Maximizing the quality of SDTV in the Flat-panel environment

EBU Broadcast Technology Management Committee (BMC)

The broadcasting environment is changing because of digital technology. Further changes will be needed soon, if flat-panel displays become widely used in home receivers. The quality demands of large-screen flat-panel receivers will call for new care and attention from broadcasters in providing "conventional-quality" television. This article is intended to help broadcasters understand the factors which affect quality in this new world, and it offers suggestions for ways of maximizing the delivered picture quality.

The changing environment

With television screen sizes becoming progressively larger in the home, defects in the transmitted picture quality are becoming more and more noticeable – and also more annoying – for the viewer. Display technology is changing from the CRT to LCD or AC-PDP flat-panel displays. These types of displays – particularly AC-PDP – mask the picture impairments to a lesser extent than CRTs and thus, compared to CRT displays, are apparent "magnifiers" of the impairments. Television is moving to an age where high picture quality is becoming more important.

EBU Members have broadcast in PAL or SECAM for the last 40 years; in recent years, digital broadcasts have used the MPEG-2 video compression system. The picture quality delivered in an MPEG-2 channel depends on many factors but a limiting factor is the channel bitrate. Most European broadcasters use bitrates of 2.5 – 5.0 Mbit/s. But, for a number of reasons, there are circumstances where the programme's inherent picture quality cannot be delivered satisfactorily to viewers using flat-panel displays [1][2].

EBU Members need to review the ways in which they make and deliver television programmes in the light of these new large home displays – indeed, at some stage sooner rather than later, broadcasters will need to improve the picture quality that is delivered to viewers using flat-panel displays.

This article, based on EBU Technical Information I39-2004 [3], describes the steps that broadcasters should take to improve picture quality in the standard-definition TV (SDTV) environment. Of course, in responding to the new age of large displays, some broadcasters may decide to introduce high-definition TV (HDTV) services. This scenario may indeed be the most far-sighted. However, it is not the subject of this article. The issues associated with a change to HD delivery will be considered in a future EBU document.

Studies conducted within the EBU over the past two years [1][2] have suggested that, in an MPEG-2 SDTV channel (with currently-available encoders and decoders), the more critical kinds of scene content must be delivered at a bitrate of 8 - 10 Mbit/s [1] if they are to be reproduced with good "conventional" quality on large-screen flat panels. This is a rule of thumb for ensuring high quality for all types of content produced for digital delivery in the flat-panel age, even though such high bitrates will not be required for some types of picture content found in average programmes.

If bitrates adequately higher than those used today are possible for SDTV broadcasting, a major part of the potential limitation on flat-panel quality is removed. This is the step that will have most effect on critical content impairments. But whether the bitrates can be raised or not, there are other steps that can be taken to make the best of the prevailing situation. There are "good practice" steps that are worth taking, whatever the available bitrate limit. It is these steps that are the subject of this article.

In time, practical experience will be gained by Members on which bitrates and measures are needed to optimize picture quality on flat-panel home displays, which can then be shared with others. In the meantime, broadcasters should evaluate the extent to which they can adopt the measures suggested in this article. Furthermore, they should consider setting organization-wide picture-quality targets for digital television. Having such a benchmark will make it possible for broadcasters to evaluate the costs of making the necessary improvements, and allow them to plan the appropriate measures needed to achieve these improvements.

Recommendations for best practice

1) Thorough research on relative performance should be done before buying MPEG-2 encoders. It will be a good investment. The state of the art needs to be reviewed frequently.
2) If the service is a ***green field*** with no legacy receivers to serve, consider using codecs more modern than MPEG-2. Make buying the encoder the last thing you do before the service starts.
3) Check if the picture quality limits, due to the delivery mechanism, match the quality limits possible in programme production. If the delivery mechanism is a significant constraint on quality transparency across the chain, programme makers may be wasting their investments in programme production. Our public service mission calls for technical quality which does justice to our high programme quality.
4) Take great care in the broadcasting chain to ensure end-to-end high-quality 4:2:2 signals, and never allow the signal to be PAL or SECAM coded.
5) If possible, preserve 10 rather than 8 bit/sample values for the components in the 4:2:2 signals flowing through the programme production and broadcasting chain.
6) Explain to production staff what kind of production grammar (shot composition, framing and style) will lead to poor quality on large flat panels. Encourage and train them to avoid high entropy – unless you can use higher broadcast bitrates.
7) Encourage flat-panel receiver manufacturers to develop high-quality standards conversion and scaling electronics, and advise the viewing public about which are the best flat-panel receiver types.
8) For mainstream television programme production in compressed form, use no less than 50 Mbit/s component signals.
9) Do not trans-code between different analogue or digital compression schemes, and use signal exchange technologies such as SDTI and File Transfer which handle compressed signals in their native form.

