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"Unique Digital Radio" for Europe

The history of Digital Radio in Europe, since the definition of DAB in 1993, is a history of difficulties, scarce investments by industry and broadcasters, and commercial success limited to some specific areas only. In order to track back over the history of Digital Radio, let us cut some slices from past articles in the Techical Review.

In 1998, an Editorial titled ***DAB – is it already out of date?*** by Phil Laven concluded:

" Radio is essentially a mobile or portable medium. We must pay tribute to the tremendous foresight of the individuals in the Eureka-147 consortium which, from its earliest days, recognized the need to deliver digital audio services to mobile and portable receivers – even under the most difficult reception conditions. Not only did they successfully meet this challenge, they have also developed a superb flexible mechanism for the delivery of high data-rate multimedia services. "

In 2002, another article by Delphine Josse of WorldDAB Forum said:

" DAB, now hitting the market on an industrial scale, has moved into a phase of "industrialisation", with many new broadcast services starting throughout Europe and beyond. The choice and availability of different types of DAB receivers is also expanding at an encouraging rate. "

A more recent article in 2008 titled ***Digital Radio — a receiver manufacturers viewpoint***, by Colin Crawford of PURE Digital, reports:

" It is well known that the stand-out market for DAB digital radio is the UK, with around 7 million receivers now being used in approximately 27% of UK households. What is less well known is that a small number of other countries have seen similar success when viewed in proportion to the population. Denmark in particular has a thriving DAB market, with a household penetration almost identical to that of the UK. Norway follows close behind Denmark, with Belgium and Switzerland not far behind that. So what is it about these countries which has created successful markets where other countries, notably France, Germany, Spain, Italy and Portugal have so far failed to generate any tangible success? "

The "Babel tower" scenario

Along with the delays and the slow take-up of Digital Radio in certain parts of Europe, a new phantom started to destabilize the Digital Radio investors: new technologies were being developed progressively on top of, or in place of, DAB. This was justified by the progressive out-dating of DAB technologies, in particular those of audio coding, where the use of MPEG-4 AAC (HE AAC v2) allows us to improve the spectral efficiency many times compared to the original MPEG-1 Layer 2 (while the original DAB was not more efficient that analogue FM!).

Candidate Digital Radio systems around Europe now come in a variety of different types:

- DAB, DAB+, DAB-IP and DMB in VHF band III and L-band;

- DRM in the bands below 30 MHz and DRM+ in the bands up to 120 MHz (under consideration);
- DVB-H mainly oriented to mobile-TV services in the UHF bands.
- Not to speak about proposals coming from other continents, such as HD Radio and MediaFlo.

Together with the audio features, a different mix of additional technical features are supported by the different systems listed above, such as text display (Dynamic Labels, Intellitext, Journaline), travel information for car radios (TPEG and RDS), multimedia transport and rendering on screens when the receivers are equipped with a graphics video processor (BIFS, Broadcast Website, Slide-show), up to real mobile TV services (MPEG-4 H.264 video).

To add even more confusion, different systems are designed to operate in different frequency bands, and regulations may be different country-by-country.

The varying national preferences for Digital Radio might result in different and incompatible receivers being needed in different countries and, when crossing borders, a given car radio or jukebox radio might even go silent!

The "Unique Digital Radio" approach for Europe

In the analogue radio world, the public benefits from having full access to any radio service, everywhere in Europe (or even the world), in given frequency bands. In fact, nearly all receivers sold are FM/AM models of which many can also receive "RDS" services, allowing station identification and more.

In May 2008, the EBU Technical Assembly brought different stakeholders together for a panel session. One statement said that Digital Radio was "in a coma". Everybody had a different view or position on the situation, defined by their own stake. Nobody could give a solution to solve the Digital Radio situation European-wide. Action towards harmonization was needed to give Digital Radio another, or maybe a last, chance.

WorldDMB and the EBU Technical Committee decided shortly afterwards that:

" It is timely not only for Public Service Radio Broadcasters, but for all participant in the radio market, to establish a strategic alliance in order to guarantee 'continuity' of Digital Radio services across Europe. In the interest of the European public, and to create the largest possible pan-european market, there should be only a single Digital Radio technology platform, which is branded as "Digital Radio" rather than by technical acronyms and terms. "

In cooperation with EICTA (the European digital technology industry association), it was natural to join efforts for a common great strategic target – the *"Unique Digital Radio"* concept, which should work ANYWHERE in Europe (and hopefully also in other Countries).

Profiling the receiver market

The *"Unique Digital Radio"* concept is simple and useful, but it has to be traded with the clear need to allow different classes of receivers, in terms of features and cost. Therefore the Unique Digital Radio concept was extended as follows: a receiver must be able to decode anywhere in Europe all services within its PROFILE (or in lower profiles). This is possible within the current developments and roadmaps of Digital Radio chip manufacturers.

Three profiles have been agreed for services and corresponding receiver features:

Receiver Profile 1 - Standard Radio Receiver

Describes a purely audio receiver with a basic alphanumeric display. In order to avoid fragmentation of markets, standard profile receivers should be able to decode the audio track of advanced profile broadcasts together with the features of the basic profile. The standard radio receiver can cope with different radio technologies such as DAB, DAB+ and DMB.

Receiver Profile 2 - Rich Media Radio Receiver

Describes an audio receiver with a colour screen display of at least 320 x 240 pixels. The receiver is designed to include more functionalities than Profile 1 to deliver a rich media experience to the radio user.

Receiver Profile 3 - Multimedia Receiver

This is a multipurpose receiver with a colour screen display, capable of rendering a full video experience.

It is interesting to note that for all receiver profiles, FM and AM analogue reception is also recommended.

These receiver profiles provide reassurance to: (i) broadcasters that the services they plan will be receivable, and (ii) manufacturers that their technology investments will be supported by broadcast services.

The consumer also gains from knowing that the product they have chosen contains the necessary features to provide them with a consistent quality of experience as well as assured levels of interoperability across many countries.

Alberto Morello
RAI Director of Research
Chairman of the EBU Technical Committee

Lieven Vermaele
EBU Technical Director

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European Broadcasting Union
L'Ancienne Route 17A
CH-1218 Grand-Saconnex
Geneva
Switzerland

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Technical trial of the EBU P2P media portal

Franc Kozamernik
Senior Engineer, EBU

The EBU P2P Media Portal (EBUP2P) was developed as a demonstration tool for EBU Member organizations to show their television and radio channels internationally.

A 6-month trial of the portal was set up by EBU Project Group D/P2P in the first half of 2008 to evaluate P2P (Peer-to-Peer) technology – via the example provided by the company Octoshape. This article reports on the outcome of the trial.

EBU Project Group D/P2P (Peer-to-Peer), chaired by Frank Hoffsümmer (SVT), was set up in 2006 in order to:

- evaluate newly-emerging peer-to-peer technologies;
- formulate potential EBU requirements for such systems;
- to carry out technical experiments and trials on a working P2P system.

The Group was encouraged by the large attendance at a seminar organized by the EBU Technical Department in February 2006 in Geneva, which identified significant interest among EBU Members in studying this new technology.

The initiative for an EBU Media Portal came from the Group D/P2P at its meeting in June 2007. The Group proposed that EBU Members should come together and set up a common Internet portal through which Members' TV and radio channels could be made available to the general public worldwide. The portal – if ever established permanently as a non-commercial collaborative EBU project – could mean much more than just a technically advanced and innovative project: it could become a one-stop shop window of Members' programming achievements.

What is Peer-to-Peer?

In this article, P2P is considered as an Internet *media distribution* system which relies on end-users' computers to propagate content through existing computer networks. Such a P2P system has nothing to do with napsterization or illegal content-sharing. Quite the contrary, P2P offers an attractive possibility for broadcasters to distribute their content efficiently across the Internet.

As P2P does not require any special emission infrastructure to be installed, the investments and maintenance costs are significantly lower than those of more traditional Content Distribution Networks (CDNs) which may use several thousands of special streaming servers. In addition, P2P does not have a single point-of-failure, so its service reliability is very high.

On the downside, P2P is a relatively new technology which requires a lot of further studies and hands-on experience in order to turn an interesting technical innovation into a viable business proposition.

Prior to the advent of P2P, EBU Members were extensively using different server-client approaches such as CDNs (Content Distribution Networks), IP Multicasting and a great variety of proprietary streaming solutions from Microsoft, Real Networks and QuickTime. A common characteristic of all these systems is that they are relatively expensive ... because broadcasters must pay an ISP (Internet Service Provider) for each connected stream (i.e. user). Thus, the more users there are, the higher the ISP's costs will be. Effectively, broadcasters pay more because of their own success.

As an example, in 2005, the Eurovision Song Contest was distributed via the Internet using a CDN system serviced by Akamai. Being a highly popular event, it generated a lot of interest worldwide (several tens of thousands of Internet users). The calculated cost of video streaming the event was about one CHF per user per hour, which amounted to around CHF 100'000 (€ 65'000) for the 3-hour show.

P2P may change this paradigm radically. Video can be streamed via P2P at a cost that is below € 0.05 per GB[1]. As a result of the competition from P2P, the cost of CDN services has also dropped significantly but it is still much more expensive than P2P by an order of magnitude.

In addition to the cost factor, P2P technologies have many advantages compared to other Internet distribution systems: no central server streaming "farm" is required and there is no central point of failure (assuming a decentralised, distributed tracker). However, P2P is still in its infancy and many challenges are still to be resolved. Setting up EBUP2P is only the first step in the direction of gathering experience and solving potential issues relating to P2P.

Requirements for an Internet media-distribution system

Broadcasters have the following requirements for any Internet distribution system they might wish to use:

- low distribution cost (ideally independent of location, time, quality and number of users);
- reliable delivery (no glitches or interruptions, reasonable end-to-end latency, fast zapping);
- high quality levels – SD, even HD (including multichannel audio if required);
- large channel capacity (in principle, there are no frequency spectrum constraints as in conventional broadcasting);
- the largest number of concurrent users possible (several hundreds of thousands of concurrent P2P users have been successfully demonstrated).

The P2P trial

In order to make the whole operation manageable, we had to limit the number of Member participants to about ten (see *Table 1)*. The P2P system chosen for the trial was provided by Octoshape, already described in an earlier edition of EBU Technical Review [2].

Basic portal description

During the trial, there was a highly-visible vignette "P2P Media Portal Trial" on the EBU's home page, which took the user to the portal's own home page [3]. Access to the portal was open to all users worldwide and *Fig 1* shows an earlier design of the home page.

1. Octoshape states a price of 2 Eurocents per GB on its website: **http://www.octoshape.com/**
2. Visit: **http://tech.ebu.ch/docs/techreview/trev_303-octoshape.pdf**

Table 1
Member participants in the EBU P2P Portal trial

		Channel	Organization	URL	Comment
TV	1	HR	Hessischer Rundfunk (HR)	www.hr-online.de	
TV	2	DW - TV	Deutsche Welle (DW)	www.dw-world.de	
TV	3	TV SLO 1	RTV Slovenia (RTVSLO)	www.rtvslo.si	
TV	4	TV SLO 2	RTV Slovenia (RTVSLO)	www.rtvslo.si	
TV	5	24H tve	RTV Spain (RTVE)	www.rtve.es	
TV	6	DOCU tve	RTV Spain (RTVE)	www.rtve.es	Discontinued
TV	7	TV Ciencia on-line	TV Portugal	www.tvciencia.pt	Since May 08
TV	8	iTVP	Polish TV (TVP)	www.itvp.pl	Since May 08
TV	9	Taiwan TV			Since June 08
Radio	10	radio-suisse jazz	SRG-SSR	www.srg-ssr.ch	MP3, 192 kbit/s
Radio	11	radio-suisse pop	SRG-SSR	www.srg-ssr.ch	MP3, 192
Radio	12	radio 3	RNE	www.rne.es	WM, 96
Radio	13	radio classica	RNE	www.rne.es	WM, 128
Radio	14	youfm	HR	www.hr-online.de	MP3, 160 – up to the end of April 08
Radio	15	RSi	RTVSLO	www.rtvslo.si	WM, 192
Radio	16	Val 202	RTVSLO	www.rtvslo.si	WM, 192

During the trial, the design of the web portal underwent continuous improvements, both graphically and in terms of accessibility and user friendliness. *Fig. 2* (on the next page) shows the current graphical design of the portal, as produced by Nathalie Cullen from the EBU's Communication Service.

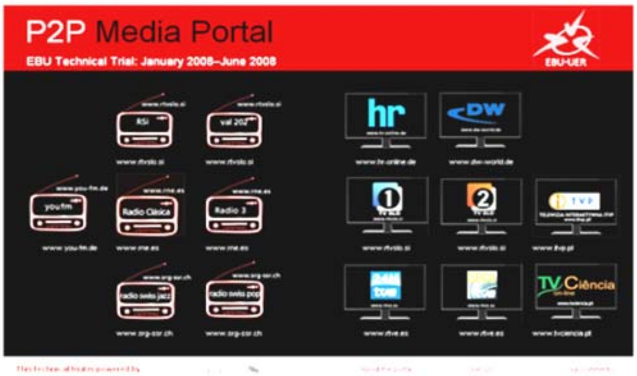

Figure 1
EBU P2P Media Portal - Windows Media Player only *(Courtesy: Nathalie Cullen, EBU)*

Each Member participant is represented by an icon which emulates their logo. On the top right side, there are eight icons representing TV channels, while below them are six radio channels. In this new design, users during the trial had the flexibility of using either an embedded player (which starts playing automatically when you first open the page) or Windows Media Player (which opens in a separate adjustable-size window).

3. The deep link to the Media Portal can still be found here: **http://www.ebu.ch/members/EBU_Media_portal_Trial_1.php**

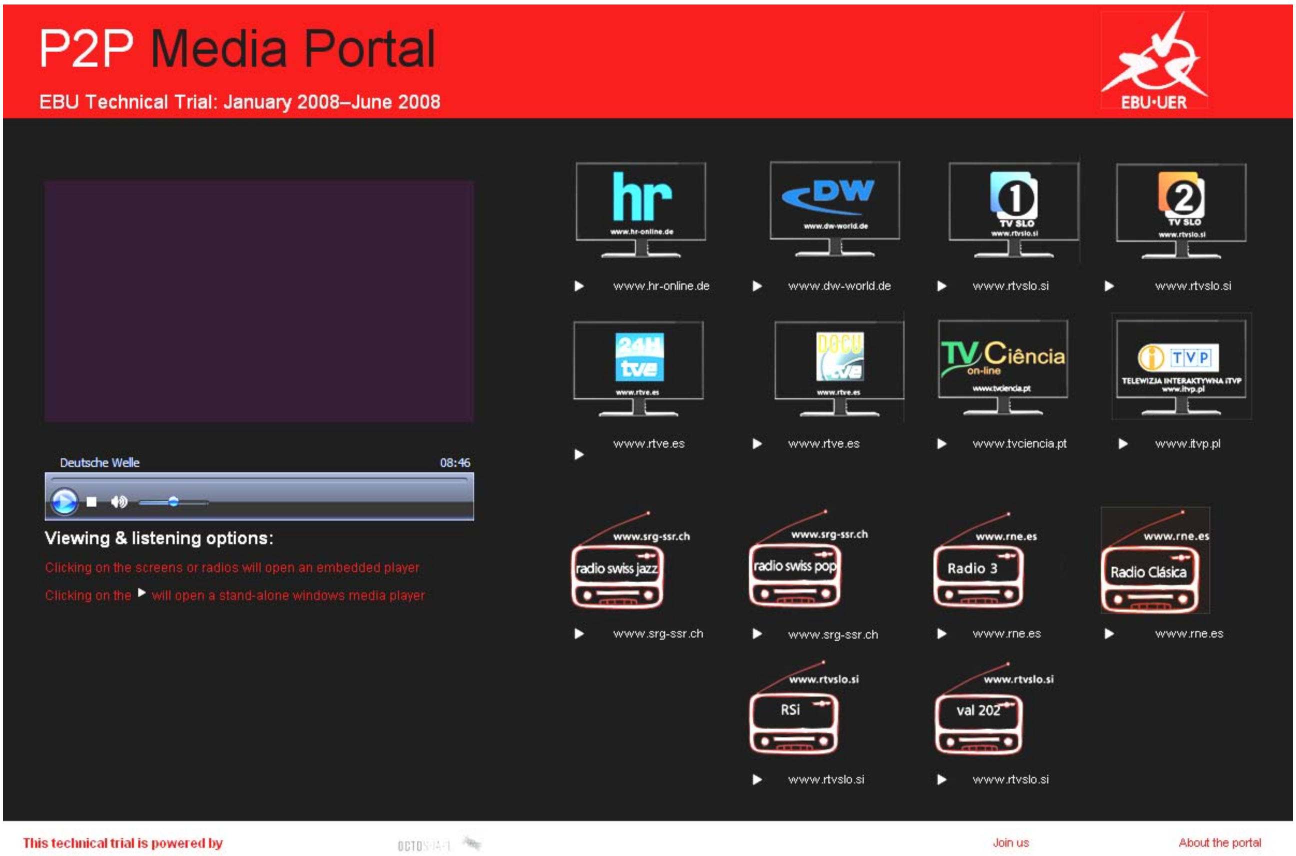

Figure 2
Final design of the EBU P2P Media Portal *(Courtesy: Nathalie Cullen, EBU)* **– which uses either Windows Media Player or an embedded player in the browser**

Underneath each logo we put a link to the Member's URL, allowing the users to consult the schedule of programmes and access some additional information about the channel concerned.

