EBU Technical Information I34-2002
The potential impact of flat panel displays on broadcast delivery of television

EBU Committee	*First Issued*	*Revised*	*Re-issued*
BMC	2002		

Keywords: **Digital television broadcasting**

SUMMARY

1. In this document, the term 'Flat Panel' is used to mean a wide-screen plasma display panel (PDP) of diagonal size 32″ or greater. At present there are three flat panel formats available to the general public: the WideVGA panel, the WideXGA panel, and a panel having 1024×1024 pixels[1]. The first two are progressive scanned whilst the last is interlaced. They are very attractive, offer a greater sense of reality and size convenience for the viewer than CRTs, and they will sell well if the prices are low enough. But, if they become popular, this will bring significant challenges for broadcasters.

2. Original studio Rec. 601 pictures are sharp and clear in a WideVGA environment; but, when MPEG-2 compressed, 8-10 Mbit/s will be needed to do justice to the display. This is considerably higher than bit rates used for digital broadcasting today in Europe. This may call for a new broadcast bit-rate strategy.

3. To do the WideXGA flat panel environment justice, HDTV delivered via a 720p channel will produce the highest quality efficiency. Using this format for delivery will also allow broadcasters to maximise the quality the public sees, whatever production format has been used.

4. New thinking will soon be required about the delivery strategy for digital television as public expectations for quality rise through exposure to DVD quality, and as display transparency rises through global penetration of flat panels and other large-screen displays.

CURRENT SITUATION AND PROSPECTS FOR FLAT PANEL TECHNOLOGY AND MANUFACTURE

Flat panel displays are just starting to make inroads into the domestic TV market. CRTs still take 99% of the market, but flat panel TV sales have, in the last couple of years, started to take off, and are forecast to grow very much faster than projection-type displays. Worldwide sales, and planned manufacturing capacity, of flat panel displays have been growing dramatically year on year for the last few years.

[1] These are sometimes known as ALIS panels

Currently Plasma and LCD are the only flat panel technologies of any significance in the TV market. LCDs are difficult to make larger than 25", with the largest currently marketed around 30". PDPs on the other hand are easiest to make in the 40"-50" range, with 32" and 60" models now also appearing. Price to size ratios are currently similar for LCDs and PDPs. However there are new PDP manufacturing technologies, involving newly patented panel structures and new drive methods, which are likely to reduce dramatically both manufacturing costs and power consumption (and hence cooling issues) in the next two years. LCD has to work very hard on power consumption, given the inherent characteristic that much of the illumination from the backlight, permanently on, is lost in the panel, compared to the PDP where cells only generate light as required. It thus seems unlikely that LCD will be able to compete with PDP at the larger sizes.

Another technology to watch for in the future is the TDEL (Thick Dielectric Electro-Luminescent) Display, where iFire, in conjunction with TDK, are planning to produce a 34" display to challenge the PDP.

In 2000, televisions made up only a quarter of PDP sales. By 2006, Stanford Resources (a leading market/technology research company in the display field; June 2001) expect the TV market to take 77% of PDP production. They note too that it is Europe and Japan that currently lead the way in PDP sales, but they expect the North American market to overtake them in the next year. Two huge new PDP factories are under construction in China, which is now the world's largest market for TV sets, and Korea and Taiwan are also entering the PDP market.

Display Search (a specialist market research and consulting organisation) see the main driver for PDP sales growth being a marked reduction in PDP production costs. Prices of plasma display TVs are already falling, from between $10,000 and $13,000 last year to currently as low as $6,000 (Fujitsu 42" satellite receiver/display, marketed in Japan). The cost reductions due to improved manufacturing techniques outlined above should see the price of a 42" plasma TV stabilize in the region of $3,000.

Aside from falling prices, there are two other drivers for the uptake of improved TV displays. One is digital television transmissions, where a larger screen makes the most of the HDTV broadcasts being planned and introduced around the world. However, a more important stimulus in the near future could be the uptake of DVDs, delivering the highest quality pictures to the home for the first time. The rate of DVD take-up is twice that achieved by CD players, and three times that of VHS. The DVD market is growing in all regions, with penetration in Japan (25%) and the US (36%) leading the way. In the UK, the penetration is only 12%, represented by 3 million DVD players. However, 550,000 of those were sold in December 2001 alone!

DVDs are developing fast as well. Progressive scan output, ideal for display on PDP, is now being introduced on even the cheaper DVD players thanks to a new chip from Cirrus. For the future, Toshiba and Matsushita have demonstrated blue-laser HDTV-DVDs and Sony and Philips are also developing such products.

Display Search are expecting flat panel display sales revenue (predominantly from the computer display market) to surpass the CRT this year. There can be little doubt that the flat panel display industry will be shifting their sights to the huge television market to maintain current growth levels as the computer display market begins to saturate.