1. In the case of HDTV, a bitrate of 15 - 22 Mbit/s is required for good quality using MPEG-2 compression – depending on the scanning format used and the acceptable level of degradation relative to the uncompressed HD picture quality.

10) If noise reduction is required it should be introduced before encoding. However, noise reducers should be used with caution after a careful consideration of the options given in the Appendix.

11) Set clear organizational broadcast quality goals, and use the professional skills of your staff to keep to them.

Appendix

Options for optimizing SDTV picture quality in a flat-panel environment

The way compression systems work

Before outlining the measures in more detail, it is useful to review the way that digital compression systems work. While yesterday's analogue compression system – "interlacing" – applied itself in exactly the same way to *any kind* of scene content, digital compression systems *adapt themselves* to the scene content. This makes them much more efficient, but also it makes describing the way they perform more complex, and identifying ways to optimize the quality is more complex as well. Nevertheless, worthwhile good-practice elements can be identified if care is taken.

The key element of picture content that affects the way compression systems perform is the degree of detail and movement in the scene (sometimes called ***entropy***). It is mainly this that determines how taxing the scene is for the compression system. Scenes with less detail and movement are "easier" to compress, in the sense that the input is more closely reproduced at the output, but the reverse is true for scenes with a lot of detail and movement – particularly over the whole picture, rather than in just parts of it. The point where "easy to compress" become "difficult to compress" is determined by the delivery bitrate limit. When the scene is difficult to compress, the compression system introduces impairments of its own ("artefacts") in the picture.

Programme-makers need to understand the different types of scene content and they way they behave in compression systems.

The most difficult or taxing scenes to compress are those containing high detail and movement over the whole scene. The most taxing or "stressful" type of content is usually material shot originally with video cameras, showing scenes which have an elaborate "canvas". This usually means sports events or light entertainment. These are the kinds of programme that will look worse on the new large displays, because the compression process will introduce its own impairments into the picture – unless the bitrate is high enough.

The easiest or least taxing scenes to compress are usually, but not always, cartoons or those shot on celluloid film at 24 pictures per second. This usually means fiction/drama or documentary material. Movie material will usually look "good" on large displays at low bitrates, because the compression process is least likely to introduce artefacts of its own – though film grain can make compression more difficult if it is present, as explained later. The higher the field or frame rate, the higher the entropy. For the same camera shot, 50 Hz interlaced television scenes are easier to compress than 60 Hz interlaced scenes.

Unfortunately "noise" or "grain" in a picture, which may be unintended and unwanted, can also be interpreted as entropy by an encoder, and can thus "stress" the encoder and lead to impairments. The encoder has no way of knowing whether detail is desirable or undesirable, so noise or grain contribute to the overall entropy of the picture. Noisy pictures whose wanted content is "noise-like" may be masked by unwanted picture noise, causing impairments in desirable parts of the picture. **"Clean" pictures always win twice – they are better to look at, and they are easier to compress.**

Apart from noise itself, creating a PAL or SECAM analogue picture leaves a certain technical “footprint” on the picture. This footprint can pass unnoticed when a viewer first sees the picture, but it can also be interpreted by the digital compression system as more entropy. For PAL, the footprint takes the form of fringes around objects. Thus, PAL pictures can be “stressful” for compression systems. Note also that analogue PAL broadcasts can look poor on flat-panel displays [1][2].

The need for "headroom"

It is inevitable that television signals will have to go through a number of processes before they reach the viewer in his/her home. Thus, when deciding on the *adequacy* of a set of technical parameters for a television signal, it is important to remember that the full desired picture quality must be available *at the end* of the broadcast chain (and not just at an earlier point). For system-wide adequacy, a safety factor (i.e. ***headroom***) should therefore be added at other points in the chain – to allow the signals to undergo further processing while still “protecting” the chosen parameter values.

The precautions mentioned below should ensure that the picture quality is protected during the many stages of processing that the signals may have to endure, before reaching the viewer’s large flat-panel display.