On the bottom of the page we included a temporary link "Your Comments", allowing the users to send in reports and comments about their viewing experiences. During the trial we received more than a hundred comments which were all consistently positive about the user experience.

The page also included information about what the user needed in order to access the portal content. These are as follows:

- a suitable broadband connection;
- a PC running Windows, Mac or Linux;
- Internet Explorer (IE) or Firefox browser;
- Active X (in the case of IE);
- Windows Media Player (video and audio);
- MP3 player;
- Octoshape plug-in.

Abbreviations

CBR	Constant Bit-Rate	**HTTP**	HyperText Transfer Protocol
CDN	Content Delivery Network	**ISP**	Internet Service Provider
CE	Consumer Electronics	**P2P**	Peer-to-Peer
DRM	Digital Rights Management	**SDI**	Serial Digital Interface
EPG	Electronic Programme Guide	**WM**	(Microsoft) Windows Media
FS	Full Scale	**XML**	eXtensible Markup Language

The trial plan

The first issue in the process of establishing an operational EBU Media Portal was to identify a suitable Internet distribution technology and to agree some operational parameters. A technical trial Group consisting of ten EBU Members held a kick-off meeting on 10 July 2007 in Geneva, in order to define the technical and operational parameters based on peer-to-peer (P2P) technology [4]. Once these parameters had been set, the trial could start informally in autumn 2007 but officially it started in January 2008. It then continued for six months until the end of June 2008.

Table 2
Technical tests planned

	Test	Description	Participants
1	Accessibility of contents from the EBU web site	working links, smooth zapping of channels, only one stream at a time	all
2	Overall quality performance (continuity and reliability) under different broadband network conditions	different upstream and downstream capacity, different network load (resulting in packet loss and jitter)	all
3	Scalability: 200 and 700 kbit/s	number of concurrent users	all
4	Different computer platforms/operating systems	PC, Mac, Linux	IRT
5	Different browsers	IE, Firefox, etc	IRT
6	Geolocation (dynamic)	displaying the messages for non-availability of streams	?
7	Rights Management	Different DRM system including MS DRM, DVB CPCM	?
8	Audience statistics	immediate return of data for each broadcaster	All, EBU
9	Pre-roll advertising	Octoshape inserts a up to 3 s pre-roll ad. Content of add should be mutually agreed by channel owner and Octoshape	HR, TVP
10	Audio Watermarking [a]	Embed about 100 bit/s	?
11	Flash codec [a]	In addition to WM, we should test Flash codec	?
12	On-demand delivery [a]	Video on -demand play out of files	?

a. To be tested in the second phase (subject to agreement with Octoshape)

The Trial Group was coordinated by the Author and operated under the auspices of the D/P2P Group. It held three meetings in order to supervise the development and monitor the technical quality of the portal.

The principal objective of this trial was to assess whether or not the Octoshape P2P technology is an efficient and reliable platform for live streaming of Members' television and radio services. We also seized the opportunity to try some peripheral services such as the graphical design and accessibility

4. Octoshape P2P technology was selected on the basis of some comparative tests conducted by Project Group D/P2P during IBC 2006 and also as a result of Eurovision Song Contest events from 2005 onwards, for which Octoshape was very successfully used.

of the Portal (e.g. how the user accesses the site and changes channels – zapping), along with video encoding, geolocation, pre-roll advertising, etc

Based on the above system and the operational requirements, a test plan was developed, as shown in *Table 2*.

Technical specification of the trial

The agreed technical parameters for the audio and video streams is given in *Table 3*.

Table 3
Technical parameters used in the EBU P2P Media Portal

<table>
<tr><td rowspan="6">Television</td><td colspan="3">Video</td></tr>
<tr><td>Codec</td><td>Bitrate</td><td>Aspect ratio & resolution</td></tr>
<tr><td>MS Windows Media</td><td>about 700 kbit/s</td><td>4:3 480 x 360 px; 16:9 520 x 360 pixels</td></tr>
<tr><td colspan="3">Audio</td></tr>
<tr><td>Codec</td><td>Bitrate</td><td>Stereo/Mono</td></tr>
<tr><td>MS Windows Media 9</td><td>64 kbit/s</td><td>48 kHz, stereo (A/V) 1-pass CBR</td></tr>
<tr><td rowspan="4">Radio</td><td colspan="3">Audio</td></tr>
<tr><td>Codec</td><td>Bitrate</td><td>Stereo/Mono</td></tr>
<tr><td>MS Windows Media 9</td><td>96/128/192 kbit/s</td><td>44.1/48 kHz, stereo (A/V) 1-pass CBR</td></tr>
<tr><td>Mpeg Layer 3</td><td>192 kbit/s</td><td></td></tr>
</table>

Players: Windows Media and embedded Octoshape player.

Distribution via Internet: P2P and HTTP.

Distribution of work

The following is the list of tasks that each participant had to accomplish in order to make the trial a successful operation.

Octoshape

Octoshape provided the following services to the Portal:

- Information to the EBU to enable EBU Members to encode their streams in WM;
- Octoshape-specific Source Signal Solution (SSS) software to all Members for encoding their material;
- If required by a Member, performed encoding (or asked third party to do it);
- Information to EBU to inform EBU Members how to send streams to Octoshape;

- User's plug-in (Octoshape-specific) with regular updates;
- Powered the Portal by providing P2P services for live streaming;
- Provided audience statistics on request to all participants;
- Provided geolocation services (if required);
- Provided pre-roll advertising (if required).

EBU staff

The EBU had the following responsibilities:

- Ensured that the technical, legal and programming interests of EBU Members were fully respected and taken into account;
- Coordinated the evaluation process;
- Developed a dedicated website in coordination with Octoshape, and according to Octoshape requirements, and provided a link to the EBU home page;
- Ensured a proper design of the web page, with constant improvements to the look and feel;
- Ensured a balanced (non-discriminatory) visibility to all the channels involved;
- Provided all the information required for the end user to access all the channels and other information required;
- Enabled the user to download the latest version of the required media players and the Octoshape plug-in;
- Reported regularly to the various EBU bodies on the progress of the technical trial;
- Ensured some publicity for the portal in order to maximize the use of the site;
- Promoted the portal at relevant events, EBU seminars, conferences and trade shows;
- Discussed common strategies for pre-operational and regular services with Octoshape, i.e. the future steps and business model options to be considered.

EBU Members - Trialists

The EBU Members that participated in the trial coordinated their activities through the EBU Technical Department. Participants conducted the following activities:

- Provided the content, i.e. selected the TV/radio channels or any other streaming content they wished to publish on EBU website [5];
- Granted rights to the EBU for their content to be published on the EBU website;
- Encoded their streams (by using appropriate technologies);
- Forwarded their streams to Octoshape;
- Defined the coverage constraints (if and when required) and instructed Octoshape how to apply geolocation filtering;
- Provided a link to the EBU website on their own website, so that users in their country could easily access other EBU Members' content;
- In the case of pre-roll adverts, Members performed editorial control of the ad content.

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5. Generally all webcasts should be available for 24 hours a day but it is up to the individual Members to decide on their webcast times. In the latter case, information should be given about the broadcast times.

Legal matters

Throughout the course of the trial, legal matters – particularly copyright issues – played an important role in our discussions. Initially, EBUP2P thought we could be considered a kind of re-broadcaster of EBU Members' content and be treated as a cable network. To this end, the EBU (as owner of the portal) needed explicit permission from Members to re-broadcast their channels. If required, the EBU also needed to clear the rights issues with the collecting societies. All participants were required to sign a rights clearance form that there were no legal obstacles for the EBU to make the TV channel(s) available to the general public, free of charge and in unchanged form and simultaneously with the terrestrial broadcasts of these channel(s).

A later discussion showed that, in practive, the end user who clicks on the icon on the EBU website to access a certain TV channel is merely redirected to the original stream of the actual content provider. Therefore, the EBU is not re-transmitting the stream. It was agreed to publish a disclaimer which reads:

> ***It should be noted that the users are redirected to the original stream of the actual content provider and the EBU is not re-transmitting the stream.***

Another solution for a future portal would be for the EBU to simply provide the links to the Members' web pages containing embedded players.

Evaluation results

Audience

The table below shows how many unique users were able to join the trial across all channels offered during the January - June 2008 period. It also shows the aggregate time (in hours) of user media consumption for each month.

Month	Unique users	Total hours
Jan	9'072	32'375
Feb	8'157	39'777
March	8'652	44'898
April	7'031	41'519
May	3'808	26'247
June	2'936	24'184

Fig. 3 shows an example of the audience variations on two Hessicher Rundfunk channels, one TV and one radio, during the political campaign before the elections at Hessen, Germany. Members of political party SPD were able to watch the TV stream via our P2P stream, as they did not have TV sets in their offices.

Please note that the Octoshape system was limited to serve no more than 600 concurrent users, as the broadcaster did not notify Octoshape in advance (see the section on "Scalability" below).

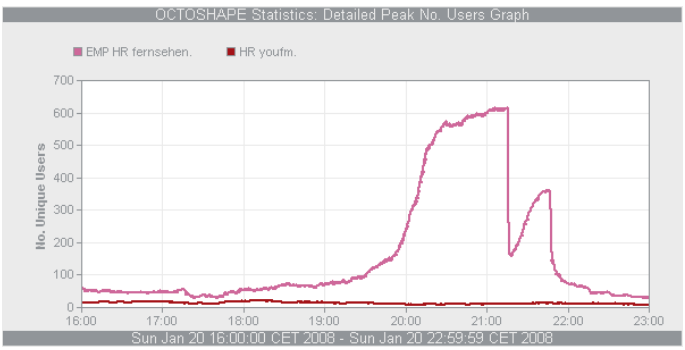


Figure 3
Audience variations on HR's radio and TV channels

Accessibility

All web links were working satisfactorily, zapping of channels was smooth and only one stream at a time was available (as required). Some occasional glitches (e.g. missing sound, lip-sync problems) occurred due to poor encoding. The Spanish Documentary channel is not available outside of Spain, due to copyright, and the geolocation filtering was applied to implement this. The end user was informed about this via a message that popped up "This stream cannot be viewed in your country".

Several users had problems with downloading the Octoshape plug-in. Some people, particularly those located in large corporations (including some large broadcasting organizations) could not download the plug-in at all, and consequently were not able to access the Portal services. This element of the Octoshape system needs to be considered, as it represents an obstacle to audience acceptance.

Overall quality performance

There has been no evidence that network traffic load, asymmetricity or last-mile issues affected the overall quality performance of the Octoshape system in any significant manner. It should be stressed however that only large-scale laboratory tests, allowing for controlled repeatability of results, could yield scientifically-valid results. According to the reports received, our experience about the service quality was positive – we can deduce that Octoshape performed correctly on all networks.

The service quality therefore mainly depends on the encoding quality. We detected some errors performed by Members in encoding video material, in particular regarding the correct aspect ratio when the source material was produced in HDTV (16:9).

Should there ever be a regular service, the question of correct encoding requires extremely careful consideration. Differences between different sources should be avoided, so that zapping from one channel to another does not result in level and other differences. Broadcasters should adopt a common set of coding parameters. Square pixels should be consistently used.

Resolutions: 4:3 — 512 x 384 pixels

16:9 — 512 x 288 pixels

De-interlacing problems should be handled in the hardware (encoder card). Complexity coding should be enabled. If possible, performance could be enhanced by a 2-step encoding. Use of SDI sources is highly recommended while composite sources (to reduce cross-colour and cross-luminance interference) is to be avoided

Audio level: 0 dB FS level (full scale).

Scalability

On a major Internet event in May, HR experienced a service breakdown. Octoshape explained that the 600 [6] user limit was configured on the Octoshape P2P network by default (which means that the service was effectively cut down when more than 600 peers joined the network). This was explained as a normal precautionary measure, as Octoshape does not know the network (ISP) limits which may vary from one network to another. Octoshape is however able to scale bandwidth to the ISP limits.

6. Octoshape explained that the number 600 is really arbitrary and can well be set to a much higher value if required (especially for live events).

Such a service breakdown could have been avoided if Octoshape had been informed in advance of an event where it was likely that a larger number of peers may join. Octoshape can scale down the quality from 700 kbit/s to 200 kbit/s [7] either automatically or manually.

In order to implement the scalability and ensure continuous services (even when the number of users increases), it is necessary to encode the streams in two (or three) bitrates. In this way, Octoshape can perform an automatic switch to a lower bitrate, as soon as the number of peers reaches a certain limit.

It should be pointed out that dual bitrate encoding can be implemented by a single PC.

Octoshape has already demonstrated on a number of occasions that it is a very scalable system, e.g. for the Eurovision Song Contest during which it was able to support around 45'000 simultaneous streams without any problems.

Computer platforms and browsers

There was no evidence of any problems resulting from the use of different computer platforms, operating systems and browsers.

Geolocation

Throughout the trials, the Group gave very serious consideration to issues relating to geolocation filtering, as this tool is essential to limit coverage to specific areas, mainly for copyright reasons. The geolocation system must obey very strict requirements in terms of security, accuracy and reliability, in order to prevent any leakage of content outside the granted zone.

The Octoshape geolocation system is an advanced commercial product called "IP2location". This system enables identification of the geographic location and Internet domain name by means of an IP address. The IP2location database is used to match an incoming IP address to the country, region, city, latitude, longitude, zip code, Internet Service Provider (ISP), time zone, network speed and domain name of the Internet user. Octoshape merely provides an interface to this database. Octoshape believes that the geolocation system they are using provides excellent accuracy and security. In the many years that they have been using this system, no difficulties have been experienced whatsoever. If necessary, the Octoshape system would be able to interface to any other geolocation system including Akamai or Quova if required. Members agreed that EBUP2P should meet the highest level of geolocation performance and security as required.

In the case when geofiltering is applied, copyrighted content is only available within the copyrighted zone, whereas outside this zone a message board should be displayed on the screen. The text on the message board may say the following:

> ***"Due to copyright restrictions, the currently broadcast programme is only available within the authorized zone. Your location lies outside this zone, therefore at the moment you have no access to the content. We apologize for any inconvenience."***

Preferably the above message is shown in the national language and in English; other languages may be added of course. Geofiltering can only be applied to video, while leaving the audio available.

The scheduling of geofiltering could be two-fold: [a] pre-scheduled (pre-determined start and end times) or [b] flexible (time stamps or manual activation of geofiltering).

7. The lower limit of 200 kbit/s has been increased to 350 kbit/s to improve the lower quality limit.

Rights management

Digital Rights Management (DRM) was not tested: it is independent of the P2P system in use.

Pre-roll advertising

A pre-roll system is an example of a business model in which the end user receives all video and audio streams for free. For the testing of EBUP2P, Hessischer Rundfunk used a 5s pre-roll service. Octoshape confirmed that they were able to provide a pre-roll advertising technology which is very similar to the Zattoo one. However, if pre-roll is to be used for an operational service, several related open questions apply:

- Who provides the pre-roll ad content?
- Should the ad content be adapted to the destination market?
- Is the ad content both channel- and zone-specific (leading to different pre-rolls for different markets)?

