set not just by the basic picture quality seen in the studio, but should take into account the quality 'processing headroom' that is available in the signal.

All systems used for the programme production process should consider the sum of these two aspects: basic picture quality and processing headroom.

2.2 Recording, acquisition and editing

2.2.1 Sub-sampling

A golden rule for maintaining quality is to only use 4:2:2 originated materials and never use further sub-sampled luminance and chrominance signals e.g. 3:1:1, 4:2:0 or 1440 samples per luminance line, etc.

Early HD equipment that employs sub-sampling should be phased out.

2.2.2 Bit depth

For higher quality HDTV productions a bit depth of 10 bit per sample should be mandatory.

2.2.3 Interlaced scanning

Interlaced scanning is the oldest method of analogue sub-sampling to reduce bandwidth and should be avoided in future since modern digital compression systems perform much better than interlacing. Whilst legacy formats and shorter term business needs can be arguments in favour of using interlace, any future production system investments should plan to use progressive scanning only.

There is evidence that the 1080i/25 production quality will be delivered to the consumer by a transmission in the 720p/50 format provided that a good motion-compensated format converter is used.

Note: See EBU-Tech 3299 for HDTV Image formats.

2.3 Bit rates for studio compression systems

A sufficient bit-rate must be employed for material exchange, recording/storage, and Non Linear Editing.

- If the production/archiving format is based on I-frames only, the bit rate should not be less than 100 Mbit/s.
- If the production/archiving format is based on long-GOP MPEG-2, the bit rate should not be less than 50 Mbit/s.

Post Production should either be in native format or use other codecs at 160 Mbit/s or more.

The EBU is currently (March 2011) conducting investigations concerning the 1080p/50 picture format as part of its Strategic Programme on integrated file-based HDTV production. Reports on the outcome of these tests will be made available to EBU members in a series of BPN documents.

2.4 Cascading different compression formats

The cascading of different compression formats must be avoided as this quickly leads to deterioration of the overall picture quality. It is far better to choose a single compression family for mainstream television production within the production chain as this enhances production efficiency and avoids time- and quality-consuming conversion processes.

2.5 Standards conversion

Standards-conversion equipment must contain motion compensation for any required frame rate conversion, or picture quality will be seriously compromised by judder. Fast sports in particular will be affected.

For up-down conversions between SDTV and HDTV and for cross-conversions between HDTV formats of equal frame rate, motion compensation may not be needed. The quality of those conversions must however be carefully assessed and it is important that only converters with the highest possible picture quality are employed.

Note: Do not use software or hardware converters incorporated into VTRs or provided by NLE system software without a quality check. Such tools are often designed for monitoring purposes only.

Note: See EBU-Tech 3299 for HDTV Image formats.

2.6 Contribution

For HDTV contribution networks (MPEG-2) it is recommended that at least 60 Mbit/s (MPEG-2) be maintained for a single hop, and 90 Mbit/s for a double hop. Quality loss should always be less than 6% with the most critical content ('high entropy content').

Note: Recent HDTV contribution encoders operating with H.264/AVC or JPEG 2000 compression algorithms have been evaluated by the EBU and results are published in EBU Technical Report 008.

2.7 Continuous monitoring

Flat panel screens with Grade 1 specifications are currently only available in small screen sizes (up to about 23”). As long as this is the case, both “Grade 1 reference monitors” and large flat panel screens (50”) such as plasma displays should be used to evaluate video quality. These large displays make artefacts caused by compression or moving graphics and captions more visible than do smaller reference displays and assist in evaluating the quality as the consumer may experience it.

It must be noted that large flat panel displays may themselves introduce picture artefacts, and their use for quality evaluation entails some experience.

2.8 HDTV programmes based on film material

The following **35mm** film types and stock are acceptable for high definition acquisition:

- 3 perf - any exposure index although an exposure index of 250 or less is preferred
- 2 perf – only if daylight stock with an exposure index of 250 or less is used

To avoid causing problems with high definition transmission encoding film should be well exposed and not forced more than one stop.

Currently there are still two diverse procedures for acceptance of Super 16 film in place:

a) Some EBU member organisations specify for delivery of television programmes that Super16 film is *not* considered to be high definition no matter what processing or transfer systems are used.

b) Other EBU member organisations specify for delivery of television programmes that Super 16 film will be accepted, but only in well justified circumstances. This presupposes that acquisition, processing and transfer are applied with the greatest care. It is obvious that only daylight stock with an exposure index of 250 or less is used.