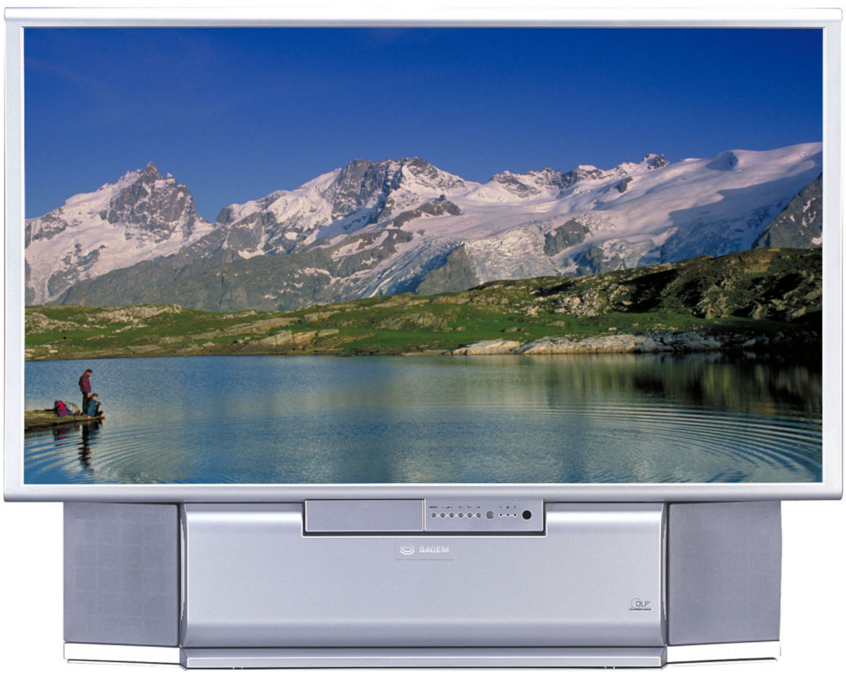
The role of sound

The perceived quality of a television programme is influenced by the presence or absence of sound, and by the sound quality itself. The presence of sound appears to have a distracting effect on viewers’ perception of the picture quality. So, if broadcasters take care with the sound then, within the limits of home equipment, this should positively help with the image perception too.

Quality and Impairment factors

Picture quality is considered to be made up of a range of ***quality factors*** which affect perception of the quality. These are elements such as “colorimetry”, “motion portrayal” (picture rate and scanning format), contrast range, and others. It is the combination of these various elements which defines the perceived picture quality.

In addition, for convenience, we consider there is a range of ***impairment factors*** which also can contribute to picture quality. They are similar to quality factors, but the term is used for impairments added by compression systems or coding. They include elements such as “quantization noise”, “static or dynamic ringing” (mosquito noise), “temporal flicker” and “blockiness”. Sometimes non-technical analogies are used to describe these elements – for example, the “heat haze” and the “ice cube” effects. These impairments mostly arise when the bitrate is too low for the degree of detail and movement contained in the scene.



Quality factors include those which increase the potential entropy – definition and motion portrayal. At the same time, these very same elements can induce impairment factors to "kick in", because the compression system becomes over-stressed. The process of optimizing the end-to-end broadcast chain is often a case of finding the best balance between these two contrasting factors.

The broadcasters' objectives

Broadcasters will always want to deliver their material at the lowest possible bitrates they can successfully use. Channel bitrate is a precious resource which can be used to provide more multimedia services or more programme channels within a multiplex. However, broadcasters must develop an end-to-end strategy which uses the lowest bitrate that is consistent with acceptable picture quality, or with other constraints.

To optimize the broadcast chain in a 576/50/i (conventional quality) transmission environment, broadcasters need to do two things:

a) they must deliver (to the final MPEG-2 encoder) pictures which have the *minimum entropy* possible, taking into account the programme-maker's intention and the impact the pictures will have.

b) they must use MPEG-2 encoding arrangements that will result in a *minimum of coding artefacts* being introduced into critical high-entropy content.

Suggestions for a) are considered in the Section immediately below, titled "*Production and contribution arrangements to maximize quality"*. Suggestions for b) are considered in a later Section titled "*Delivery channel arrangements to maximize quality*". A further Section below, "*Receiver arrangements to maximize quality*", looks at ways in which the receiver manufacturers can improve the perceived picture quality, by designing certain features into the receiver.

While these points can be discussed separately for convenience, always remember that the broadcast chain *as a whole* needs to be considered. The measures taken in production and delivery need to be proportional. **There is no reason to take special care in production – if poor arrangements are used for encoding, and vice versa.**

Production and contribution arrangements to maximize quality

Quality is more than technical parameter values alone.