Preliminary conclusions

The principal conclusions of this trial can be summarized as follows:

- EBUP2P represents a state-of-the-art technical solution and fulfils all the tested technical and operational requirements – in terms of the service quality, scalability, video and audio quality, accessibility, security and user-friendliness.
- EBUP2P has no technical limitations regarding the number of radio and TV channels to be accommodated in a Portal. Members can flexibly join in and opt out at any time.
- EBUP2P can fulfil our requirements concerning copyright, by applying territorial filtering (geolocation) and watermarking.
- EBUP2P enables a number of business models.
- EBUP2P is future proof and will be extended towards CE (consumer electronics) devices.

In spite of the very limited human and financial resources available for conducting the EBU P2P Media Portal trial, we brought the trial to a successful end, according to the schedule planned. The participants in the trial performed a large number of technical and operational tests.

Franc Kozamernik graduated from the Faculty of Electrotechnical Engineering, University of Ljubljana, Slovenia, in 1972.

He started his professional career as an R&D engineer at Radio-Television Slovenia. Since 1985, he has been with the EBU Technical Department and has been involved in a variety of engineering activities covering satellite broadcasting, frequency spectrum planning, digital audio broadcasting, audio source coding and the RF aspects of various audio and video broadcasting system developments, such as Digital Video Broadcasting (DVB) and Digital Audio Broadcasting (DAB).

During his years at the EBU, Mr Kozamernik has coordinated the Internet-related technical studies carried out by B/BMW (Broadcast of Multimedia on the Web) and contributed technical studies to the I/OLS (On-Line Services) Group. Currently, he is the coordinator of several EBU R&D project groups including B/AIM (Audio in Multimedia), B/VIM (Video in Multimedia) and B/SYN (Synergies of Broadcast and Telecom Systems and Services). He also coordinates EBU Focus Groups on Broadband Television (B/BTV) and MultiChannel Audio Transmission (B/MCAT). Franc Kozamernik has represented the EBU in several collaborative projects and international bodies, and has contributed a large number of articles to the technical press and presented several papers at international conferences.

The number of participating EBU organizations was restricted to about ten. We could not accept more participants, as our logistic resources are so limited. Also the number of end users were quite modest, as we did not carry out any significant promotion of the portal.

These EBU tests cannot be considered rigorous scientific tests. They were more akin to "proof of concept" and "experience-gathering" evaluations. Octoshape is not the only commercial P2P system available in the market but we selected it because our previous experience with this system was positive.

The main conclusion of the trial is that Octoshape is an excellent Internet distribution system for carrying audio and video streams to PC users. The system is scalable, reliable, easy to manage and interoperable with a number of codecs, operating systems, browsers and geolocation systems. In the course of the project a large number of issues were successfully resolved, although several issues were left open for future activities *(see the next section)*.

The P2P Media Trial has shown that Octoshape can be used by our Members as a viable and technically appropriate system for the distribution of audio and video streams across the Internet. It can be used either as a standalone distribution system or in combination with some CDN or IP Multicasting technologies.

Required future work

Running a Media Portal is a complex issue and technologies evolve very rapidly. It is not enough to show that the P2P distribution system functions correctly and according to our expectations. For a possible future commercial portal, the following additional issues may also be considered:

- Watermarking (and Fingerprinting) – optionally embed audio watermarking signals to detect the originator of the content (if required);
- Allow for both customized media players (which open in a separate page) and embedded players;
- Optionally embed DRM in the stream (if required to control consumption of the media received) [8];
- Develop an XML-based template for EPGs and optionally provide an EPG (daily, weekly) for each channel;
- Provide additional coverage of special events (if required);
- Extension of portal services to embrace content downloading and VoD (on-demand) services (documentaries, archives, recorded sports events, etc);
- Hybrid TV receivers with broadband (Ethernet or Wi-Fi) connection: embedded P2P client in commercial TV sets and set-top boxes (such as in DVB);

Acknowledgements

The EBU would like to thank all participants for their very kind cooperation in this field trial. Particular thanks should go to the Octoshape staff – Stephen Alstrup, Theis Rauhe and Lasse Riis – for their fast and efficient resolution of all problems that may have arisen during the tests. Many thanks also go to Nathalie Cullen from the EBU Communication Service for the attractive and functional web design of the portal. And last (but not least), thanks should also go to the EBU management for providing continuous support and encouragement for conducting this project.

8. Participants will be able to apply different DRM (digital rights management) tools in order to protect their content.

Miro — open and decentralized Internet TV

Dean Jansen
Participatory Culture Foundation

Miro is a free, open-source platform for Internet TV. Ideal for high-definition video, it features an open content guide with over 5,000 channels that can be freely subscribed to. The application boasts nearly 500,000 users and has been downloaded more than three million times in the last year.

Miro has been compared to Tivo, Firefox and iTunes; it functions as both a video library and a very intuitive system for subscribing to and watching internet video channels. Additionally, Miro can search and save videos from video-sharing sites, such as YouTube and Daily Motion.

For public broadcasters, Miro (**http://getmiro.com**) offers a distribution platform that is perfect for moving high-quality, long-form video to a large, non-technical audience. The user-friendly integration of ***BitTorrent*** in Miro lets publishers leverage the scalability and low cost of P2P distribution without confusing non-technical users. Public broadcasters can create custom versions of Miro that feature their own content and their own brand. Furthermore, Miro is open source and cross-platform, leaving broadcasters and their audience independent of any proprietary software (Adobe Flash, Apple iTunes) or operating system (Miro can run on Mac, Windows and Linux).

Miro's user base and content guide are both expanding rapidly. The application itself is on a tight development curve, releasing major updates and improvements five to seven times per year. Miro is being developed by the Participatory Culture Foundation (PCF), a US.based 501c3 non-profit organization. The PCF's mission is to make television more open and democratic as it moves online.

Thousands of channels ... exciting partnerships

Miro has a content guide that is integrated into the application itself, which is also accessible from the web browser (**http://miroguide.com**). The guide is home to more than 4,500 RSS video channels on every topic from space telescopes, to French food, to sketch comedy. All the channels are free to subscribe to, and many of them are in crisp high-definition. Because the guide is open to nearly all content (pornographic content and unapproved copyrighted material withstanding), it is constantly expanding.

The Miro Guide aggregates content from a massive variety of professional, semi-professional, and amateur video producers. Public broadcasters such as PBS, NRK, NDR and Deutsche Welle sit side-by-side with content from commercial players such as HBO, Discovery Channel, CBS, NBC, ABC and many more. Miro also showcases material from new internet video networks such as

Typical Miro content guide

Revision3 and Next New Networks, which produce original programmes, such as *Diggnation* and *Indy Mogul*. Also in the mix are amazing independent creators, such as Democracy Now!, plus countless individual and amateur producers.

Miro helps users find video they like using a star rating system coupled with a channel recommendation system. When users rate channels that they do or don't like, Miro can give recommendations based on how other users have rated similar channels. This helps users find the best channels to subscribe to, in light of having so many to pick from.

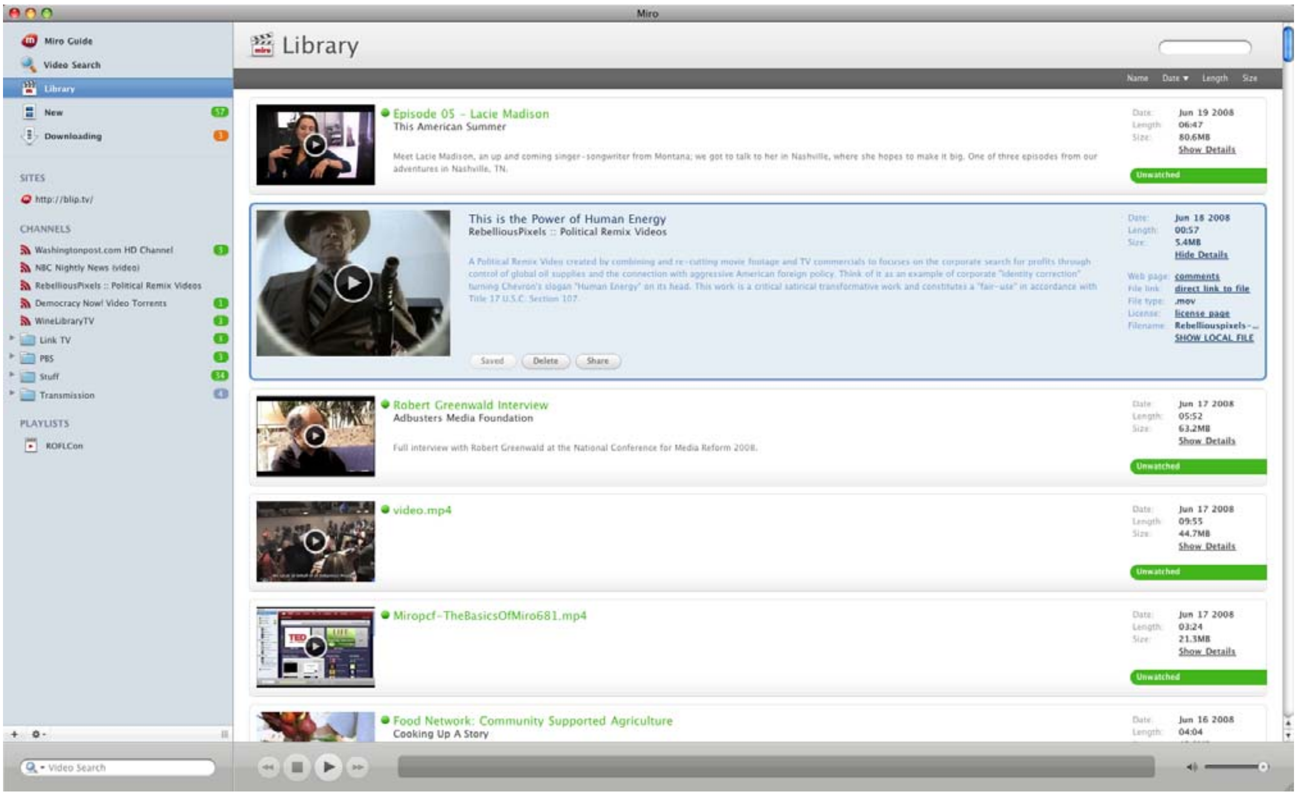
Additionally, Miro is completely open and is very resistant to gatekeeping. Because the RSS channels are an open standard, users can easily bring channels into the application from anywhere on the internet. This also means that a channel that works in Miro will work in any other application that can read standard RSS feeds. Furthermore, new channel guides (which are simply web pages) can easily be added to the Miro interface at any time. Miro is in a unique position to be the most neutral and open space for online video aggregation, which is exactly what viewers and broadcasters need.

Play anything + HD = happy viewers

Pretty much all video, whether it's on YouTube, blip.tv, or a creator's own website, is accessible using Miro. The two most common ways to interact with video are subscribing to channels (Media RSS feeds) or searching video-sharing sites.

Once an RSS channel has been added from a content guide or an external URL, the user has access to all the media already present in the channel, plus Miro will automatically download new videos, as they are released. After videos are watched, they are marked for automatic deletion and will be erased from the hard drive to free up space for new content, unless the user chooses otherwise.

Video searching is simple and, by default, spans a wide variety of sharing sites and hosting services, such as YouTube, Revver, and blip.tv. A single search will automatically bring in results from all services, and the user is able to choose which videos to download and save. Furthermore, the search query can be saved and added to the Miro sidebar alongside other channels – from then on,



Example of a user's library in Miro

whenever new videos on the search topic become available they will automatically be downloaded to the user's library.

With content coming from all directions, it's vital that Miro can play back nearly every format out there, and it does. So whether it's Flash video, Windows Media, QuickTime or something more esoteric, Miro can probably play it back. This is critically important from a usability standpoint, because no one likes to be told they need to download an extra component to view a video, or worse yet, to be barred from watching at all.

Because Miro downloads the files in advance, it is perfect for the highest definition video out there. High-definition goes hand-in-hand with long-form video – no one likes squinting at a tiny embedded video, but they don't mind leaning back for a nice full-screen HD experience. Miro can make this happen without jitter, over-pixelation or loss in quality (on a reasonably modern machine).

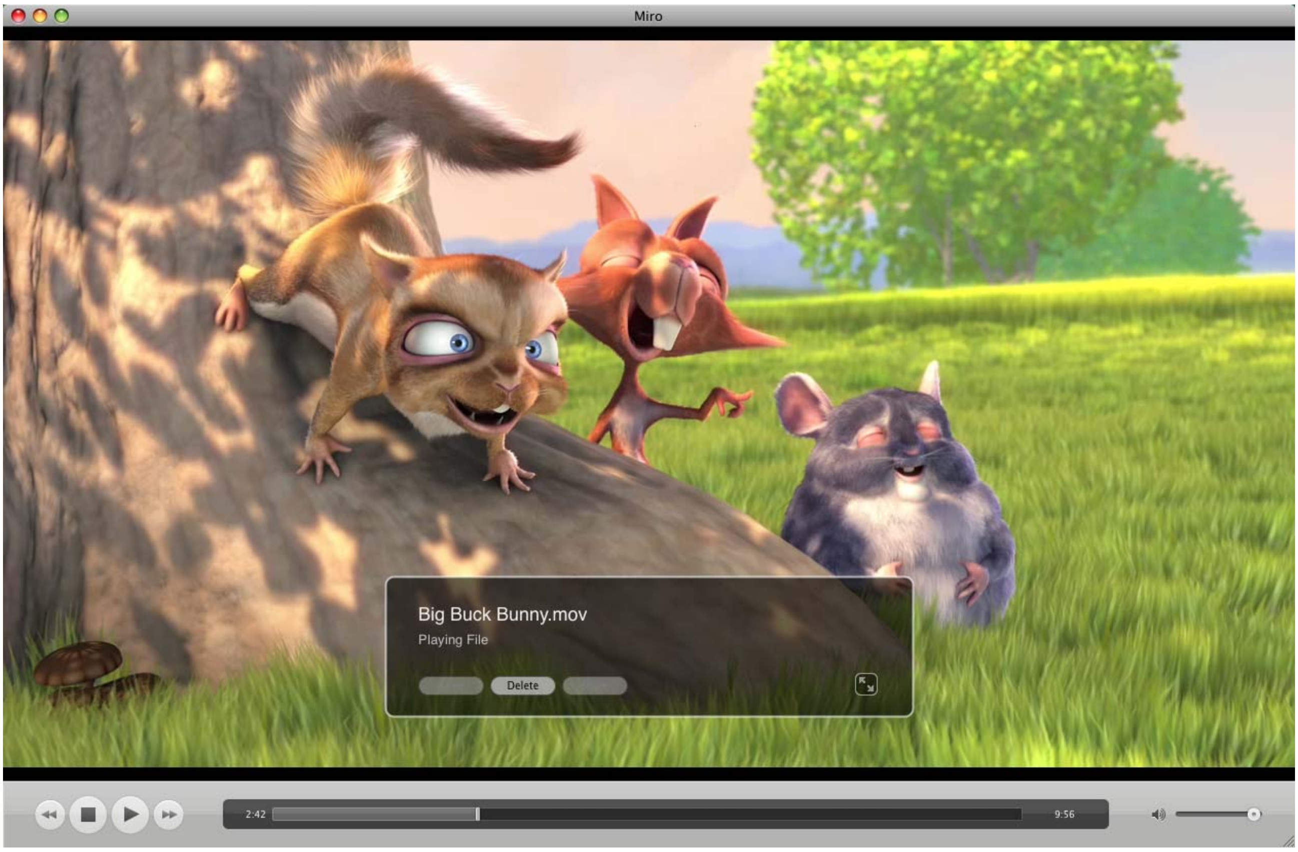
Cutting bandwidth bills while delivering HD video

Serving up high-definition video to hundreds of thousands of users isn't cheap, unless you're using peer-to-peer distribution. BitTorrent is an open protocol that distributes the bandwidth load amongst users, as opposed to having all viewers coming directly to the publisher. This means that massive files can be distributed to very large audiences at shockingly low cost.

