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Technologies for efficient emission of HDTV across Europe

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Abstract

This paper covers the technologies currently used for digital television delivery, applied to High Definition Television services. It outlines the experiments and demonstrations devised by BBC Research & Development to deliver HDTV broadcasts and investigate the best way to efficiently launch HDTV services across Europe. This involves new video compression technologies as well as new delivery technologies.

Additional key words: DVB-S2 VC-1 H264

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1 Introduction

It is important that the challenge of delivering High Definition Television (HDTV) in Europe should be met with technologies capable of meeting the multi-channel requirements of many neighbouring countries. This gives an opportunity for broadcasters who wish to deliver high quality images to adopt all of the latest technologies in one step, without the restriction caused by legacy equipment. At present, using MPEG-2 requires 18-20 Mbps to achieve a relatively artefact free image. Using DVB-S, this can dominate an entire satellite transponder or with DVB-T, an entire multiplex.

By adopting new video compression techniques along with the DVB-S2 delivery platform, up to 6 HD channels could potentially be delivered in a single transponder. New codecs such as VC-1 and H.264 allow for the delivery of artefact free HD material at bitrates potentially as low as 8Mbps.

This White Paper covers the technologies currently used for digital delivery applied to HD and the use of new compression and delivery technologies to more efficiently launch HDTV services across Europe.

2 HD Formats

There are many SMPTE standardised formats for High Definition video. In recent years, two main active picture sizes have been adopted. These are 1280 horizontal pixels by 720 rows and 1920 horizontal pixels by 1080 rows. In practice, the horizontal pixels are often sub-sampled for mild compression on storage formats. For example, HDCAM reduces the horizontal pixel count from 1920 to 1440 and DVCPRO HD sub-samples the horizontal pixel count from 1280 to 960 (although this is not always the case). For the purpose of this document I will assume that no horizontal sub-sampling has taken place.

As well as the two picture sizes, there are a variety of frame-rates and interlace or progressively scanned images. Normal film has a frame rate of 24 Hz. If the film is scanned into a digital format, this usually provides us with 1920 by 1080 progressive image at 24Hz. In Europe this is usually speeded up to 25 Hz with each frame displayed twice as either two fields or two progressive images at 50Hz for television delivery. However, the USA and Japan convert to 60Hz by a conversion process know as 3:2 pulldown, which essentially makes 5 video fields from 2 film frames and this often causes visible motion artefacts.

Some content requires a higher frame-rate than that provided by film. This gives us the 50Hz progressive standards. The bitrate for uncompressed 1920 by 1080 at 50Hz is high, around 3 Gbps requiring dual HD-SDI links, and as such it is rarely used. To make this data rate more manageable two options are currently available. Firstly the resolution could be subsampled to the 1280 by 720 format and kept progressive at 50Hz. This works well in the current climate given that most flat panel displays are progressive devices and 480 or 768 lines in resolution. Secondly, the traditional compression concept of interlace can be used. This gives us the 1920 by 1080 interlace format which displays well on High Definition CRTs but requires an interlace to progressive scan conversion for flat panel displays. Such conversion can be done well with temporal compensation; however cost limitations in some consumer displays require the use of cheap chipsets which can cause a drop in quality.

The table below gives the abbreviations for the video formats that I will use in the rest of the paper.

	Horizontal Pixels	Number of Lines	Progressive or Interlace	Frame-rate
720/P/24	1280	720	Progressive	24 Hz(film)
1080/P/24	1920	1080	Progressive	24 Hz(film)
1080/I/25	1920	1080	Interlace	25 Hz (50 Hz fields)
720/P/50	1280	720	Progressive	50 Hz
1080/I/30	1920	1080	Interlace	30Hz (60Hz fields)
720/P/60	1280	720	Progressive	60Hz

3 High Definition using MPEG-2

3.1 United States and Japan

The USA and Japan have already started broadcasting HD services. Currently they all use MPEG-2 for High Definition but Japan is starting to look towards advanced video codecs. In the USA, some broadcasters use 1080/I/30 and others use the 720/P/60 standard. Opinion is divided about which standard is most appropriate to which genre of programme.