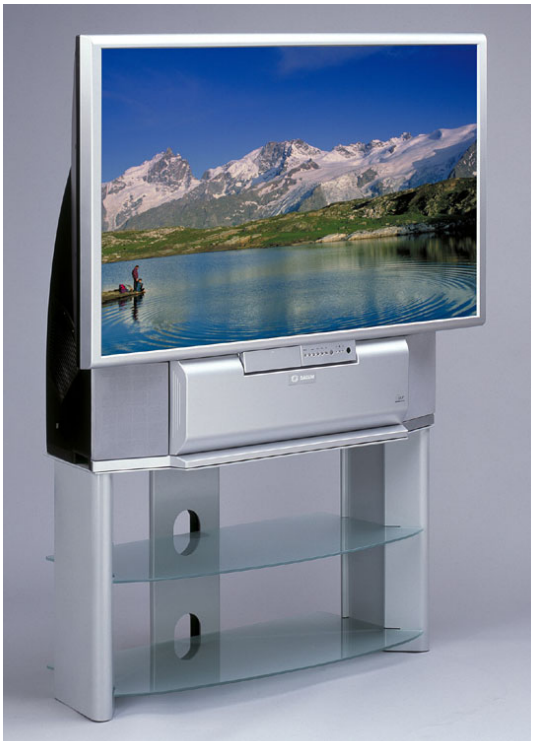
The perceived technical quality of a television picture is not based purely on the technical fidelity of the picture, and the lack of impairments in it. Our impression of picture quality is also determined by our interest in the scene. This means that picture quality is influenced by the professional skills of the cameraman and editor in shot-framing and scene composition.

The "quality factors" of the scene (as described earlier) are also influenced by the professional skills of the cameraman and editor. They are responsible for elements such as colour balance, colorimetry, lighting and the effects of contrast and noise. Control and care not only reflect on the impact of the pictures ... but also upon the entropy of the pictures.

Capture

Production staff need to keep in mind the final delivered picture quality. There are two main areas to consider here. The first is the impact that shot composition, framing and style (sometimes called "production grammar"), as well as lighting and camera settings may have on the picture entropy. The second is the influence that production techniques may have on noise or grain levels in the picture.

Production "grammar" influences, among other things, how much visible detail and movement there is in the picture. Camera pans and zooms over *detailed* areas should be avoided if possible, obviously depending on the context of the production. Camera tracking is (for our technical purposes) better than panning. Shooting with lens settings that lead to short depths of field – i.e. with low detail in the background and, hence, lower entropy – may reduce the encoding artefacts in the received pictures.



Production lighting, camera settings and types of equipment can influence the noise level in the picture. Low lighting with high gain settings should be avoided. Although it may not be noticeable to the naked eye, the signal-to-noise ratio is degraded – there is less “headroom” in the signal.

To improve picture sharpness, the camera processing introduces “aperture correction” and/or “contour/detail” correction which amounts to boosting the high frequency end of the spectrum. By improving picture sharpness, it also makes the signal-to-noise ratio worse. In addition, the “thickness” of the “contours” is magnified and hence is more unnatural when viewed on a large flat-panel display, at a shorter viewing distance in the home. Aperture/contouring correction should be used with caution in any camera. In low-cost cameras (i.e. DV camcorders), the correction circuits are often not as well designed as they could be (to lower costs), and their use should be avoided. In these cases it is better to apply any indispensable “peaking/sharpening” tweaks using subsequent high-quality processing equipment.

Since aperture and detail correction also corrects for (a lack of) “lens sharpness”, the best possible lenses should be used to minimize the need for these corrections.

Processing

Pure production with no compression, in accordance with ITU-R Rec. BT.601, will produce the best quality for delivering to the encoder. However, this may well be impractical.

Nevertheless, 4:2:2 sampling structures should be used throughout the production process.

The use of helper signals such as “MOLE” [4] – which carry information on the first application of compression “coding decisions” along the production chain – could in principle be useful for maintaining quality in production. In practice, we have not been able to identify any organization which has been able to successfully apply them. These technologies are arguably most useful when very high levels of compression are used, rather than the low levels usually used for production. Furthermore, it is difficult to pass the MOLE signal entirely error-free through the production process.

In the production chain, multiple decoding and recoding of compressed signals must be avoided. Compressed video should be carried throughout production in its “native” compressed form (i.e. as it first emerged from the camcorder).

For real-time transfer via the existing SDI infrastructure, the Serial Data Transport Interface (SDTI – SMPTE standard 305) should be used.