BitTorrent has historically been a difficult to use technology, requiring external applications and separate video players. Miro has changed all that, and is quite the simplest way to consume media over BitTorrent. In fact, most users don't even know they're getting video over BitTorrent when they use Miro – the experience is nearly identical to the normal video-watching experience.

NRK's use of Miro and BitTorrent: a mini case-study

Norway's public broadcaster, NRK, saved thousands of dollars when they distributed their full-resolution high-definition series, *Nordkalotten 365* using Miro and BitTorrent. Although their viewers



Example of HD playback in Miro

were able to use alternative clients for downloading the series, NRK recommended Miro as the easiest and simplest way to subscribe to the show. As a result, they drew a massive audience and logged an estimated 90,000 full downloads in a two month period.

The 29-minute episodes were in full resolution HD, thus generating very heavy traffic yet, because they were being served via the BitTorrent protocol, the vast bulk of the bandwidth was shared amongst viewers. NRK's total bandwidth bill for the two-month / 90,000-download period was under $300 total. Had NRK opted for direct downloads, the bill would have been closer to $8,000 for the same amount of bandwidth.

Because the distribution was spread across thousands of users, which compounds the upload speed, NRK reported that viewers were getting incredibly short download times for the huge video files. This speed and ease of use, combined with the beautiful HD pictures, made the project a big win for NRK viewers. As a result of the positive experience, NRK has released subsequent series using Miro and BitTorrent. They are currently working to license even more of their content for open distribution over Miro.

Open platforms vs. closed gateways

Many networks and video services are fighting an intense and gritty battle – they all want to attract the largest viewing audience to their content, site or services. Furthermore, many of the players have chosen centralised websites and applications for their online video strategy, which creates the potential for gateways and control over the audience.

The stakes in "Open vs. Closed" are incredibly high. As we see with YouTube – which has a firm (and increasing) grip on the world's largest video-viewing audience – a single actor can dominate when there is no open foundation for content to live on. YouTube's success is mostly due to the sheer network effect of having millions of users watching and uploading video on a platform that doesn't interoperate particularly well with competing services.

Sites and services can be regarded as “closed platforms” in a variety of ways: from who is able to publish video on it, to how users share and access video – these attributes dictate how open a site is. Openness can be summed up as the degree of standards-based interoperability that a host maintains with external sites, services and players. Additionally, Adobe’s proprietary Flash player (the de-facto standard for viewing web video), further complicates the openness of a given web video solution.

The important point here is that as long as video is closed (read: less interoperable and less standard), viewers will naturally gravitate towards a small number of dominant video websites or services. This, in turn, provides an incentive for content creators to publish to these popular websites, which attracts even more viewers. This cycle is a symptom of having closed or proprietary systems, and these are most vulnerable to gatekeeping.

In a closed world, there are a relatively small number of big winners who control access to the majority of the consumers, something more like traditional television than the internet, as we know it today. As a result, those who don’t happen to have a controlling stake in the winning service(s) must make deals with the winners, in order to access the most substantial audience.

The choices broadcasters are making now, in terms of online content distribution, will have a real impact on the future of mass media. As long as openness prevails, audiences will be more accessible in a democratic and meritocratic fashion. Good content, as opposed to connections with whoever happens to control the winning video service(s), will become the basis for attracting viewing audiences.

Openness promotes variety and attracts viewers

The good news is that consumers love openness, and when given the choice they will flock to it. In the early 90s, consumers chose the open internet in favour of closed alternatives, such as Compuserve, Prodigy and AOL. This was largely because of the decentralisation; the variety and amount of content on the open internet vastly outweighed what the closed networks could offer. This same principle holds true for video, and Miro plays a key role in advancing the state of openness and interoperability of mass media as it moves online.

While gatekeeping won’t be an issue in a more open future, brand recognition and position in the marketplace will be. Being an early mover in the open video ecosystem will confer many benefits, including a head start in market-share, a competitive advantage in brand recognition and a quicker uptake in niche markets. One huge advantage is that open media generally spreads exponentially faster than its closed counterpart. Audiences can be reached more fluidly, and as a result your brand, content and messages can literally go further.

Miro is Open Source and promotes Open Standards

Miro is open source software, which means the underlying code used to build the program is available for anyone to view, use and modify. This is important for interoperability and customisation, because it makes the software much more flexible and viral. For example, if a hardware manufacturer wants to include Miro as software on a set-top box, he doesn’t need to ask for permission or make a bargain – he can just go ahead and make the alterations, improvements or extensions.

Open source software has been around for decades and is very mature; in fact, open source powers most of the servers that make up the internet. Additionally, a number of very successful, high profile projects, such as Firefox and Linux are open source.

In addition to being open source, Miro promotes open standards and interoperability. Every channel you see in Miro has adopted the RSS standard, and the larger Miro grows, the greater will be the pressure on video hosts to add the feature. Because RSS is an open standard, interoperability (without permission) can happen. It is precisely this openness and interoperability that makes the internet such a vibrant, decentralised and exciting space. Furthermore, when media is enclosed in RSS, it becomes easier to index, search and discover.

The promise of Digital Rights Management

Digital Rights Management (DRM) is a form of digital lock meant to prescribe exactly how each consumer is able to access each file. The actual methods of control can vary greatly, from preventing copying and playing across different machines to automatic deletion after viewing. While DRM may sound like a great way to protect media online, it is actually terrible for the consumer and is ultimately a bad deal for the producer too.

A consumer who purchases media with DRM is getting an inferior product that will only be playable on compatible machines. Think of playable only on an iPod or Zune (Microsoft's iPod competitor), but never both, because the two companies have competing DRM schemes. It is exactly this lock-in with DRM that gets producers and content owners into trouble. When a media owner invests in a particular DRM platform, they become beholden to the owner of the technology (as do their customers). The music industry faced this problem with Apple and iTunes, and after realising the extent of Apple's influence, they began offering DRM-free music at places such as Amazon.com.

Another argument against DRM is that it doesn't work very well; for every protected piece of media, there are thousands of unprotected equivalents. DRM doesn't stop most pirates, who are already planning on downloading the non-DRM files. However, honest and paying customers are punished by DRM. Using the Apple iTunes store example: the buyer can ONLY listen to the music they bought on a very limited number of peripheral devices and computers. Those who download the same music illegally get a superior product that can be played on any type of mp3 player, on any computer, at a friend's house, etc. The iTunes example also holds true for video and other forms of media. DRM, while it may sound good, is really an anti-competitive, backwards technology that hurts content creators and consumers alike.

Miro is yours

When deciding how to distribute video online, certain broadcasters assume they face a build-it, or buy-it proposition. For instance, the BBC, when developing their custom iPlayer software, spent tens of millions of dollars to develop a proprietary player that only functioned on the Windows operating system, thus providing a poor user experience. In the end, the iPlayer flopped and the BBC had to spend even more money to reformulate their online video plan.

Building a website to provide access to a limited selection of content can also be risky, most notably when it doesn't interoperate with popular sites and services. Viewers will always gravitate towards sites and services where they can get more content; thus the potential for interoperability, aggregation and search indexing all become very important.

Dean Jansen is Outreach Director for the Participatory Culture Foundation. His work at PCF is very varied and includes: travelling, speaking, designing, project managing, blogging, advocating and fundraising among many other things.

Along with his work on Miro, Mr Jansen is a leader in the Free Culture movement, which is organized as grassroots chapters at universities across the USA and abroad. The mission of Free Culture is to spread awareness and create discourse around issues affecting our ability to create, repurpose, use and participate in digital culture and information. He is a core contributor and front-end designer for YouTomb.mit.edu, which is an MIT Free Culture project that scans YouTube for videos that have been taken down due to alleged copyright violation or other reasons.

Broadcasters turning to proprietary video distribution systems may find themselves locked into particular vendors who don't provide access to any of the underlying technology. With Miro, there is no possibility for lock-in and the potential flexibility is unlimited, since the code is freely available and modifiable by any person or organization. This open base is a big reason why Miro is so attractive to content owners that prefer to remain independent from big players like Apple, Google and Microsoft.

Miro can be customized

Miro offers simple co-branded versions of the software to broadcasters and other content creators. The custom player gives viewers the great experience of the original, plus it puts a strong focus on the partner's content and brand. A custom Miro player includes all of a partner's channels pre-subscribed, along with a custom channel guide, name and application icon.

Because the custom versions of Miro are built on the same base as the default software, they offer all the usual benefits: access to a huge open ecosystem of content, full-screen and HD playback, the ability to organize and search video from all over the internet, and so on. Additionally, custom versions of Miro will be automatically updated, right along with the vanilla software.

Who is partnered with Miro?

Miro has partnered with a number of players in both the commercial and non-commercial sectors. A large handful of public broadcasters, including PBS (USA), NDR (Germany), NRK (Norway) and Deutsche Welle (Germany), have already released or are currently negotiating co-branded players. Miro teamed up with the Technology, Entertainment and Design (TED) Conference to produce a custom version of the player that was handed out on USB thumb drives at the 2008 TED Conference in Monterey, California. Miro has also worked with Revision3, a new Venture Capital-funded internet TV network that produces fifteen original series, most of which are available in high-definition. The Revision3-branded player includes all of the Revision3 channels, a unique application icon and a totally customized content guide.

Who makes Miro

The application is developed by the Participatory Culture Foundation (PCF), a 501c3 non-profit organization based in Worcester, Massachusetts, USA. The PCF's mission is to create a more decentralized and vibrant ecosystem for television as it moves online. The twelve-employee non-profit foundation is going head-to-head with big players such as Apple, Comcast and Joost. Each commercial player has its own vision for the future of online TV, and all of these competing visions are far more closed and susceptible to gatekeeping and tolls. Miro takes some of what makes the internet truly democratic and open ... and translates it to easily-accessible online video.

HDTV production codec tests

Massimo Visca (RAI) [1] and Hans Hoffmann (EBU)
EBU Project Group P/HDTP

To address the need for more efficient HDTV studio compression systems, vendors have recently introduced new HDTV studio codecs. In 2007, an EBU project group investigated these codecs and this article describes the methodology used for the tests and summarizes the results obtained.

The introduction of HDTV in Europe requires that broadcasters renew their production equipment. Whilst HDTV equipment in the past has targeted tape-based solutions, the user requirements for modern HDTV production workflows are file-based, non-linear and non-real-time – with shared access via networks and servers – and, last but not least, they have to be cost-effective. These requirements put challenges on the video compression format applied in mainstream HDTV production equipment – particularly on the trade-off between the data rate and video-quality head-room.

To meet these requirements, the industry has offered several codec solutions for mainstream HDTV production and the EBU decided to test these codecs in its P/HDTP (High Definition Television Production) project group. New codecs were provided for these tests by:

- AVID (DNxHD);
- GVG/Thomson (Infinity J2K);
- Panasonic (AVC-I);
- Sony (XDCAM HD422).

Existing legacy systems were also included in the evaluations in order to gather an understanding of the improvements achieved by new technology over legacy systems.

All tests on the new codecs were performed with each of the vendor's products individually (i.e. non-comparative tests) and the test plan and the results obtained were discussed between the EBU project group and the individual vendors.

The tests were carried out between spring and August 2007 and were conducted by several key EBU Members of the P/HDTP project. The AVID tests were performed by the IRT (Germany), the GVG/Thomson and Sony tests by the RAI (Italy), and the Panasonic tests by the EBU (Switzerland) with the assistance of RTVE (Spain). A representative of the vendor concerned was present at each test and at the subsequent expert viewing sessions.

1. Massimo Visca acted as project coordinator and team leader for the codec tests.

1. Scope of the tests

The EBU codec tests focused on the image quality which the individual compression algorithm would provide after multi-generation processing. This codec performance is certainly only a part of the overall equipment performance of a recorder/server or camcorder device, camera, etc. But, in particular for HDTV with its inherent demand for high quality images, it is a very important parameter. The multi-generation codec assessment – by means of introducing pixel shifts after each generation – simulates how the production chain affects the images as a result of multi-compression and decompression stages.

For SDTV, the agreed method of multi-generation testing was to visually compare the 1st, 4th and 7th generations (including pixel shifts after each generation) with the original image under defined conditions (reference video monitor, particular viewing environment settings, and expert viewers). The same method was adapted to the current HDTV codec tests. In addition, an objective measurement – the PSNR – was calculated to give some general trend indication of the multi-generation performance of the individual codecs.

2. Algorithms under test

The framework of the tests was aimed at investigating the performance of practically all the HDTV compression algorithms available on the market or under development in the manufacturers' laboratories. The test plan included both the so-called "Legacy" algorithms, applied in the most widely used systems since the start of HDTV production, and the "New" algorithms that were planned for market launch in the shorter term at the time of testing: some of these, at the time of writing this article, are now commercially available.

2.1. *"Legacy" algorithms*

The main features of the video compression algorithms employed in the "Legacy" equipment are summarized in *Table 1*.

Table 1
Video compression algorithms employed in the "Legacy" equipment

	Video Bitrate (Mbit/s)	Bit depth	Subsampling	Compression	Format	SMPTE standard
HDCAM	116.64	8	1440 Y 480 C_b/C_r	DCT based (Intra)	1080i/25 1080p/25	SMPTE 367M-368M
DVCPRO	100	8	1440 Y 480 C_b/C_r	DV based (Intra)	1080i/25 1080p/25	SMPTE 370M-371M
	100	8	960 Y 480 C_b/C_r	DV based	720p/50	
HDCAM-SR	≈440	10	NO	MPEG-4 SP (Intra)	1080i/25 1080p/25 720p/50	SMPTE 409-2005
XDCAM@35	35	8	1440 Y 720 C_b/C_r 4:2:0	MPEG-2 (GoP)	1080i/25 1080p/25	-

2.2. “New” algorithms

The new HDTV systems – AVID (DNxHD), GVG/Thomson (Infinity J2K), Panasonic (AVC-I) and Sony (XDCAM HD422) in alphabetical order – employ a wide range of compression algorithms, differing both in terms of bitrate and in the mathematical tools used to perform the compression itself.

It should be noted that this article provides only the information about these algorithms that is necessary for a general understanding of their functioning. The following Tables provide some basic information (bitrate, bit depth, etc.) but, for a complete understanding, the reader should refer to the bibliography and to any official information provided by the manufacturers. Moreover, it is worth underlining that whilst these parameters provide some objective information about the system resources (e.g. the bitrate vs. storage capacity and network bandwidth), their correlation with the available picture quality is much more difficult, if not impossible, to determine from them. This is the reason for the large effort expended by the P/HDTP group in testing real implementations of the algorithms.

2.2.1. AVID (DNxHD)

Table 2
AVID DNxHD video compression codec parameters

Name	Video Bitrate (Mbit/s)	Bit depth	Subsampling	Compression	Format	SMPTE standard
DNxHD	120	8	NO	DCT based (Intra)	1080i/25 1080p/25	SMPTE VC-3
	115	8	NO	DCT based (Intra)	720p/50	SMPTE VC-3
DNxHD	185	8	NO	DCT based (Intra)	1080i/25 1080p/25	SMPTE VC-3
	175	8	NO	DCT based (Intra)	720p/50	SMPTE VC-3
DNxHD	185	10	NO	DCT based (Intra)	1080i/25 1080p/25	SMPTE VC-3
	175	10	NO	DCT based (Intra)	720p/50	SMPTE VC-3

2.2.2. GVG/Thomson (Infinity J2K)

Table 3
GVG/Thomson video compression codec parameters

Name	Video bitrate (Mbit/s)	Bit depth	Subsampling	Compression	Format	Compression standard
Infinity	50	10	NO	Wavelet based (Intra)	1080i/25 1080p/25 720p/50	JPEG2000
Infinity	75	10	NO	Wavelet based (Intra)	1080i/25 1080p/25 720p/50	JPEG2000
Infinity	100	10	NO	Wavelet based (Intra)	1080i/25 1080p/25 720p/50	JPEG2000

2.2.3. Panasonic (AVC-I)

Table 4
Panasonic AVC-I video compression codec parameters

Name	Video bitrate (Mbit/s)	Bit depth	Subsampling	Compression	Format	Compression standard
AVC-I	54.272	10	1440 Y 720 C_b/C_r 4:2:0	AVC (Intra)	1080i/25 1080p/25	High 10 Intra Profile
	54.067	10	960 Y 480 C_b/C_r 4:2:0	AVC (Intra)	720p/50	High 10 Intra Profile
AVC-I	111.820	10	NO	AVC (Intra)	1080i/25 1080p/25	High 4:2:2 Intra Profile
	111.616	10	NO	AVC (Intra)	720p/50	High 4:2:2 Intra Profile

2.2.4. Sony (XDCAM HD422)

This algorithm employs a Long GoP (Group of Pictures) with L=12 and M=3, i.e. the GoP structure is IBBPBBPBBPBBI. This feature has some important implications on the testing of multi-generation performance, as described in detail in paragraph 3.2.3.