Stanford Resources (January 2002) are predicting that sales of Plasma Display TVs will grow from 100,000 units last year to 4.9 million by 2007. Over the same time scale LCD TVs, currently running at 855,000 a year, are forecast to rise to almost 8.2 million units. Thus plasma sales growth in the TV market will be far faster than that for LCD. These increased sales, plus a much more modest increase in projection TVs, will result in the CRT market share falling to 93%. So the CRT still has an important part to play, but LCD will make a major inroad at the portable end of the market, and the majority of high-end, top quality, large screen television displays will be plasma.

CURRENT SITUATION AND PROSPECTS REGARDING VIDEO COMPRESSION

Over recent years developments in video compression developments have been considerable, resulting in significant improvements in compression efficiency over the MPEG-2 compression system employed in current DVB transmissions. Recently, the ITU-T/SG16 Video Coding Experts Group has been developing the H.26L video coding standard which has encompassed many notable advances in technology. In December the Joint Video Team (JVT) was established by ITU-T and MPEG (ISO/IEC JTC 1) for further development of the standard (for further details, see [1]).

The H.26L standard has been designed to embody a simple overall architecture, based, like MPEG-2, on hybrid motion-compensated block transform coding, but in which each component of the codec has been optimised for high performance. The main features of the standard are [2]:

- 4x4 block-based integer transform;
- Intra-frame prediction between blocks;
- High accuracy motion estimation (1/4 or 1/8 pel) with variable-sized blocks;
- Multi-frame prediction i.e. prediction by more than two previously coded frames;
- Powerful entropy coding via CABAC (Context-based Adaptive Binary Arithmetic Coding) for mode information, motion vectors and block data.

In addition, the reference Test Models that have been developed have performed rate-distortion optimisations in the selection of motion vectors, prediction modes and block coding modes. This has improved performance and allowed the coders to operate well even at high levels of compression. Subjective test comparisons with an MPEG-4 reference coder performed in July 2001 indicated that H.26L could reduce bit rates by up to 50% over MPEG-4 (which in itself can offer a 25% improvement over MPEG-2) [3]. The tests were performed on CIF and QCIF progressive-scan sequences at a range of frame rates from 10-30 frames/s.

It is not clear as yet whether such large benefits can be reliably obtained from H.26L for SDTV and HDTV sequences and standards, since the relatively small transform block size might be expected to count against the algorithm - further tests are required. However, a number of other algorithms, for example employing wavelet transform techniques, have reportedly performed even better than H.26L [4] and can also be expected to scale well with source resolution. Highly scalable wavelet technologies are being actively studied within the MPEG Interframe Wavelet AHG.

Current developments therefore indicate that a step-change in video compression performance has occurred since the standardisation of MPEG-2. Increasingly, these advances will be available to consumers for improved quality for streamed video over the Internet. It can be

expected, for example, that the quality of streamed video using the latest technology over a 1-2Mb/s ADSL link would be comparable or better than that achieved by MPEG-2 DVB broadcasts at current bit rates. Further efficiencies in the Internet domain can be gained by time-shifted downloads, which allow bit rates to be smoothed over hours rather than fractions of a second. At the same time, blue-laser DVD technology recently demonstrated by Toshiba and Matsushita will allow films in HDTV formats to be stored on a single disk even using MPEG-2 compression.

As a result of these developments, over the coming years consumers will be exposed to high quality video delivery from a variety of sources, to compete with DVB broadcasts.

References

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[2] JVT Working Draft Number 2, Revision 2 JVT-B118r2, available at http://standards.pictel.com/ftp/video-site/h26L/
[3] 'Preliminary results of subjective assessment of responses to video call for new tools to further improve coding efficiency', ISO/IEC JTC 1/SC29/WG11/N4240
[4] G. Heising et al 'Proposal for ITU-T H.26L: A wavelet based video coding scheme using OBMC and image warping prediction', ITU-T VCEG document Q15-G-36

THE AD HOC GROUP COLLABORATIVE TEST PROGRAMME

Background and plans

At an EBU Specialised Meeting on flat panels in 1999, organised by the BMC, a number of EBU Members (BBC. ITC, RAI, IRT, SVT) agreed to work together on tests to establish whether changes would be needed in the broadcast chain, with the advent of home flat panel displays.

A first series of tests was organised at the RAI Research Centre in 2000 in Turin, and the conclusions were reported to the Management Committees and the Technical Committee. The results suggested that though Rec. 601 was a good match to an important part of the flat panel environment (WideVGA displays), there would be serious picture quality problems with PAL/SECAM, and with digital broadcasting of Rec. 601 at the compressed bit rates currently used in Europe.

In discussions in the BMC and Technical Committee in 2001, it was acknowledged that the consequences of flat panel displays would be largely in the delivery chain rather than in production. The TC and BMC encouraged the test group to continue their work, to find the facts, and to look at quality versus bit rate issues for delivery both for WideVGA display and WideXGA displays.