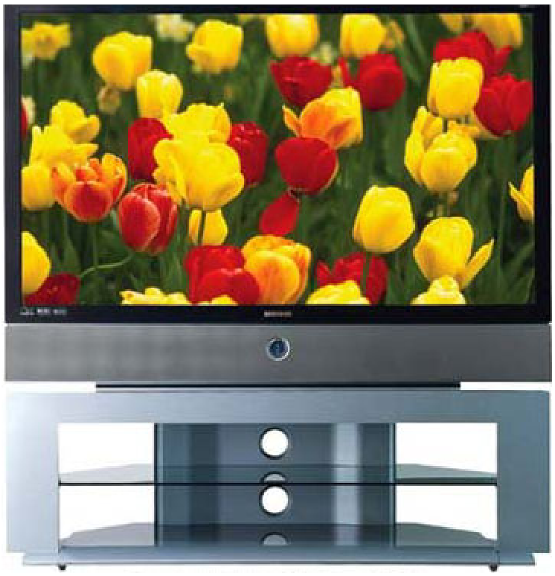
For file transfer, the MXF file format should be used as it provides standardized methods of mapping native compressed (and uncompressed) Video and Audio “essence” (e.g. DV/DV-based, MPEG-2 Long GoP, D10 etc).

Compression in mainstream television production to not less than 50 Mbit/s, as explained in EBU Technical Text D84-1999 [5], should be used.

When higher compression rates and low bitrates are necessary for high-content-value news contributions, a long GoP should be used. Compression systems that are more efficient than MPEG-2 for news feeds should be considered.

If multiple cascaded codecs cannot be avoided in the overall chain, then at least similar encoding and decoding devices should be used to minimize the quality loss.

For file transfer of programme material in non-real time, the original or native compression system should be used at 50 Mbit/s or higher, I-frame only.



Broadcasters are converting to file/server-based systems and, although ever larger storage is possible, these do not have infinite data capacity and some form of compression will still be needed. The bitrate of the compressed signal should not be below 50 Mbit/s. Do not use editing/storage equipment that has its own internal compression scheme that is different from the "native" one used in the capture camcorder.

It may be absolutely necessary to use noise reduction. If so, this should be performed before the first compression process. Noise reduction should not be introduced in the middle of a series of concatenated compression systems.

HD production for conventional-quality television

HD production which is down-converted to 576/50/i gives very good quality, particularly if the HD is progressively scanned (e.g. 720p), but also if the HD is interlaced (e.g. 1080i). This is a very effective way of preparing high-quality 576/50/i material. There are additional benefits because the material can be archived at HD resolution and used in future years when there are HD broadcast services. Material captured using cameras operating on an interlaced standard includes spatio-temporal aliasing virtually "burnt in" to the picture. If 1080i material is down-converted to 576i, much of the burnt-in alias is lost and, consequently, the signal is cleaner and easier to compress in the 576i signal domain. If the production is 720p originated, the alias is absent, so the 576i signal produced can be even cleaner than that sourced from 1080i.

Broadcasters who make HD productions are advised to produce the material in the same format as the production format. Although it might not be practical to archive a 720p or 1080i signal in base-band uncompressed form, a compressed bitrate at 720p or 1080i should be chosen that will still provide sufficient quality headroom for future repurposing and post productions. Further studies on this subject are required.

Wide aspect ratio

The use of aspect ratio should ideally be controlled in such a way that the best quality result is obtained, although the scope for using different aspect ratios will depend on the organization's broadcast policy. However, whatever arrangements are used for shoot and protect areas, 16:9 productions should be shot in the 16:9 production format ("anamorphic 16:9") and not as a letter-box inside the 4:3 production format.

Semi-professional (consumer, or even "prosumer") cameras normally provide only 4:3 aspect ratio sensors but some of them utilize in-built signal manipulation to give the 16:9 aspect ratio. Experience has shown that these internal camera manipulations should not be used. If needed for wider aspect ratios in post-production, a high-quality professional converter should be used to extract the area of interest.

PAL/SECAM signals

Do not use video signals that have been analogue composite-coded at some point. The quality headroom is already lost, and nothing can be done to retrieve it. Furthermore, PAL coding adds unwanted artefacts to the picture (sub-carrier fringing effects, and luminance/chrominance cross effects) which can consume compressed bitrate because they are interpreted as valuable picture entropy.

Primary distribution

The input to primary distribution should use MPEG-2 MP@ML encoding for transmission. It is important that encoders of a very high quality perform this encoding process, and that the highest possible bitrate is used. Statistical multiplexing should be used if more than two programmes are being distributed in the same stream.