Table 5
Sony MPEG-2 Video Compression codec parameters

Name	Video bitrate (Mbit/s)	Bit depth	Subsampling	Compression	Format	SMPTE standard
XDCAM HD50	50	8	NO	MPEG-2 GoP L=12 M=3	1080i/25 1080p/25 720p/50	-

3. Methodology

In order to evaluate the performance of the different HDTV algorithms in a production environment, the very classical approach of the multi-generation (cascading) test was used. This method has been extensively used in all EBU tests since the introduction of compression algorithms in the SDTV production environment, starting from Digital Betacam up to the more recent IMX and DVCPRO systems. It is considered by the broadcast community to be a reliable methodology which is able to provide repeatable and stable results for easy interpretation.

The method is simply based on the performance of different compression-decompression steps using the algorithm under test, in order to simulate the cumulative effect of the artefacts introduced by the compression algorithm on the picture quality.

This method was originally devised to stress traditional tape-based equipment, where each copy implied a decompression and compression step. It could perhaps be considered as not fully reflecting the workflow of a future IT production-based infrastructure, where the necessity to perform a cascading of compression could be reduced. Nevertheless, considering that in the present production scenario, cascading is still a common process, the method allows the evaluation of the so-called "quality headroom" in the system. There is a good knowledge base in the evaluation of results using this method of assessment and it was agreed to continue to use it for analysis of the performance of compression algorithms implemented in the HDTV equipment under test.

3.1. Selection and shooting of test sequences

The selection of the test sequences to be used in any test is always a very critical issue; even ITU-R Rec. BT.500 – the most important reference document, containing all the procedures for picture quality evaluation based on subjective assessment – provides only a simple guideline, stating that the sequences have to be "critical, but not unduly so". Obviously, a "biased" selection of test sequences can be used to "drive" the test. The only way to solve this problem is to select a very large amount of material, in order to include sequences that cover all the possible features in terms of:

- high-frequency content (details), motion portrayal, colorimetric, contrast, etc.;
- indoor and outdoor shooting;
- different kinds of content, i.e. natural and artificial objects, texture, skin tones, etc.

Moreover, it is better if at least a subset of the test material is brand new, in order to avoid any kind of "optimization" of the new compression algorithm using familiar sequences.

As such a library was not available at the time of testing, it was necessary to shoot brand new sequences. The shooting was performed using state-of-the-art technology (Canon FJS Series prime lens, Sony HDC 1500 camera and uncompressed storage on a DVS server via HD-SDI). The result was a large portfolio of test sequences, each of 10s duration, satisfying the above-mentioned criteria.

All the sequences were shot in different formats – i.e. 1080p/50, 1080i/25, 1080p/25 (with and without shutter) and 720p/50 – making the best effort in order to guarantee the same conditions of lighting and exposure.

Note: The 1080p/50 sequences were down-converted to obtain 1080i/25 or 720p/50 versions; they were therefore not directly used in these tests but they will provide a library that is available for future needs, such as the comparative test of the present 1.5 Gbit/s scenario with the future 3 Gbit/s.

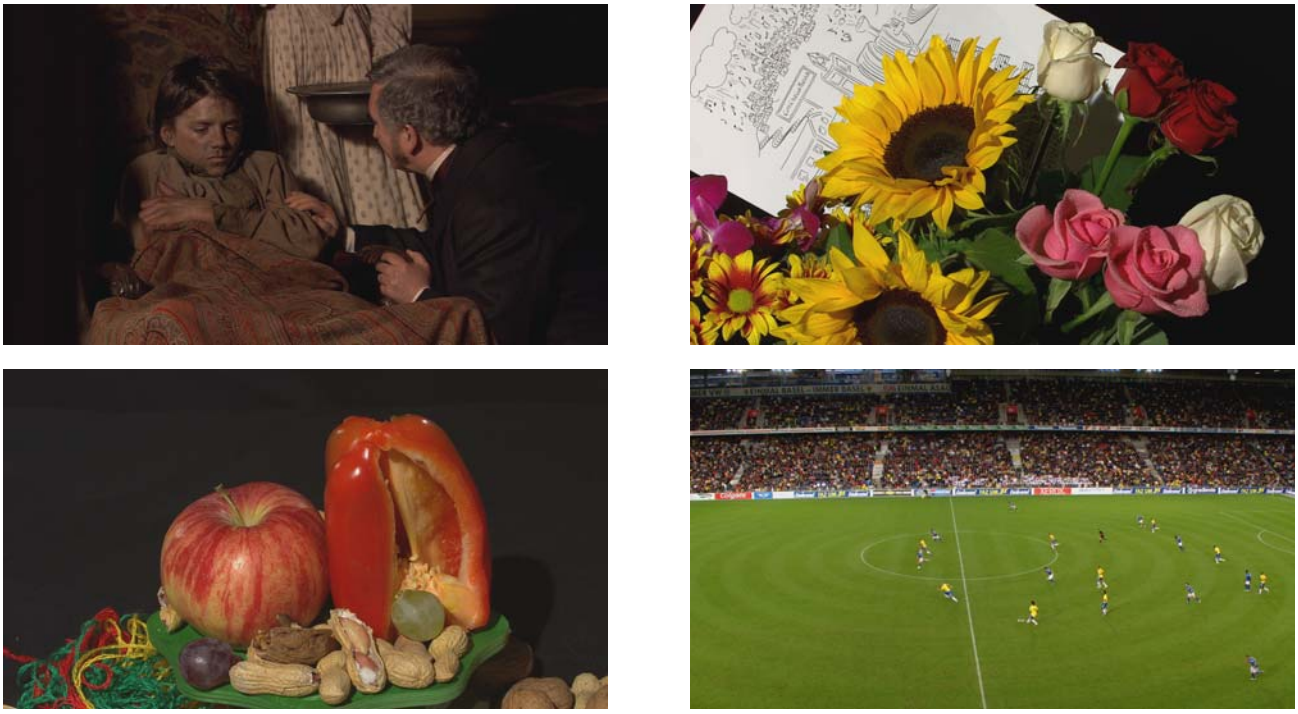


Figure 1
Still shots captured from four of the test sequences used

Some sequences were singled out from material originally shot in one single HDTV format only. Other sequences were converted from film, or from rendered graphics or even taken from the archive in PAL format. All these sequences were converted into the three HDTV formats included in the tests to obtain an even larger portfolio of 10s-long test sequences.

Note: All the technical details (equipment, software, etc.) relevant to the conversion process are available from the authors, upon request.

For the 1080i/25 and 720p/50 formats, fourteen 10s-long test sequences were concatenated one after the other (no gray or black frames included) to form a single clip.

For the 1080p/25 (shutter on) formats, only eight 10s long test sequences were then concatenated to form a single clip.

The total amount of test material employed, its different origins and the criteria of selection, guaranteed the completeness and formal correctness of the tests. Some frames extracted from the sequences are shown in *Fig. 1*.

3.2. Standalone chain

The "standalone chain" comprised a cascading of several compression and decompression processes of the same algorithm; each pair of compression and decompression processes is usually referred to as a single "generation". In order to simulate different production scenarios and to investigate different features of the algorithm under test, the chain may or may not include processing between each generation, as explained below. As already mentioned, each algorithm under test was subjected to a multi-generation process up to the seventh generation.

3.2.1. Standalone chain without processing

The standalone chain without processing simply consisted of several cascaded generations of the codec under test, without any other modifications to the picture content apart from those applied by the codec under test, as summarized in *Fig. 2*.

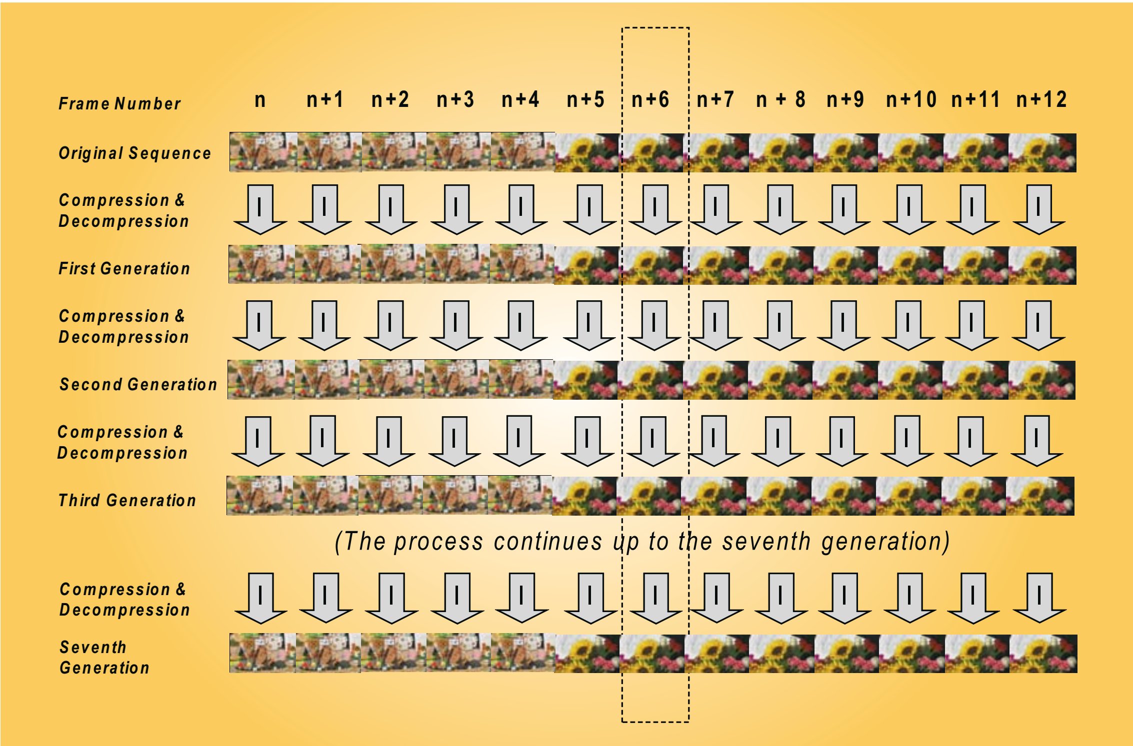


Figure 2
Standalone chain (without spatial shift) for INTRA codec

This process accurately simulates the effect of a simple dubbing of the sequence and is usually not very challenging for the compression algorithm. In fact, the most important impact on the picture quality should be incurred at the first generation, when the encoder has to eliminate some information, but the effect of the subsequent generations should be minimal as the encoder should basically eliminate the same information already deleted in the first compression step. Nevertheless, this simple chain can provide useful information about the performance of the sub-sampling filtering that is applied, or about the precision of the mathematical implementation of the code.

3.2.2. Standalone chain with processing

In a real production chain, several manipulations are applied to the picture to produce the master, such as editing, zoom, NLE and colour correction. Therefore, a realistic simulation has to take into account this issue. As all these processes are currently feasible only in the uncompressed domain, the effect of the processing is simulated by spatially shifting the image horizontally (pixel) or vertically (lines) in between each compression step, as summarized in *Fig. 3*.

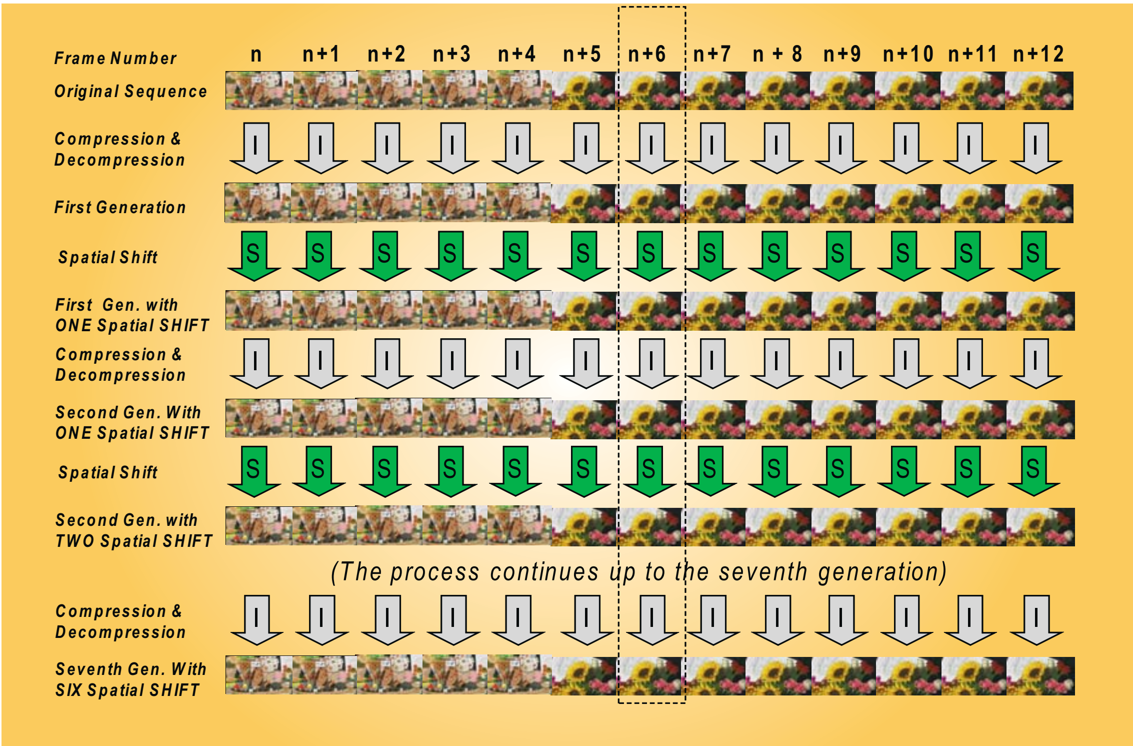


Figure 3
Standalone chain (with spatial shift) for INTRA codec

Obviously, this shift makes the task of the coder more challenging, especially for those algorithms based on a division of the picture into blocks (e.g. NxN DCT block), as in any later generation the content of each block is different to that in the previous generation.

The shifts were applied variously using software or hardware, but the method used was exactly the same for all the algorithms under test. The shifts are summarized in *Table 6* and the process is summarized in *Fig. 4*.

For the horizontal shift (H), a “positive” shift means a shift towards the right, “negative” towards the left. Only even shifts are performed to take into account the chroma subsampling of the 4:2:2 format.