3.2 Australia

Australia, unlike the USA and Japan, use a 50Hz system for television as used in Europe. From 1st July 2003, each broadcaster is required to transmit at least 1040 hours per year of HD programming in Sydney, Melbourne, Adelaide and Perth. They use the DVB-T standard for their digital services and transmit their standard definition services in parallel. They currently transmit using a 7 MHz wide COFDM ensemble, rather than the 8 MHz used in the UK.

To date, there are around a dozen HD MPEG-2 capable DVB-T set-top boxes available on the Australian market. Most of these are backwards compatible with the Standard Definition DVB-T broadcasts in Europe and can be used, for example, to receive Freeview broadcasts.

3.3 Euro1080 / HD1

On 1st January 2004 Euro1080[1] was the first HDTV channel to launch in Europe. It was started by Alfacam[2], a television facilities company who are involved with HD production facilities. They launched a main channel which included programming from America along with some content acquired in Europe. They also launched an Event channel which they used to carry the Euro2004 football to specific cinemas in Europe. In September 2004 they changed their channel names to HD1 and HDe. HD1 is aimed at the home cinema market and uses the 1080/I/25 HD format with

[1] http://www.hd-1.tv
[2] www.alfacam.com

MPEG-2, encoding the video to around 17 Mbps. HDe, however, is aimed at large venues and big events and uses MPEG-2 between 20-25 Mbps for the video.

Euro1080 have recently announced another channel, HD2, as a part-time "Pay per event" channel. This is planned for launch around June 2005 and will be using an advanced video codec rather than MPEG-2.

4 Demonstrations of MPEG-2 HD over DVB-T

With the increased availability of large flat panel displays with lowering prices and the boom in Home Cinema equipment, it is possible that consumers in Europe will start to question the quality of television broadcasts when compared with DVDs. For this reason it was important to demonstrate in Europe that HD can be possible over all delivery platforms.

BBC R&D purchased an Australian set-top box (Figure 1 - Toshiba HD-S23A) and imported it to the UK. A short 720/P/50 test sequence was created and MPEG-2 encoded at 17 Mbps using non-realtime software. This was then packetised into a DVB transport stream and transmitted locally in the UHF band using a very low power DVB-T transmitter. On 3rd December 2003, the set-top box was used to receive, decode and display the sequence on a large plasma display (Figure 2).

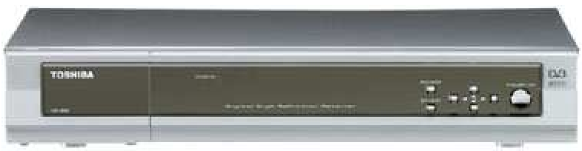

Figure 1 - Toshiba HD-S23A

Figure 2

The DTG[3] invited BBC R&D to demonstrate HDTV delivery at the Mediacast[4] event in London in May 2004. Given the multi-channel environment in many countries within Europe however, it would not be feasible to introduce HD services at these bitrates, offering one service per DVB-T multiplex. It became clear that new video compression technologies were developing and could

[3] www.dtg.org.uk
[4] http://www.mediacast.net

soon allow each channel to use considerably less bitrate whilst maintaining a significantly artefact-free picture.

5 High Definition using Advanced Video Codecs

5.1 H.264

MPEG-4 Part 10 AVC (H.264) provides a significant improvement over MPEG-2 in terms of the bitrates required to achieve an artefact free service. Its progression to a broadcast delivery format is planned by some countries for delivering SD television services, for example in Japan. The first live HD encoders have only just been announced so are not immediately available for deploying as a fully operational service. However, non-realtime software encoders for HD have been available for several months and these tools can be used for encoding the video and creating valid DVB transport streams, required for transmission. For testing, we used the Moonlight[5] Software Development Kit to create an HD encoded sequence and decode it live using software running on a fast PC.