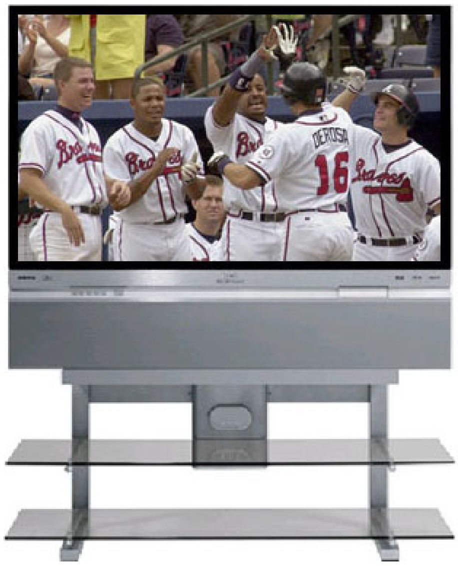
The final quality check

Production or technical staff should always check on a large-screen display during production, a version of their programme which is compressed to the level used for broadcasting. This is the only way to be sure about the picture quality. This care will pay off in the long term. This check is probably not needed if broadcast bitrates of 8 - 10 Mbit/s are being used for broadcasting.

Delivery channel arrangements to maximize quality

Choosing an MPEG encoder

The MPEG compression family is arranged specifically to allow encoders to evolve and improve. Only the form of the MPEG-2 decoder signal is specified, and as long as the signal received conforms to that, the encoder can be as simple or sophisticated as it needs. The system is also intended to be "asymmetric" in the sense that the decoder system is simple, and complexity is loaded into the encoder.



There are a range of technologies available for pre-processing and post-processing in MPEG-2 (and other) encoders. Pre-processing algorithms essentially filter the image before or during compression. This improves the performance by simplifying the image content. Post-processing algorithms identify and attenuate artefacts that were introduced into the encoder.

Noise and other high entropy elements "stress" the encoder and generate impairments, but over-application of pre-processing, denoising and filtering will blur the picture. The best quality will be obtained by finding the optimum balance between them.

More effective pre-processors and noise reducers are obtained by "loop filters" and de-blocking processors within the encoder and the decoder. Indeed these techniques are included in more recent codecs such as H.264. However, they are not included in the MPEG-2 system which is used today for digital broadcasting at conventional quality.

Noise reducers and pre-processors can be used in MPEG-2 systems before the encoder. They can be separate from the encoder or controlled by it. In the first case, the user can adjust the weight of the pre-processor and noise reducer to obtain the best picture quality during the set-up stage, even changing them scene by scene. This cannot usually be done "live" in real time. In the second case, the encoder selects the weight of the pre-processor and noise reducer by measures such as "buffer fullness" (which is related to entropy). The second approach could be more effective than the first because changes can automatically be made at small time intervals, but this may cause resolution pumping as an unwanted side effect.

The performance of MPEG-2 commercial encoders has improved dramatically since MPEG-2 was standardized in the mid 1990s. As a generalisation, the average performance has improved by 5 - 10% a year over the past six years, and overall the performance has improved by about 40%. Thus, the MPEG-2 encoder should be the last item of equipment to buy when starting digital broadcasting. The very latest models should be used, and the encoder should be periodically replaced to take advantage of recent improved performance.

The performance of MPEG-2 encoders also varies significantly from manufacturer to manufacturer. Variations in the performance of equipment available at any given time can be as much as 30%. Users should evaluate all available encoders, either with their own tests or based on reports of the experience of others. As a rule of thumb, the same type of MPEG-2 encoder used across the broadcast chain provides better overall quality than a mixture of types.

"Two-pass" MPEG-2 encoders offer higher encoding efficiency than "single-pass" encoders, but they suffer higher encoding delay. They can be up to 20% more quality efficient than single-pass encoders, and should be used where the delay is not important.

Statistical multiplexing increases effective encoding performance [2]. The gain is higher in multiplexes of many programmes, but it is still useful in multiplexes of only three or four programme channels. The unchecked application of statistical multiplexing can lead to impairments when particular combinations of content entropies occur. To reduce the effects on premium content, different priority levels can be applied to different programme channels. In this case, a request for bitrate from a high-priority channel will be satisfied before requests from low-priority channels.

The new NHK MPEG-2 encoder

EBU Project Group B/TQE has recently tested a new MPEG-2 encoder developed by NHK, the Japanese Broadcasting Corporation, principally to improve the quality efficiency of compression of 1080/60/i HD signals. The system uses adaptive selection of the picture structure to optimize the encoding and reduce the amount of signalling needed for motion compensation. This leaves more data free for coefficient data. Thus a given data rate can deliver a higher quality. Tests made by NHK show major benefits for 1080/60/i compression. The bitrate needed for impairment-free delivery falls from about 22 Mbit/s (an NHK measured bitrate which agrees with EBU tests) to about 15 Mbit/s – an improvement of 25 - 30%.