For the vertical shift (V), a “positive” shift means a down shift, “negative” an up shift. The shift is applied on a frame basis and is always an even value. For progressive formats, the whole frame is shifted by a number of lines corresponding to the vertical shift applied, while for interlaced formats

Table 6
Spatial (vertical and horizontal) applied between each generation

Shift between	Spatial Shift
First and second generation	+4H and +4V
Second and third generation	+2V
Third and fourth generation	–2H
Fourth and fifth generation	–2H
Fifth and sixth generation	–2V
Sixth and seventh generation	–4V

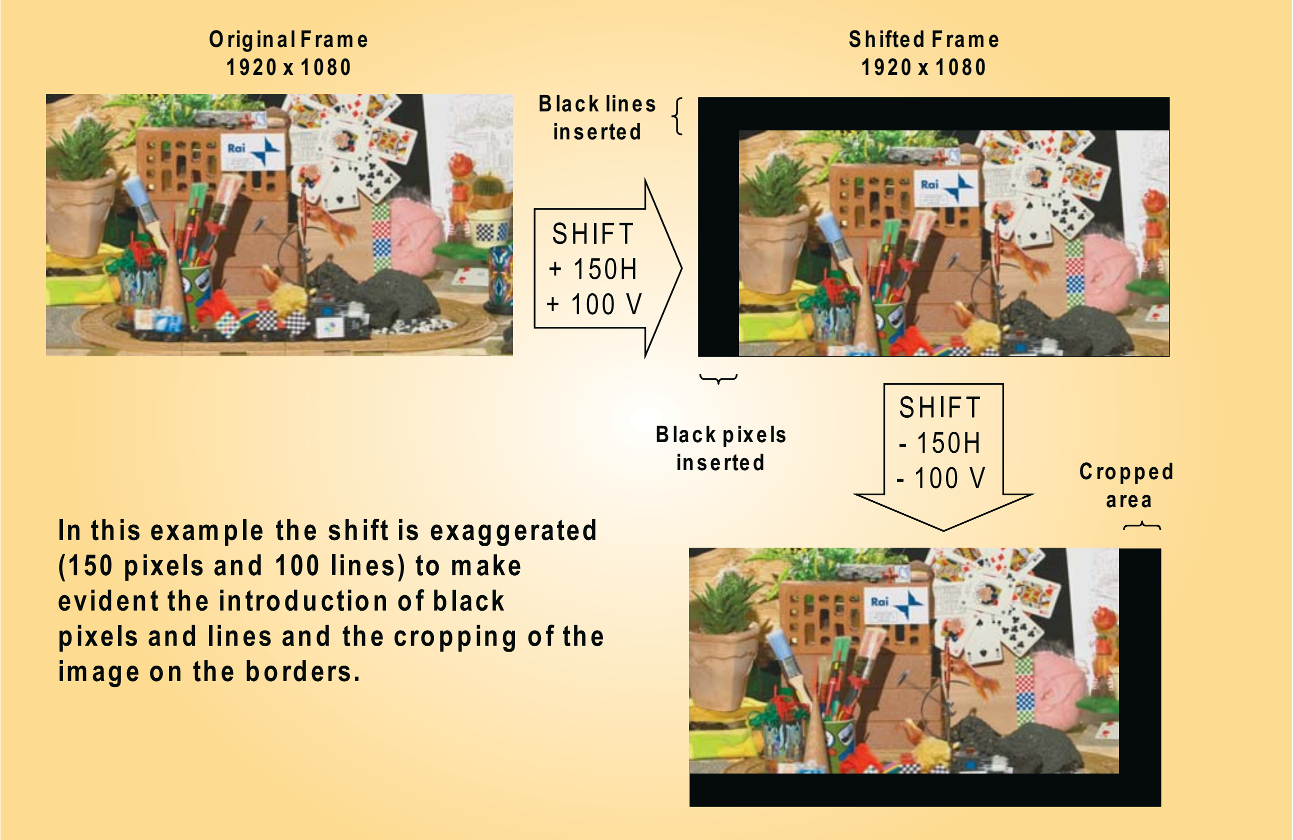


Figure 4
The shift process in the standalone chain

each field is shifted by a number of lines corresponding to half the shift applied. For example, a shift equal to +2V means two lines down for progressive formats and 1 line down for each field of an interlaced format.

The shift process introduces black pixels on the edges of the frame if/when necessary.

3.2.3. Standalone chain for GoP-based algorithms

As shown in *Table 5* (on *page 4*), the XDCAM HD50 system exploits the MPEG-2 motion compensation tools and, in particular, Long GoP coding with L=12 and M=3 (i.e. IBBPBBPBBPBBI); even if each MPEG-2 encoder applies a rather sophisticated strategy to allocate its bitrate resources on the different kinds of pictures, all the MPEG-2 algorithms usually guarantee the best quality for the Intra picture (I), a reduced quality for the Predicted picture (P) and, in the same manner, an even lower quality for the Bidirectional picture (B).

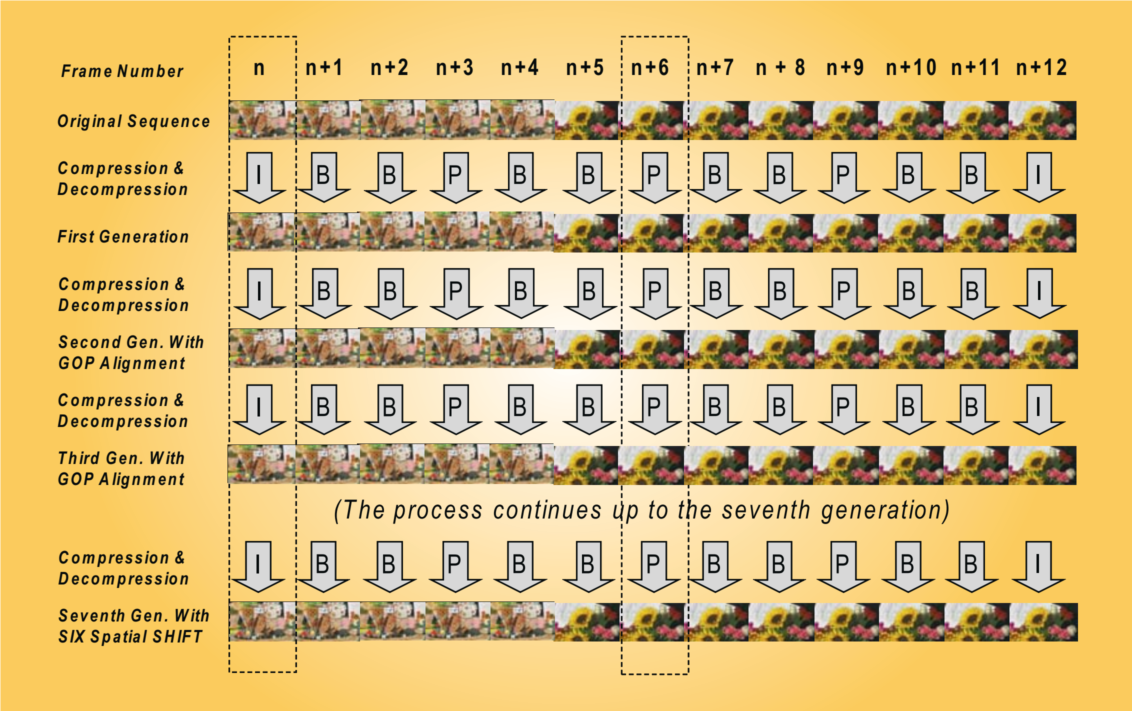


Figure 5
Standalone chain with GoP alignment (without spatial shift) for INTER codec

Therefore, the GoP structure has some important implications on the way the standalone chain has to be realized, and introduces a further variable in the way the multi-generation can be performed – depending on whether the GoP alignment is guaranteed between each generation (GoP aligned) or not (GoP mis-aligned).

As explained in *Fig. 5*, the GoP is considered to be *aligned* if one frame of the original picture that is encoded at the first generation using one of the three possible kinds of frame – Intra, Predicted or Bidirectional – is again encoded using that same kind of frame in all the following generations: for

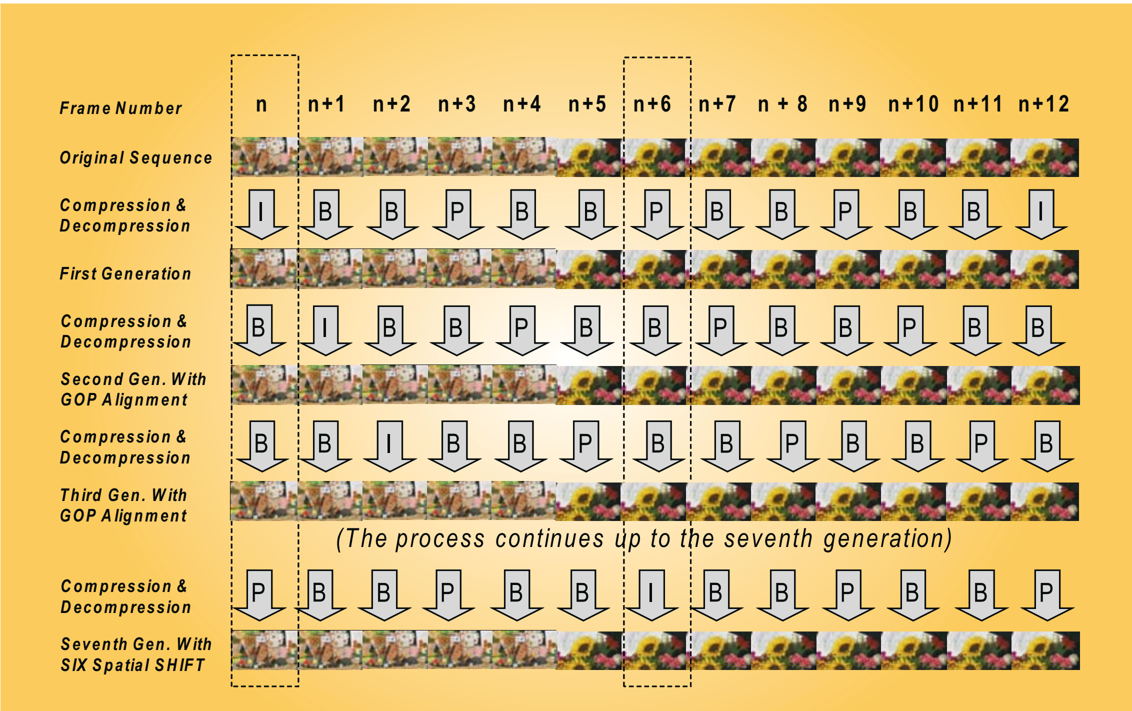


Figure 6
Standalone chain without GOP alignment (without spatial shift) for INTER codec

example, if frame *n* of the original sequence is always encoded as Intra and frame *n*+6 as Predicted. It is therefore possible to have only one multi-generation chain with "GoP alignment".

On the contrary, if this condition is not guaranteed, several conditions of GoP mis-alignment are possible; considering the GoP length L=12, for the second generation 11 different GoP mis-alignments are possible, then for the third generation 11 by 11 and so on, making the testing of all the possible conditions unrealistic. It was therefore agreed to apply one "temporal shift" equal to one frame between each generation, as explained in *Fig. 6*, so that the frame that is encoded in Intra mode in the first generation is encoded in Bidirectional mode in the second generation and, in general, in a different mode for each following generation. It is interesting to underline that the alignment of the GoP in the different generations was under control (not random) and that this was considered the likely worst case as far as the mis-alignment effect is concerned, and was referred to in the documents as "chain without GoP alignment".

Taking into account also the necessity to simulate the effect of manipulation by means of the spatial shift, it was agreed for the GoP-based system (XDCAM HD50) to consider and to realize four different possible standalone chains up to the seventh generation, as follows:

- Multigeneration chain with GoP alignment (without spatial shift) *(see Fig. 5)*
- Multigeneration chain without GoP alignment (without spatial shift) *(see Fig. 6)*
- Multigeneration chain with GoP alignment AND spatial shift *(see Fig. 7)*
- Multigeneration chain without GoP alignment AND spatial shift *(see Fig. 8)*

All the abovementioned chains were carried out on the "Legacy" systems and on the "New" systems. The resultant sequences were all stored in YUV 10-bit format.

Note: For the XDCAM @35 chain it was not possible to obtain the GoP alignment control and therefore this multi-generation has to be considered "random" in terms of GoP alignment)

The tests on the AVID DNxHD codec were performed by the IRT, the tests on the GVG/Thomson codec were performed by the RAI using an Infinity prototype camera, the tests on the Panasonic AVC-I codec were performed by the EBU using a prototype encoder, and the Sony XDCAM HD50 was tested by the RAI using a prototype encoder. Engineers from the respective manufacturers attended the tests for at least the first day to ensure the correct working of the equipment.

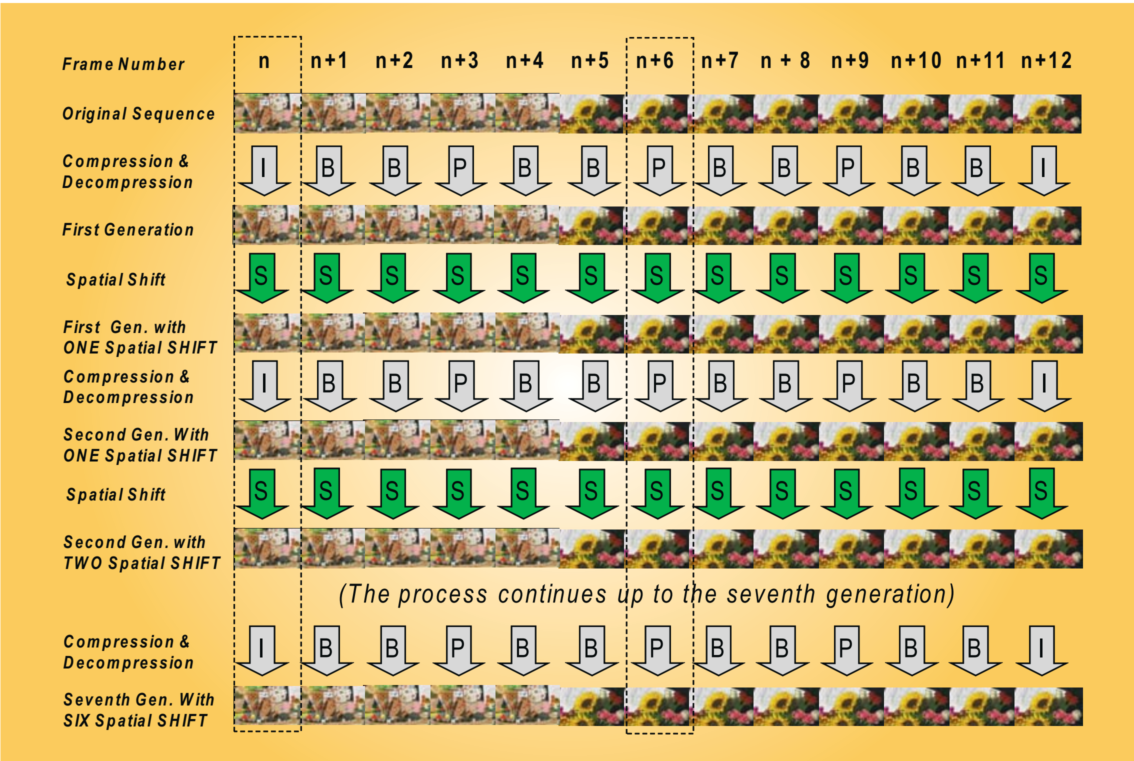


Figure 7
Standalone chain with GoP alignment AND with spatial shift for INTER codec

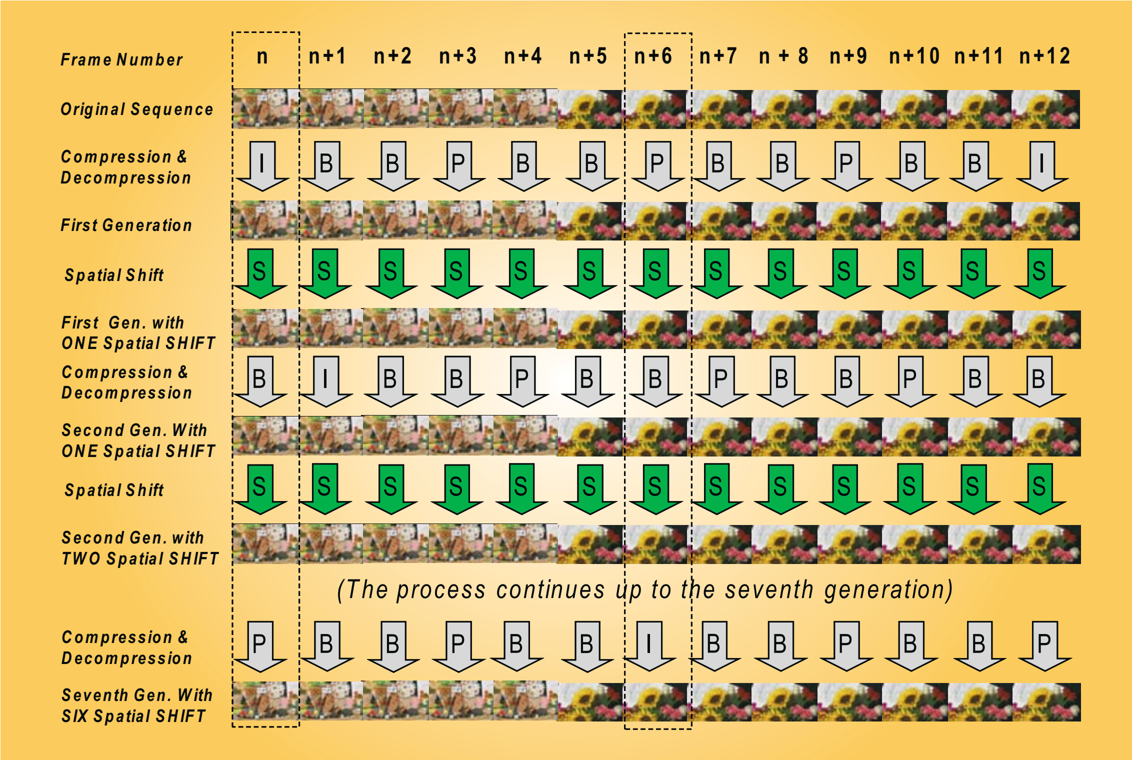


Figure 8
Standalone chain without GoP alignment AND with spatial shift for INTER codec

4. Analysis of the performance of the algorithms

The analyses of the performance of the algorithms was performed both using objective measurements (PSNR) and visual scrutiny of the picture (i.e. expert viewing), as described in the following sections. These two methods provide different kinds of information and they are considered to be complementary.