In principle, film cameras applied must be equipped with lenses that provide sufficient performance for the intended HDTV program utilisation.

Take into account that film grain and noise in the video signal may "overload" the emission encoder thereby introducing additional visible artefacts in the picture at consumer level. This is an example of taking into consideration how the whole programme chain operates from a quality perspective.

Note: See EBU Tech. 3315 "Experiences with telecine transfer of film to digital formats".

2.9 Acquisition using HD cameras depending on their performance

Based on the physical or operational parameters of a camera and the scoring of the key points, a camera can be placed in a tier (ranking for intended usage). As camera and codec technology develops there will inevitably be a quality overlap between cameras in adjacent tiers, however operational parameters will always be the primary factor in camera category selection.

The most critical tiering criteria for cameras are resolution, sensitivity, noise, alias, exposure range, codec or recording format (for cameras with recorders) and the complexity of the subsequent workflow necessary.

Note: See EBU R118 for tiering of HD cameras and EBU Tech 3335 for imaging performance of Cameras (both documents are under development).

Although a camera can meet the requirements of a Tier it may be let down (or even downgraded by an on-board codec. Section 2.3 recommends minimum acquisition codec to be:

- 50 Mbit/s 4:2:2 minimum for inter-frame codecs, or
- 100 Mbit/s 4:2:2 minimum for intra-frame codecs.

For Journalism/News these standards can be relaxed to allow

- 35 Mbit/s MPEG-2 inter-frame codecs at 4:2:0, or
- 50 Mbit/s AVC intra-frame codecs at 4:2:0.

However, low cost HD and HD consumer formats are solely acquisition formats. They should never be used for the acquisition of HDTV content on a regularly basis.

If employed in special circumstances such as covert video journalism, reporting in crisis areas, etc. it is strongly recommended that further processing in the original acquisition format is avoided.

2.10 Graphics and text

Large, clear lettering should be employed for captions, text and graphics to ensure readability on all domestic receivers. 40 HD lines is recommended as the minimum HD font height for captions

Note: EBU Recommendation R95 Safe areas for 16:9 television productions.

2.12 Quality evaluations

End-to-end quality evaluations should be made for the entire signal chain from acquisition to the consumer display in the viewer's home. The final quality can only be evaluated after transmission encoding is taken into account.

This advice is also valid for the acceptance check of external productions and programmes.

A high-sensitivity method (such as the EBU Method III, the triple stimulus method) should be employed to detect quality loss down to about one quarter grade on a 5-point quality scale. The method is described in EBU Tech 3328, Appendix 2.

Programme production chains should be engineered so as to introduce an end-to-end loss of less than one quarter grade on a 5-point quality scale, measured using the above method.

Note: One quarter grade on a 5-point quality scale equals 3% on a continuous scale.

2.13 Audio

Compression (data rate reduction) must not be used in the production of audio signals.

For HDTV programmes, 5.1 surround sound should always be used to enhance the value of the production.

If Dolby E is, however, implemented in the production chain, actions such as mixing and adding voiceovers requires careful implementation of a decode / encode cycle. The one frame delay that is inherent in the use of Dolby E equipment must be managed carefully to ensure synchronisation with the video.

Note: Article: "Managing Audio delays and lip-sync for HDTV" on bbc.co.uk./rd

Broadcasters using Dolby E in the production chain may also get advice in BBC White Paper WHP 175: http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP175.pdf

Note: EBU R48-2005: Allocation of audio tracks on digital television recorders, and R123: EBU Audio Track Allocation for File Exchange.

Concerning Lip-sync: All audio signals must be locked to the video clock. Audio and video must be maintained in sync throughout the whole production chain to the TV station output, and this should be checked also in the emission transport stream.

Any delay should not be noticed[1] by the end user with a correct home set up.

2.14 New television production facilities

All new television production facilities should be specified for HDTV. Installations should support all HDTV formats identified in EBU Tech 3299.

Support of 1080p/50 (3G) is especially important for equipment with long "economic life" such as routers.

Make your Archives HDTV ready.

Note: Further work on this topic is under way in the EBU ECV group (Expert Community Video) and the ECI group (Expert Community Integrated Production).

3. Quality maintenance in Programme Delivery

3.1 Bit rates for video delivery

Tests carried out on H.264/AVC HDTV emission encoders in 2007 and 2008 recommended that bit rates should be at least 10 Mbit/s for 720p50 signals and 12 Mbit/s for 1080i25 signals.