In principle, the same techniques can be applied to any other scanning format, interlace or progressive. NHK kindly helped the EBU group to evaluate the new technique working with 576/50/i material. The technique brings less saving at conventional quality, because less of the overall bitrate is taken up with motion compensation signalling than is the case for 1080/60/i. The results suggested that on most (but not all) critical material, the NHK system can offer a bitrate saving of about 12% with conventional-quality material. This is definitely worth gaining, and thus EBU Members are encouraged to look for encoders which use this technique [3].

Using new compression systems

If a "green field" service is to be launched, then one of the new more efficient compression systems should be considered. These are ***MPEG-4 Part10*** (also known as H.264 and AVC), and ***Microsoft VC-9***. Both are significantly more quality-efficient than MPEG-2 at conventional quality levels. Tests made by the RAI in Italy suggest that savings of 50% could be made at conventional (SDTV) quality, even with the early implementations of MPEG-4 Part10. Full tests have not yet been made with VC-9, but the savings are likely to be somewhat less though still significant. There is no guarantee that they will be included in commercial set-top boxes, and if broadcasters wish to use the new algorithms, they will need to convince manufacturers to make receivers using them.

The licence costs of using these two systems are not yet entirely certain and this needs to be checked by potential users.

2. See EBU Technical doc. BPN 037, available by post from **Mrs Lina Vanberghem**.
3. Adaptive field/frame picture structure, motion vector detection scheme which minimizes the transmission data.

Receiver arrangements to maximize quality

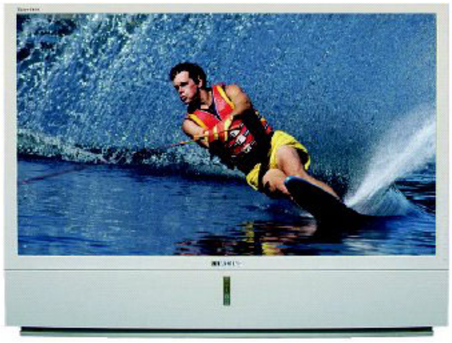
Flat-panel technologies

A major design problem for Plasma Display Panels (PDPs) has been arranging for good motion portrayal. Colour fringing can become visible because of the pulse-width-modulated greyscale used, which is typically limited to an 8-bit linear depth. In fact, 12-bit depth would be needed for transparency near black. There is also a difficult trade-off to be made between panel lifetime, and the settings for brightness and contrast. High brightness reduces lifetime but makes the display attractive at the point of sale. Improved contrast can also only be achieved at the cost of reducing the brightness.

The advantage of PDPs over LCDs has been the ease of making physically large panels. High resolution was more difficult to achieve in PDPs, and this was reflected in the wide initial availability of 480-line panels of around 40 - 42 inch diagonal, and subsequently 768-line panels, usually around 50 inches in diagonal size. Only now are 1080-line HD-resolution PDPs being demonstrated in prototype form, and only at sizes over 50 inches.

LCD technology has the ability to more readily provide displays of higher resolution. LCD technology is likely to dominate the flat-panel market in terms of volume, with prices falling rapidly following a vast ramp-up of production volumes in different parts of the world.

LCD may not seem to be the ideal technology for television. Indeed, many of the LCD TVs seen in shops today are far from ideal in picture quality. Until very recently, LCD was not seen as a serious contender for the large-screen television market. This was not just due to the yield problems of making the larger sizes, but also due to motion blur caused by slow response speeds, poor colorimetry and viewing angles, as well as higher costs. However, these drawbacks are now being overcome.



Colorimetry improvements have proved relatively simple to implement. LCD picture quality can now surpass Plasma for the first time. Motion blur is greatly improved by a variety of proprietary techniques which aim to speed the transitions between grey levels by modifying drive voltages during the transition. LCDs with 170° angles of view are becoming increasingly common, and cheaper backlights, now a significant part of the cost of a large display, are under development. The key to solving the remaining questions of cost and panel size lie in the new fabrication plants (fabs) now under construction. For example, one new fab due on stream next year will simultaneously make six panels at 46-inch size.

Display pre-processing

The pre-processing of video signals for display on these new panels is a major challenge. Traditional TV manufacturers have never needed to de-interlace interlaced broadcasts, as a CRT can display an interlace signal directly. Similarly, image scaling/resolution changes are accommodated by adjusting the scan size with a CRT. In the case of the new displays, with fixed rasters addressed sequentially, the TV manufacturers need to incorporate de-interlacing and scaling technologies. These technologies are well understood in the professional broadcast environment, but less so by the consumer electronics and PC industries.