4.1. Objective measurements

The PSNR has been computed via software and obviously applied a procedure to re-establish the spatial alignment between the original and the de-compressed version of the test sequence. Moreover, it skipped 16 pixels on the edges of the picture to avoid taking measurements on the black pixels introduced during the shift.

The formula used to evaluate the PSNR via software was:

$$PSNR = 10Log_{10}\left(\frac{Vpeak^2}{\frac{\sum_{i=1}^{Ncol}\sum_{j=1}^{Nlin}\left(ori(i,j) - cod(i,j)\right)^2}{Ncol * Nlin}} \right)$$

where: *ori (i,j)* = original frame, *cod(i,j)* = manipulated frame, *Ncol* = horizontal resolution in pixels, *Nlin* = vertical resolution in pixel and Vpeak = $2^{10} - 1$ = 1023.

The results are expressed in dB.

It is well known that PSNR does not correlate accurately with the picture quality and thus it would be misleading to directly compare PSNR from very different algorithms. On the other hand, this parameter can provide information about the behaviour of the compression algorithm through the multi-generation process.

4.2. Expert viewing

Analysis of the algorithm performance (from the point of view of picture quality) was carried out using so-called "expert viewing". Even if this method is not formally included in any ITU Recommendation, it is very often used as it provides fast and consistent results. Under the generic name of "expert viewing" are included several kinds of analysis of the picture quality evaluation.

For the purposes of these P/HDTP tests, it was agreed in advance with manufacturers to use the following interpretation of what "expert viewing" would entail.

> All the sequences (original and those subjected to compression) were stored in uncompressed form (YUV10 format) on two video servers that were able to be run in parallel. The sequences were displayed simultaneously in a vertical split-screen condition (original on one side, those subjected to compression on the other side). During the expert viewing, the T bar of the mixer that provided the split-screen effect (a Panasonic type AV-HS300) was moved to compare the same areas of different versions of the same sequences, as was found necessary. The position of the split was made more evident by applying a just-noticeable vertical white bar at the transition between the two images; a real example is shown in *Fig. 9*.
>
> The viewing distance was marked on the floor and was set to 3H, where H defines the vertical dimension of the display, and the observers were asked to respect this viewing

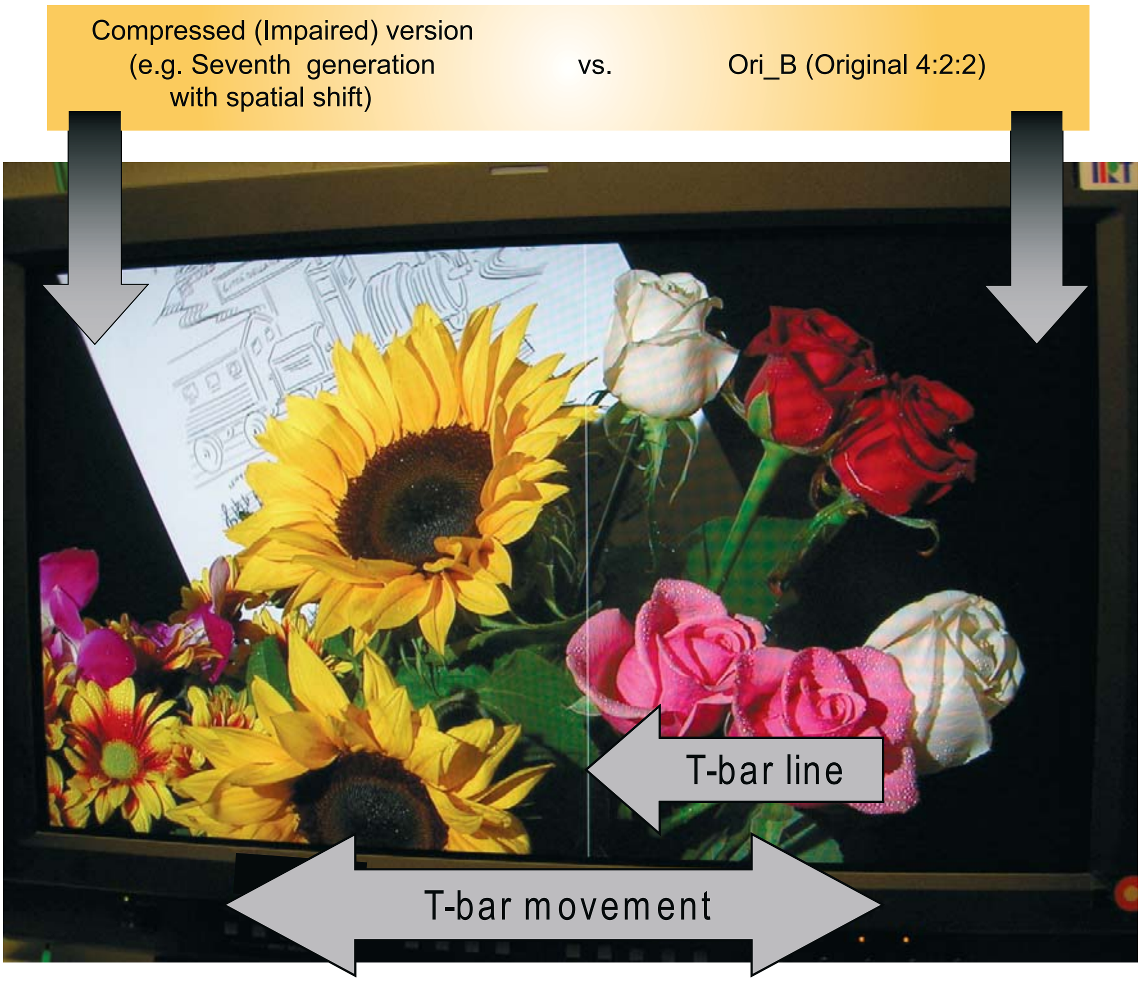


Figure 9
Split-screen analysis

distance. Sometimes a closer viewing distance, e.g. 1H, was used to closely observe small details and artefacts and, when used, this condition was clearly noted in the report.

It should be made clear that this method allows the evaluation of very small impairments, near to the visibility threshold, and it must be considered a very severe analysis of the picture quality.

As mentioned, the tests focused on the performance of the algorithms at the first, fourth and seventh generations, comparing the picture quality with the original (headroom evaluation) or with legacy system (improvement provided by the new system). A test list, which summarized in the form of tables all the different comparisons planned, was prepared and discussed in advance.

Each expert was provided with a paper copy of the test list, so she/he was always completely aware of what sequence was displayed in each part of the screen.

For example, in the case of a comparison between the "Original" sequence and the version subjected to seven generations of algorithm "A", including a spatial shift between each generation, the expert was provided with the following table:

Compressed (Impaired) version (e.g. Seventh generation with spatial shift)	**vs.**	**Ori_A (Original 4:2:2)**
Ratio: loss due to seven generations with post-processing		

The expert was aware that "A" meant a specific vendor and was given full details of each test condition (bitrate, GoP aligned or not, etc.). The table also included a short sentence describing the "rationale" of the test and, in order to avoid any misunderstanding, the position (right or left) of the sequences was the same on the paper table and on the display; c.f., the Original sequence on the right side and the processed sequence on the left side in the above table.

All the experts were formally requested to refrain from expressing their opinions during the sessions, in order to avoid biasing other people. Only after the complete analysis of the test sequence (for its full length) was a discussion started to summarize in a few sentences the opinions of the different experts. Sometimes it was not possible to get an agreement on the visual analysis of a sequence and in this case the sequence was repeated. If even in this case an agreement was not possible, the situation was noted in the report.

Best efforts were made to guarantee that the panel of experts was comprised of the same people during the different expert viewing sessions; this condition was readily met during each single day and almost perfectly so during different days. One day of expert viewing was dedicated to each manufacturer, and representatives of the individual vendor took part in the expert viewing as well.

The results of the expert viewings were collected in a series of EBU BPN documents; BPN 076 (results for Avid DNxHD), BPN 077 (results for GVG/Thomson JPEG2000), BPN 078 (results for Panasonic AVC-I) and BPN 079 (results for Sony XDCAM HD50). These documents are published by the EBU exclusively for its Members.

The reader should be aware that, due to the complexity and framework of the tests, only a deep analysis of these documents can provide a complete appreciation of the results.

4.2.1. Display

The following displays were used during the tests:

- CRT 32″ Sony — Type BVM-A32E1WM
- CRT 20″ Sony — Type BVM-A20F1M
- Plasma Full HD 50″ — Type TH50PK9EK Panasonic
- LCD 47″ — Type Focus

The displays were connected through HD-SDI interfaces. The displays were aligned according to the conditions described in ITU-R BT.500-11 and the room conditions were set accordingly.

The final assessment was always done while considering the quality perceived on the CRT displays.

Nevertheless, there was a general agreement that the flat-panel displays, both LCD and plasma, magnified the impairments.

5. Results

It was agreed between the EBU project group and the vendors to make the reports about the test details available to EBU Members only. In late 2007, the results of the test were published as BPN076 to BPN079, as noted above.

Note: Due to the importance of the subject, vendors and the EBU agreed to provide some preliminary results in a PowerPoint presentation given at the IBC-2007 conference, before the actual BPN reports became available to EBU Members. This PowerPoint presentation contained a short summary of the test results in tabular form. The published reports BPN076 to BPN079 contain a much larger framework of test conditions than shown in the IBC-2007 PowerPoint. Neither the test reports nor the PowerPoint tables are intended, or suited, for comparative studies. The tabular form of the PowerPoint presentation did not include information about whether the tests were conducted with or without pixel shift.

The EBU Production Management Committee then subsequently concluded in a recommendation (EBU R124-2008) [2] that:

> ***For acquisition applications an HDTV format with 4:2:2 sampling, no further horizontal or vertical sub-sampling should be applied. The 8-bit bit-depth is sufficient for mainstream programmes, but 10-bit bit-depth is preferred for high-end acquisition. For production applications of mainstream HD, the tests of the EBU has found no reason to relax the requirement placed on SDTV studio codecs that "Quasi-transparent quality" must be maintained after 7 cycles of encoding and recoding with horizontal and vertical pixel-shifts applied. All tested codecs have shown quasi-transparent quality up to at least 4 to 5 multi-generations, but have also shown few impairments such as noise or loss of resolution with critical images at the 7th generation. Thus EBU Members are required to carefully design the production workflow and to avoid 7 multi-generation steps.***

The EBU recommends in document R124-2008 that:

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

Furthermore, the expert viewing tests have revealed that:

- A 10-bit bit-depth in production is only significant for post-production with graphics and after transmission encoding and decoding at the consumer end, if the content (e.g. graphics or animation) has been generated using advanced colour grading, etc.
- For normal moving pictures, an 8-bit bit-depth in production will not significantly degrade the HD picture quality at the consumer's premises.

2. R124-2008: http://tech.ebu.ch/docs/r/r124.pdf

Abbreviations

720p/50	High-definition progressively-scanned TV format of 1280 x 720 pixels at 50 frames per second
1080i/25	High-definition interlaced TV format of 1920 x 1080 pixels at 25 frames per second, i.e. 50 fields (half frames) every second
1080p/25	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 25 frames per second
1080p/50	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 50 frames per second
AVC	(MPEG-4) Advanced Video Coding, part 10 (aka H.264)
DCT	Discrete Cosine Transform
GoP	Group of Pictures
ITU	International Telecommunication Union http://www.itu.int
ITU-R	ITU - Radiocommunication Sector http://www.itu.int/publications/sector.aspx?lang=en&sector=1
JPEG	Joint Photographic Experts Group http://www.jpeg.org/
MPEG	Moving Picture Experts Group http://www.chiariglione.org/mpeg/
NLE	Non-Linear Editing
PSNR	Peak Signal-to-Noise Ratio
SMPTE	Society of Motion Picture and Television Engineers (USA) http://www.smpte.org/
YUV	The luminance (Y) and colour difference (U and V) signals of the PAL colour television system

6. Bibliography

[1] ITU-R BT.500-11: **Methodology for the subjective assessment of the quality of television pictures**
ITU-R Geneva, 2003.

[2] ITU-R BT.709-5: **Parameter values for the HDTV standards for production and international programme exchange**
ITU-R Geneva, 2002.

[3] SMPTE 296M: **1280 x 720 Scanning, Analogue and Digital Representation and Analogue Interface**
SMPTE New York, 2001.

[4] SMPTE 292M: **Bit-Serial Digital Interface for High-Definition Television Systems**
SMPTE New York, 1998.

[5] SMPTE 274M: **1920 x 1080 Scanning and Analogue and Parallel Digital Interfaces for Multiple Picture Rates**
SMPTE New York, 1998.

[6] Sony: http://www.sonybiz.net and search for XDCAM-HD 422

[7] Panasonic: http://www.panasonic.com/business/provideo/p2-hd/white-papers.asp

[8] Avid: http://www.avid.com/dnxhd/

[9] Thomson Grass Valley: http://thomsongrassvalley.com/products/infinity/

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Dolby Pulse

— combining the merits of Dolby Digital and HE-AAC

James Caselton
Dolby Laboratories, Inc.

In late 2007, Dolby Laboratories acquired Coding Technologies, the company which had developed techniques such as Spectral Band Replication (SBR) and Parametric Stereo (PS) for enhancing the efficiency of the Advanced Audio Coding (AAC) compression standard.

This article outlines how Dolby Laboratories, Inc. has now integrated HE-AAC into the Dolby family to create a new audio coding system – called *Dolby Pulse* – for broadcasting and other applications where bandwidth is restricted.

Over the last 18 months, various national HDTV specification groups and European industry groups – such as the EBU, DVB and EICTA – have considered various audio coding systems that could be used for next-generation broadcast applications, including HDTV, that will use MPEG-4 video compression. The requirements call for an efficient audio coding technology that can deliver the next-generation consumer experience with assured reliability, consistent audio and far-reaching compatibility with the pre-installed base of home theatres, set-top boxes and television sets.

Amongst the coding schemes evaluated by the EBU in 2007 [1], Dolby Digital Plus and HE-AAC (High Efficiency Advanced Audio Coding) stood out from the rest, but for different reasons:

- Dolby Digital Plus™ was seen as the next step onwards from the industry-standard Dolby Digital™ format. It offered enhanced sound quality over Dolby Digital at comparable bitrates, an increased number of audio channels, as well as offering higher bitrates and increased meta-data functionality.
- HE-AAC was evaluated to be the most data-efficient codec [1] at lower bitrates (typically 160 kbit/s), but still lacked industry-standard metadata – critical for maintaining consistent broadcast audio quality.

For broadcasters, the lack of metadata maturity within HE-AAC was a real issue.