The 1080i25 format requires about 20% more bit rate to achieve the same perceived picture quality as 720p50.

Since these tests, many manufactures have produced upgrades and new (third generation) encoders implementing the full H.264 tool sets that have significantly reduced these bit rate requirements.

Good implementations of the H.264 codec will produce a picture quality as good as, if not better than the 2007 - 2008 tests at about 9 Mbit/s (CBR). It is expected that encoding efficiency will continue to develop over the next few years.

Delivery chains should be maintained to less than one grade loss observed at a viewing distance of 3H using content "that is critical but not unduly so".

Statistical Multiplexing will result in higher overall quality than fixed bit rate multiplexing for the same number of programmes in the multiplex.

[1] EBU Recommendation R37-2007 specifies that the A/V synchronisation at each stage of a programme chain should be verified as being within the range of 5ms early (sound before picture – equivalent to a 1.7m difference in microphone placement at sea level and 20°C) to 15ms late (sound after picture). An overall range of ≤40ms early to ≤60ms late is specified for any output intended for emission. These limits are those that have been established on the basis of subjective tests of the relative A/V delays of standard definition television at which failure of the synchronism between lip movements and speech becomes perceptible to 50% of observers under viewing conditions defined in EBU R28. The subjective visibility of lip sync in HDTV is currently being evaluated.

Note: See EBU-TR 005 Nov. 2009, and EBU Tech 3334.

3.2 Bit rates for audio delivery

Maintain at least:

- 192 kbit/s per stereo channel for all MPEG-1/Layer 2 stereo audio. If capacity is available 224 kbit/s for Layer II will provide a greater guarantee of high quality for complex signals.
- 64 kbit/s per stereo channel for all advanced audio compression systems (such as AAC) delivery.
- 192 kbit/s for 5.1 multichannel audio in HE-AAC coding. The use of Spectral Band Replication imposes an upper limit on audio quality regardless of bitrate.
- 320 kbit/s for 5.1 multichannel AAC/AC3.

Note: See EBU Tech 3324 "Evaluations of Multichannel Audio Codecs".

3.3 Loudness

Loudness differences are a source to considerable audience complaint (within and between programmes). A shift from peak level metering and normalisation to loudness metering and normalisation is desirable. This will allow serious quality improvement of audio material, including the creative use of the available dynamic range.

Note: The EBU ECA group (Expert Community Audio) is addressing the problem of Loudness differences, including problems associated to the use of sample peak meters. See EBU R128 and Tech Docs 3341, 3342, 3343 and 3344.

3.4 Video Quality evaluations

Quality evaluations for the delivery environment typically follow the methodology for the subjective assessment of the quality of television pictures that is set out fully in ITU-R BT.500-11.

This is an exceedingly involved process and is very demanding in resources.

No less than ten different test methods are set out in this document, each used to address particular assessment problems. The scoring method used in these assessment methods is either the ITU-R five point grading scale or a continuous quality scale. The following table outlines the equivalence of these different scales.

Grade	Quality	Impairment	Continuous Quality Scale
5	Excellent	Imperceptible	(80 to 100 points)
4	Good	Perceptible but not annoying	(60 to 80 points)
3	Fair	Slightly annoying	(40 to 60 points)
2	Poor	Annoying	(20 to 40 points)
1	Bad	Very annoying	(0 to 20 points)

In Appendix 2 of EBU Tech 3328 a novel and fairly quick method of assessing subjective quality is presented. This involves three flat-panel displays arranged vertically on a special stand that has been demonstrated to provide consistently reliable results. This triple stimulus method produces

results on a continuous quality scale that can be analysed according to ITU-R BT.500-11 and can be related to the ITU-R five point scale that is commonly used by broadcasters to describe their signals.

- HDTV programmes seen by the consumer at home must be a minimum of grade 4 for vision quality.
- Grade 3 is borderline pass where there are valid reasons for technical exemption, whereas grades 1 and 2 are automatic fails.

Several types of equipment for automatic video quality measurements are available on the market. In general they are complex to operate; a large number of measurement parameters needs to be to be set, and additionally, the results they provide are very dependent on the software versions (firmware) running in the equipment. Absolute measurements are not practicable.

This means that the equipment can only realistically be used within a single organisation to measure if and where in the production chain something has changed.

Software-based measurement of the quality, and especially the available “quality headroom” in the HDTV video signal, is not yet practicable, although work is ongoing to achieve this.