5.2 VC-1

The Microsoft Windows Media 9 codec has been around for a while and is currently making progress in the introduction of HD-DVDs. Several titles are available in the USA with HD encoded material at both 1080/P/24 and 720/P/24, using this compression format. Microsoft is currently submitting the codec through the SMPTE who are creating a standard known as VC-1. This provides an open standard video codec that can be used over DVB for broadcasting. We worked with Microsoft to encode some 50Hz progressive HD material, which had not been done before, and to create a valid DVB transport stream which could then be transmitted and decoded in software.

6 DVB-S2

DVB-S2 is a new transmission standard, backward compatible with DVB-S but offering 30% greater efficiency than DVB-S. A single 36 MHz satellite transponder can carry a transport stream of 54 Mbps allowing greater capacity for services. By combining advanced video codecs such as H.264 and VC-1 with DVB-S2, potentially as many as 6 HD channels could be carried on a single transponder.

More details on the DVB-S2 specification can be found on the DVB website[6].

7 IBC 2004 demonstration

The DVB office asked BBC R&D to help to provide a demonstration of HD delivery using advanced video codecs and DVB-S2 at IBC 2004 in Amsterdam. Conexant and Radyne Comstream provided a DVB-S2 modulator/demodulator pair and SES Astra provided the satellite transponder and dishes for the up and downlinks. Figure 3 shows a block diagram of the system that was built and demonstrated.