There are several chipsets available that claim to do everything necessary. Experience suggests that many of the scaling chips are characterized by poor de-interlacing, and insufficient taps on their scaling filters. They have features to partially mask these shortcomings, but are used with inadequate additional memory. The best way of mapping a picture to such a display is to transmit the signal in a progressive format, pixel mapped to the display. This is one of the reasons for the suggestion in EBU Technical Texts I34/I35 [1][2] that progressive scanning should be used for new HD services. For legacy 576/50/i broadcasting, we are obliged to use interlace scanning, and do the best we can with it.

On a digital panel, the overscan used systematically for CRT displays might be seen as redundant, since the edge of the picture is clearly defined. However, there may be a case for a few pixels overscan: (i) to allow easy scaling ratios, (ii) to mask archive programme content which was not made with a totally "clean aperture" (microphones in shot etc.) and (iii) to cope with unwanted incursions into frame during live programming today.

Another area where most currently-available panels are inadequate is in the presentation of film-mode material carried on an interlaced format (sometimes known as PSF – Progressive Segmented Frame). The pre-processing in nearly all current displays fails to treat film-mode material as such. Instead, it applies a de-interlacer to the signal, thus degrading a signal which, by the progressive nature of flat-panel devices, should in practice be easier to scale and display. **The broadcast signal should flag "film mode", when appropriate.**

Presentation of pictures with coding artefacts would be improved by adaptive pre-processing that is able to distinguish between picture features and coding-block edges. Better interlace-to-progressive conversion, using two- or three-field spatio-temporal filtering, would also improve the picture quality of currently broadcast pictures.

To scale an image to a particular raster size, the scaling filters need to be carefully chosen to obtain the best final image quality. Therefore the scaling chips should include pre-selected filters, with an adequate number of taps, for the common conversion ratios that they are likely to encounter. A "one size fits all" filter design will not produce the best image quality when scaling from, for example, 720 to 768, if it is optimized for scaling from 1080 to 768.

Physical interfaces between equipment and display screen

Digital interfaces, such as DVI and HDMI, offer the possibility of making transparent the transfer of picture data to the display screen. Experience of panels with digital inputs suggests that this will enable the panel to display a clean signal (so much so that coding artefacts become more prominent). The mechanism for this is the lack of an optical output filter on the flat-panel display, compared to the Gaussian spread and hence filtering effect of the CRT spot. This could be mitigated by having many more pixels on the screen than in the source, and appropriate up-conversion filters. This would smooth block boundaries, as well as effectively providing extra bit depth in the display by means of spatial dithering, provided the processing were done to an adequate bit depth.

HDMI – the High-Definition Multimedia Interface [6] – specifies a means of conveying uncompressed digital video and multichannel audio. It can support data rates up to 5 Gbit/s, and video from standard definition, through the enhanced progressive formats to HDTV at 720p, 1080i and even 1080p at 60 fps and lower, including 50 fps. This is an appropriate interface for digital connections to flat-panel displays.

Included in the HDMI is HDCP (High-bandwidth Digital Content Protection) [7] to prevent piracy of the uncompressed digital signal. The system encrypts the signal before it leaves the "source" (e.g. the set-top box) and the "sink" (e.g. the display) then decrypts the signal to allow it to be watched. HDCP is a link encryption system. The first products incorporating HDMI interfaces are now available. However, some issues about the licensing and use of HDMI and HDCP remained to be resolved at the time of writing (March 2004).

The DVI (Digital Visual Interface) [8] is the predecessor of HDMI. It is increasingly used on computers and display products, and uses very similar technology to HDMI, but lacks the audio capability. There is a measure of electrical compatibility between the two, enabling adaptors to be used between the different connectors [4]. One advantage of HDMI over DVI will be cable length. Usually limited to about 2m for DVI, 15m (and beyond) should be possible over HDMI.

4. The connectivity will be lost if a DVI/HDMI-capable "source" with HDCP enabled does not sense an HDCP-enabled DVI/HDMI "sink" at the other end. Hence most display manufacturers who are targeting Home Entertainment and Television systems now implement HDCP functionality to their DVI/HDMI interfaces to avoid complaints about unwatchable content.

Abbreviations

CRT	Cathode Ray Tube	**HDMI**	High-Definition Multimedia Interface
DV	(Sony) Digital Video compression format	**HDTV**	High-Definition Television
DVI	Digital Visual Interface	**LCD**	Liquid Crystal Display
GoP	Group of Pictures	**PDP**	Plasma Display Panel
HD	High-Definition	**SDTI**	Serial Data Transport Interface
HDCP	High-bandwidth Digital Content Protection	**SDTV**	Standard-Definition Television

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