A second set of tests was carried out by the RAI in Turin in 2001, which suggested that the bit rates needed for Rec. 601 MPEG-2 delivery to flat panels could be over 10 Mbit/s.

Following this, SVT and IRT working together, and the BBC, carried out an extensive series of formal subjective evaluations. The results of all the tests[1] were brought together for a meeting of the Ad-hoc group at the BBC Research Department in March 2002. This is a report of some of the results and conclusions found. It draws on the tests performed in the laboratories, and on the collective trials and discussions that took place in the Ad-hoc group.

The results could be of profound importance for digital broadcasting, and are well worth careful attention. They may call for changes in technological policy among European digital broadcasters.

The three complementary evaluations

Three complementary series of evaluations were made in different laboratories, so that balanced conclusions could be drawn. In fact, all the assessments led to very similar results, thus encouraging the belief in the validity of the results.

The evaluations done by the RAI were intended to be indicative, and to bring to light issues - subjective evaluations were made at the RAI in formal conditions, but with expert assessors. The evaluations done by SVT were intended to be 'close to real conditions' - material was shot separately in all formats, but with carefully arranged similar conditions. The evaluations were done in the normal way, but at 4H viewing distance, which is closer to preferred viewing distances than those in formal methodology. The evaluations done by the BBC were intended to be in full compliance with formal methodology - measures such as down-conversion were taken to remove possible biases from the use of differing content in different formats. All the evaluations used different specific content, but with controlled attributes.

CONCLUSIONS FROM THE TESTS

1. The SDTV/Wide VGA environment

- Rec. 601 pictures, uncompressed, do full, or near full, quality justice to WideVGA displays. The pictures look as good as on any 576i CRT displays, and have the increased impact of flat panel displays, due to the high peak luminance, display regularity, etc.

- To be within a grade of uncompressed picture quality on FPs for a wide range of content, compressed bit rates in the region of 8-10 Mbit/s are needed. The bit rate needed depends on viewing distance, but the dependency is not enormous, and may be less for a flat panel environment than for a CRT environment. To be no more than one grade lower than source with material that is critical but not unduly so, needs about 10 Mbit/s at 4H and 6H, and about 8 Mbit/s at 8H.[1]

[1] The reports of the BBC, SVT/IRT, and RAI work are available separately from these organisations. In June 2002, the BBC publication is available from http://www.bbc.co.uk/whp/whp025.html and the SVT publication from http://www.svt.se/svtinfo/inenglish/dev/.

[1] The Swiss broadcasting companies are understood to have recently decided to limit the number of channels per terrestrial multiplex to three, unlike other digital terrestrial broadcasters that carry six or more channels.

- A given bit rate on a 17″ to 32″ CRT gives a quality grade 0.5 – 1 grade higher than the same bit rate on a 42″ WideVGA PDP with equivalent viewing angle. 6 Mbit/s on a CRT corresponds to 8-10 Mbit/s on a PDP with equivalent viewing angle. This is the 'artefact annoyance magnifier effect' that is characteristic of PDPs, and is due to the greater accuracy of the display mechanism, which brings a reduction in masking effects. However, PDPs are not perfect, and they do have to make compromises for motion portrayal.

- There are indications that preferred viewing distances for flat panels may be somewhat closer than for CRTs, and this will exacerbate the problem of low bit rates. The move towards the screen may be content type dependent, but it may be due to the greater sense of reality drawing viewers to the screen.

2. The HDTV/WideXGA environment

- The future broadcasting chain will need to operate with a range of production formats. Even if broadcasters decide to serve a WideXGA environment, they will not move wholesale to HDTV production of a specific format. Rec. 601, for example, will be used for very many years.

- The strategic issue is which 'delivery channel' will best serve the broadcaster and the public under these circumstances. We need to provide the highest practicable quality in the home, both to do justice to our productions, and because we are guardians of the public interest.

- The best delivery channel must be the format that is closest to the highest display format that we target. In this case, any format conversions that are needed can all be done at the production end. Conversion can be done once, and as well as we can do it, rather than millions of times and less well in each receiver.

- If the target display is the WideXGA panel, then the SMPTE 720p/50 format is the best format to use for delivery. It is virtually identical to the WideXGA display format and will effectively decouple the delivery chain from the production chain. If EBU Members decide to embark on HDTV broadcasting, this is the delivery format they should use.

- There are indications that, provided care is taken, studio conversion from either 576i or 1080i to 720p can be done very effectively, and we could be optimistic of being able to provide HDTV broadcasting services with which the public would be satisfied, with either of these production formats. Deciding on a 720p/50 delivery format would give the broadcaster the freedom to make production standards arrangements according to the legacy of other services, equipment costs, etc.