[5] http://www.moonlight.co.il
[6] http://www.dvb.org/index.php?id=294

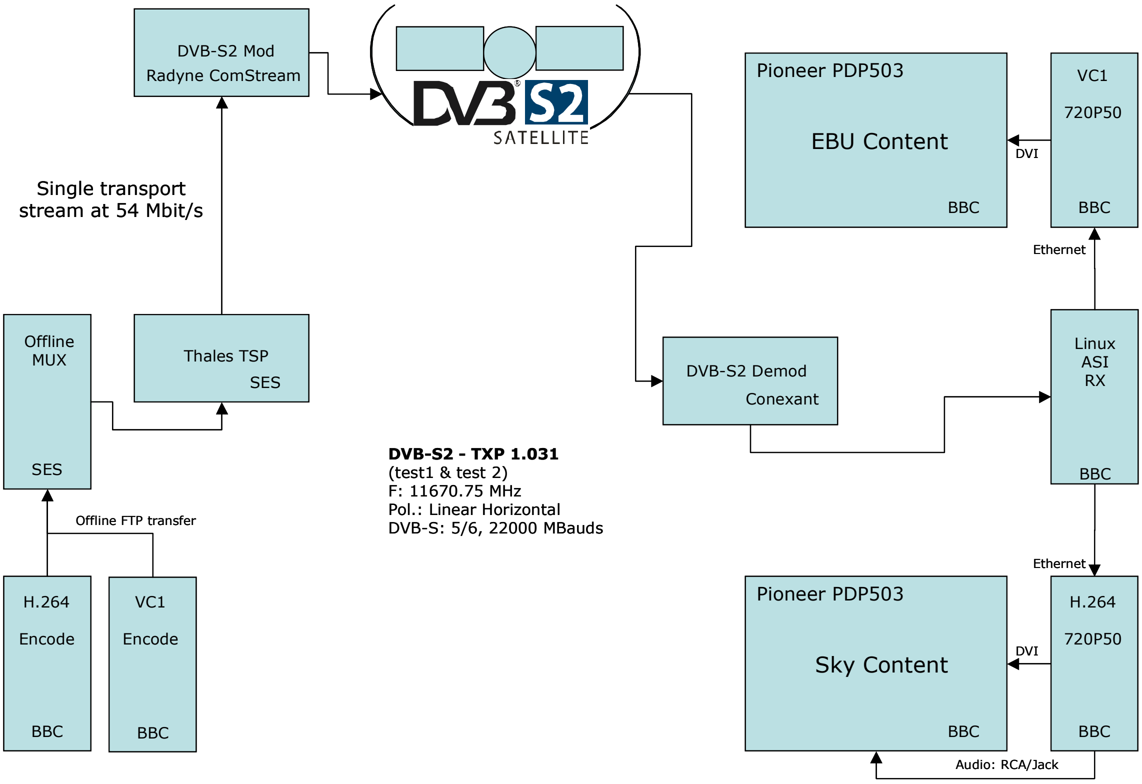

Figure 3

Two HD programmes with different content were used in the demonstration. One sequence was provided by BSkyB on HDCAM tape and converted to 720/P/50 using the Snell & Wilcox HD6300 converter[7] for capturing uncompressed into a PC system. The second sequence was a 720p50 production created in a collaboration between NDS and the EBU (BBC and SVT). This was edited using Final Cut Pro HD and transferred uncompressed to the PC system. The two sequences were then encoded using non-realtime software encoders and packtised into DVB transport streams. These transport streams were transferred to Astra via ftp where they were stored on a server. The playout system then combined the two transport streams and added the appropriate time stamps, before streaming out a single DVB transport stream.

This 54 Mbps transport stream was then modulated in DVB-S2 and transmitted via satellite to Amsterdam. The signal was demodulated using the Conexant demodulator and fed via ASI into a Linux PC. This PC extracted the two channels and passed them via Gigabit Ethernet to the other two PCs. One PC decoded the H.264 channel and the second decoded the VC-1 channel. Both images were displayed via DVI on Pioneer Plasma displays. The displays have a native resolution of 1280 by 768 so were driven pixel mapped to give the 1280 by 720 image.

Even though there were some visual impairments due to the PCs not being fast enough, many people saw the demonstration and were impressed to see the quality and efficiency that could be achieved with HD services. It was the first time in the world that all these technologies had been pulled together and shown publicly. Figure 4 shows the stack of PCs used for the live decoding and Simon Gauntlett (BBC), Peter McAvock (DVB) and Thomas Bernard (BBC) in front of the stand.

[7] http://www.snellwilcox.com/products/data/standards/hd63data.pdf

Figure 4

8 Conclusion

Delivery of HDTV in Europe will need two major attributes. It will have to provide a significant improvement over current 625-line standard definition with images substantially free from visible artefacts. Secondly, it will need to be efficient enough to satisfy the demands of multi-channel offerings in all the individual countries given the spectrum constraints.

VC-1 and H.264 video compression provides both a significant improvement in picture quality and a lower required bitrate than MPEG-2. Once hardware becomes available that can encode and decode an HD service with minimal visible artefacts, it becomes feasible to launch these services on all platforms where capacity is available. To achieve multi-channel HD services in the many countries across Europe, it is advantageous to utilise the improved efficiency of DVB-S2 coupled with the benefits of the advanced video codecs.

It is too early to say what bitrates would be required for an artefact free service, particularly given that hardware encoders are not initially going to be as efficient as the current non-realtime software encoders. It has been observed with software encoders that a wide range of material can require from around 4 Mbps to 16 Mbps to achieve artefact free video. It is therefore likely that future hardware encoders will have to work at variable bitrates in this range, allowing the use of statistical multiplexing and opportunistic data delivery for ancillary services.

9 Acknowledgments

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Moonlight SDK http://www.moonlight.co.il
Microsoft Windows Media http://www.microsoft.com/windows/windowsmedia/default.aspx
Digital Broadcasting Australia www.dba.org.au
Snell & Wilcox http://www.snellwilcox.com
Conexant http://www.conexant.com
Radyne ComStream http://www.radynecomstream.com
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