- The benefits of 720p are not only the decoupling of delivery from production; they include the benefits of progressive scanning for motion estimation. This means that there is a 'coding gain' compared to interlace scanning. The same picture quality can be delivered at a lower bit rate. The extent of the coding gain depends on the degree of compression used, but it is larger where there is more compression and the content is more difficult to compress. As an example, for material which was 'critical but not unduly so' for compression, compared to 1080i, the coding

gain for 720p at –12% (about a half grade degradation) is 2.5 Mbit/s, at –25% (about a grade) it is 4 Mbit/s, and at –50% (about two grades) it is 6 Mbit/s.

- We can consider that there is a commodity of 'quality efficiency', which is the picture quality potential normalised to unity transmitted data rate. The benefits of progressive scanning compared to interlace scanning are in higher 'quality efficiency'. There are indications that these benefits might be even greater with future compression schemes, such as JVT. Interlace scanning was optimum for analogue broadcasting, but not for digital broadcasting.

- As a rule of thumb, to be certain of obtaining quality in line with expectations for HDTV on WideXGA displays, 720p pictures need about 19 Mbit/s. However, there are wide ranges of bit rates needed for consistent quality, depending on content. The bit-rate needed for 1080i will be higher.

- For pictures which are critical but not unduly so for detail and sharpness, but not critical for compression, the 720p transmitted bit rate can be reduced to much lower values, even with MPEG-2 compression, and the picture quality will still be better than that of the same scene transmitted at 576i and MPEG-2 coded at 8 Mbit/s, when viewed on a WideXGA display. This is not to recommend that such low transmission rates should be used for 720p, but it does illustrate the flexibility that the progressive scanning delivery channel will bring if needed.

- To achieve the full amount of 'coding gain' however, the production format would have to be originally progressively scanned. The 'ideal' production formats for this environment for the 720p delivery channel would be 720p itself, or even better, 1080p. A formalised standard, 1080p production equipment has recently been developed by NHK, but will probably not be available at reasonable cost for some years, and may thus not be practical today.

- The advantages for 60 Hz over 50 Hz in the perceptibility of large area flicker are not necessarily present in the flat panel environment because of the display mechanism but 50 Hz will have a compressed bit rate advantage for a given quality.

3. Observations on compression and quality

- The relationship between picture quality and transmitted bit rate in the MPEG-2 environment is complex. There is no singular relationship between any given parameter of the transmitted signal and how well the picture compresses. The features of the picture that make it difficult to compress in general are essentially movement and detail, but perceived picture quality is also influenced by the masking effects that the actual scene contents bring, and by how random or consistent the movement and detail is in the picture.

- Using objective parameters such as input/output PSNR is unfortunately no substitute for (albeit costly) subjective evaluations, and it is unlikely that universally useful test signals could be created.

- The consistency of the results achieved in these evaluations showed that, at least, the DSCQS method is a consistent tool for evaluating picture quality

- When comparing the quality available at SDTV and HDTV at the same viewing angle, we need to take into account that the HDTV coder has processed the picture with five times as many blocks, so it can be seen as a more complex system, which produces better results, at the cost of a more complex receiver.

4. The HDTV/SDTV quality efficiency crossover

- In uncompressed form, there is a clear and substantial difference in perceived quality between high definition television and standard definition television, when both are viewed on a WideXGA display. These tests showed that for material which is 'critical but not unduly so' for sharpness and detail, this difference is about 30-40% (above one grade and below two grades) between 576i and 720p, and we can infer similar results for the difference between 576i and 1080i from the tests made.

- As increasing compression is applied to the HDTV signal, the perceived quality falls after a given threshold. The tests tried to establish the point at which the quality fell to the point where compressed SDTV would provide the same or better quality at that bit-rate. There is a parallel situation at lower qualities where QCIF MPEG-1 is thought more quality efficient than CIF MPEG-2 at bit rates below about 1Mbit/s.

- Tests were made on two kinds of picture content. The first was 'critical but not unduly so' for sharpness and detail. The second was also 'critical but not unduly so' for MPEG-2 compression. For the first type of material the crossover did not occur before the abrupt failure of the digital compression. For the second type of material, the crossover occurred at about 10-12 Mbit/s.

- Even at the bit rates needed to preserve Rec. 601 quality, which are low in HDTV terms, all the content tested looked as good or better on a WideXGA display when sourced and delivered at 720p than when delivered at 576i. This underlines the flexibility of a progressively scanned delivery format with equal horizontal and vertical resolution.

ACKNOWLEDGEMENTS

The work that led to these conclusions was extensive, and involved many extremely competent engineers and staff at the RAI, BBC, IRT, SVT, ITC, and the EBU. Subjective evaluations are the only reliable way to evaluate picture quality, but they are time and resource consuming. The work is gratefully acknowledged.