Two coding schemes for next-generation audio

It was the question of Surround Sound delivery that started to focus broadcasters' minds on the value of metadata within Dolby Digital (and Dolby Digital Plus). Knowing that all domestic surround-sound decoders employed Dolby Digital technology as standard, broadcasters realized that it was metadata which gave them the ability to find a solution. They realized they could control the loudness [2], tailor the dynamic range and optimize the audio quality for whichever system was being used to decode and play out Dolby Digital Surround Sound in the home.

For broadcasters who were not yet using Dolby Digital and for whom bandwidth optimization was of primary importance (e.g. for digital radio and TV transmissions ... but also for emerging technologies such as IPTV and Mobile TV), HE-AAC was turning out to be an interesting option.

On the other hand, for broadcasters who were already using Dolby Digital, the choice was clearer – move to Dolby Digital Plus to ensure consistency of broadcast quality, through metadata, whilst being able to broadcast more audio channels in higher quality.

In the case of consumer electronics manufacturers, it was becoming clear that broadcasters were not going to settle on a single coding scheme, for the various reasons laid out above. This led to manufacturers starting to specify both Dolby Digital Plus and HE-AAC decoders within their next-generation products.

The acquisition of Coding Technologies and the birth of Dolby Pulse

When Coding Technologies first introduced their AAC+ implementation, it combined MPEG AAC-LC with a new technology, Spectral Band Replication (SBR), which was discussed within this publication in July 2002 [3]. SBR enabled the replication of higher frequency content, based on information present at lower and mid-frequencies within the decoded stream. Coding Technologies submitted SBR to MPEG as the basis of HE-AAC, whilst retaining exclusive patent rights to the SBR technology outside of the AAC patent pool.

Dolby saw SBR as an enabling technology for the HE-AAC standard – helping it to overcome some of the audible limitations it had previously suffered, especially at higher frequencies. Dolby also felt at the time that by connecting Coding Technologies' mature industry-standard HE-AAC implementation with its own industry-standard metadata and 5.1 surround-sound technologies, a feature-rich, consistent and reliable version of HE-AAC could be conceived ... a version which the broadcasters could feel reassured by, and would adopt.

In November 2007, Dolby Laboratories, Inc. announced that it had signed a definitive agreement to acquire Coding Technologies.

Earlier this year at NAB in Las Vegas, Dolby introduced *"aacPlus by Dolby"* as a working name for the newly-acquired technology from Coding Technologies. This new *aacPlus* technology was to use the Dolby code base for an improved audio quality version of HE-AAC, whilst being fully compliant with the HE-AAC standard, by using the Coding Technologies implementation at its core. Full support for Dolby metadata was also to be added, allowing it to deliver a consistent experience across all decoders, giving it decoding capability for traditional and non-traditional multi-channel and stereo broadcast devices, such as TVs, set-top boxes, AV receivers, mobile phones, Internet appliances and PCs.

In April this year, it was estimated that most West European terrestrial broadcasters were either using Dolby Digital or planning to move to Dolby Digital Plus but with an increasing number showing interest in HE-AAC. *Fig. 1* shows the status at that time, with significant HE-AAC interest coming from Scandinavia, France and Spain amongst others.

Launched at this year's IBC show in Amsterdam, Dolby Pulse™ is a bit-stream format with a dedicated encoder and decoder which will combine the full compatibility of the MPEG-4 HE-AAC standard with SBR (based on the Coding Technologies core codec), as well as full Dolby metadata support to correctly set the loudness level while preserving dynamic range for multi-channel audio. There will be no need for simulcasting with Dolby Pulse, as a single 5.1 stream can handle multi-channel, stereo and mono with seamless switching via Dolby down-mix metadata parameters.

Since the announcement in April earlier this year about this new HE-AAC-based Dolby technology, there has been a very positive reaction from broadcasters throughout Western Europe. Most have been reassured by the news that the new standard will include the full HE-AAC standard combined with full metadata support *(see Fig. 2)*.

As DVB does not specify which audio codec should be used for next-generation broadcasts, various broadcaster / manufacturer groups have recently worked collaboratively to gain consensus on the formats desired by broadcasters, which will then be included in European receivers. The key outcomes for the multi-channel format requirements drawn up so far are outlined in *Table 1*.

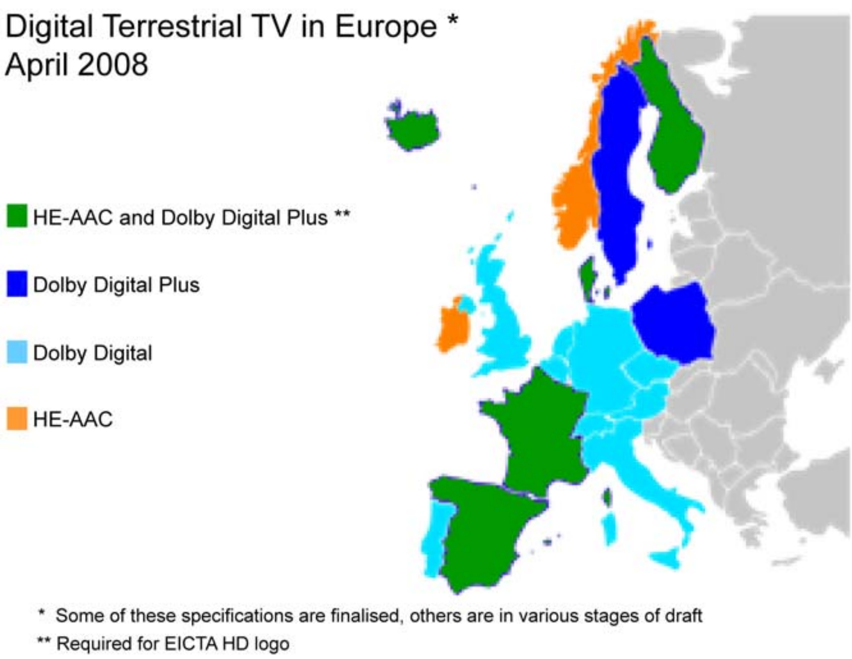

Figure 1
April 2008: Dolby remains a core technology with some HE-AAC adoption starting

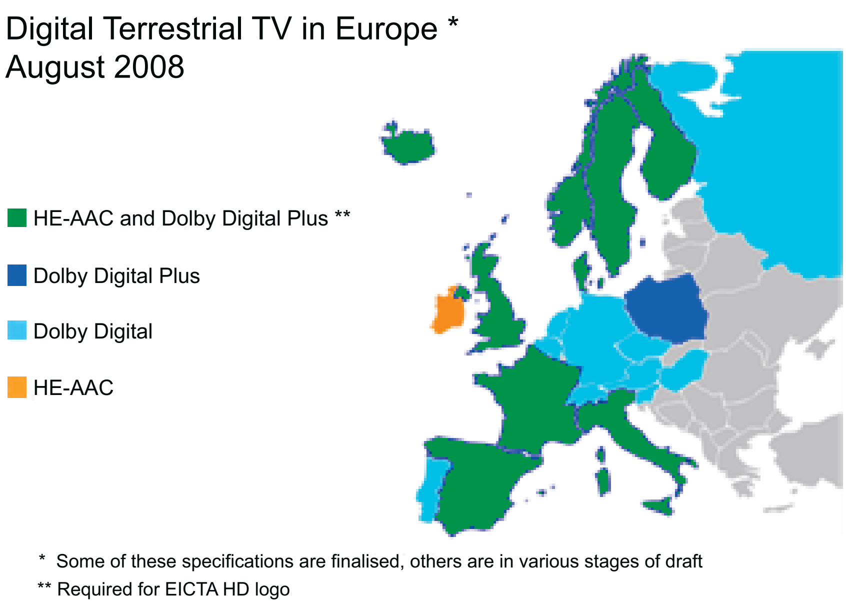

Figure 2
August 2008: combined adoption of HE-AAC and Dolby Digital Plus increasing

Table 1
Multichannel audio requirements in various European HDTV specifications

	Dolby Digital Plus	HE-AAC with Transcoder
EBU	✓	✓
EICTA	✓	✓
HD Forum (France)	✓	✓
NorDig (Sweden, Norway, Iceland, Finland, Denmark)	✓	✓
Spanish HD Forum	✓	✓

For broadcasters who have already deployed Dolby technologies in their broadcasting systems, the most likely favoured option will be to move to Dolby Digital Plus. For those broadcasters who have not yet deployed any Dolby technology in their broadcasts and who aim to start their services in approximately 18 months' time, Dolby Pulse will be the best option where efficient bandwidth utilisation is critical. For those who require a solution sooner, the choice will be between Dolby Digital Plus and the open standard of HE-AAC (without metadata support).

Three decoders, one Dolby platform

To support these multi-format broadcasting requirements, Dolby is introducing a new platform capable of decoding Dolby Pulse, Dolby Digital and Dolby Digital Plus. This platform will be able to output in true Dolby Digital as well as Stereo and Pass-through *(see Fig. 3)*. This platform will be both Dolby tested and Dolby supported.

The first decoder ICs to support Dolby Pulse are expected to be rolled out in spring 2009. Dolby's own deliverables are expected to be available very soon, facilitating broadcast roll-out in early 2010.

Abbreviations

AAC Advanced Audio Coding
DVB Digital Video Broadcasting
http://www.dvb.org/
EICTA European Information, Communications and Consumer Electronics Technology Industry Association
http://www.eicta.org/
HE-AAC High Efficiency AAC
MPEG Moving Picture Experts Group
http://www.chiariglione.org/mpeg/
SBR Spectral Band Replication

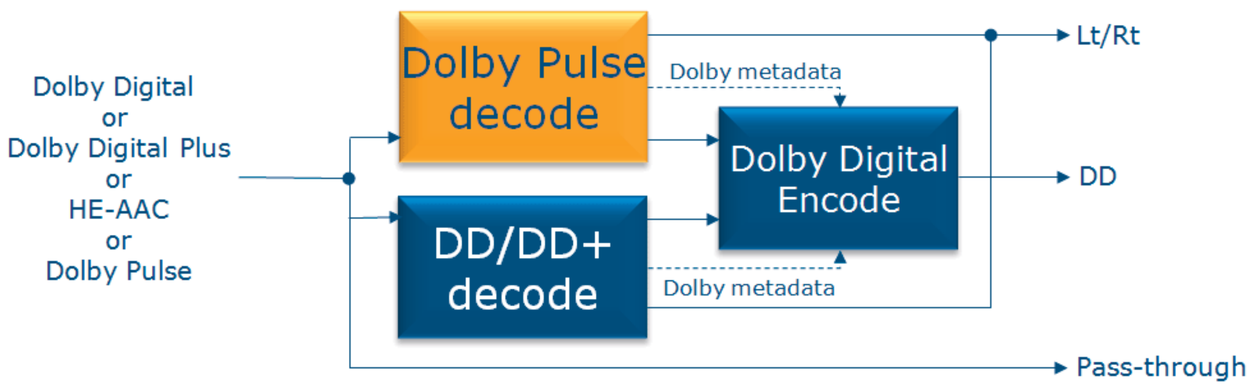

Figure 3
One decoding platform: Dolby Pulse, Dolby Digital and Dolby Digital Plus

James Caselton is responsible for marketing Dolby's Broadcast technologies & Professional products within the EMEA region. He recently joined Dolby from NXP Semiconductors, where he was responsible for the marketing of IC solutions for set-top boxes and digital TVs and where he was involved in establishing partner programmes throughout Asia and Europe with suppliers, manufacturers and retailers.

Prior to joining NXP, Mr Caselton worked for Philips, helping to develop and promote DVD+RW-based products worldwide. Before that, he gained a Communications Engineering degree from the University of Kent in England.

Conclusions

In broadcast applications, Dolby Pulse complements Dolby Digital Plus technology for next-generation applications where bandwidth efficiency is critical. With Dolby metadata and a single code base, Dolby Pulse streams provide consistent and predictable results throughout the broadcast chain to the consumer's television set.

Broadcasters must evaluate which coding scheme best suits them. Dolby Pulse should be used where bandwidth efficiency is of most concern and where a common format for both broadcast and new media content is required. Dolby Digital Plus should be adopted where bandwidth improvements over Dolby Digital are required and where higher bitrate enhanced audio is required. Dolby Digital Plus should also be used for adding more channels to existing Dolby Digital platforms.

Overall, even though broadcasters are favouring two different audio coding schemes, most agree about the importance of metadata for controllable, predictable and consistent high quality audio.

Bibliography

[1] Report of EBU project group D/MAE: **EBU Evaluations of Multichannel Audio Codecs**
EBU Tech 3324, September 2007.
http://tech.ebu.ch/docs/tech/tech3324.pdf

[2] ITU-R Recommendation BS.646-1: **Source encoding for digital sound signals in broadcasting studios**
ITU, Geneva

[3] Martin Dietz and Stefan Meltzer: **CT-aacPlus — a state-of-the-art Audio coding scheme**
EBU Technical Review No. 291, July 2002.
http://tech.ebu.ch/docs/techreview/trev_291-dietz.pdf

DTV transmitter power efficiency

— new opportunities for reducing costs and environmental impact

Keith Pruden
Nujira Limited

The worldwide introduction of digital terrestrial TV systems will lead to significant numbers of new transmitters being installed over the next few years. With the recent rise in energy prices, and increasing concerns over the environmental impact, it is important that these new transmitters are as energy-efficient as possible.

This article discusses various issues relating to the power efficiency of digital TV transmitters, and describes how Envelope Tracking technology could make a significant contribution to reducing the operational costs and environmental impact of new digital networks.

The impact of rising energy costs

Operational costs have always been a key issue for broadcasters, and a substantial part of these costs is due to the electricity required to run a transmission network, which can account for over 75% of the total electricity used by a broadcaster. Broadcasters are significant users of energy: for example, a digital TV transmission network for a typical EU country, using today's technology, could use over 12 MW of electricity, and incur an annual cost to the broadcaster of over € 12m a year at today’s prices.

Energy costs continue to rise and, in order to manage the financial risk going forward, broadcasters are committing themselves to long-term fixed-price contracts with electricity suppliers. At the same time, attention is now focussed on finding ways of substantially reducing energy usage wherever possible.

Once installed, transmitters typically remain in service for a long time (maybe 10 to 20 years) and hence purchasing decisions being made now will have a significant impact on whole-life costs, which are likely to dwarf the initial purchase price (for instance, a single 8 kW transmitter using today’s technology will incur an annual electricity bill of € 42,000 per year, even at current prices). Broadcasters are therefore paying significant attention to the energy consumption of digital TV transmitters.

Environmental impact – a growing concern

Aside from the cost argument for increased transmitter efficiency, there is also a strong desire from broadcasters to improve their environmental or “green” credentials and to be seen to be responsible in their use of energy. For example, to reduce their CO_2 “footprint”, many broadcasters are purchasing power from renewable sources of energy – often at higher prices.

Even if they do not take steps to reduce the environmental impact of their activities themselves, government legislation will force them into action. There are already plans in some countries to incentivise industry to reduce CO_2 emissions, and large users of electricity such as the broadcasting industry are an obvious target for these initiatives. For example, the UK Government has proposed a "Carbon Reduction Commitment" scheme to cover large business and public-sector organizations whose annual electricity usage exceeds 6 GWh.

In addressing the issues of energy usage and environmental impact, the broadcasting industry could consider the lead of the cellular industry, where several of the leading operators are making public commitments to reduce the power consumption and environmental impact of their radio networks, and are pushing their suppliers hard for more power-efficient equipment. As a result, base-station vendors have invested heavily in new technologies to reduce power consumption. Although the same has started to occur with digital TV transmitter vendors, the take-up has been slower to date and could be accelerated.

RF Power Amplifier efficiency is the key

Each digital TV transmitter typically uses one exciter or modulator to drive a number of identical RF Power Amplifiers (PAs, often referred to as "Pallets") – perhaps 20 and 100 for a typical low- to medium-power transmitter, in a "corporate structure" architecture, with the outputs of all the amplifiers combined to produce the total output power.

A breakdown of the energy usage in a typical transmitter shows that a relatively small amount of power is used by the exciter / modulator and interface circuitry. A significant proportion of the overall power (perhaps 55 - 60%) is used by the PAs, and a further 30 - 35% in providing cooling and AC-DC power conversion – where the power used is also largely driven by the power consumed by the PAs (i.e. the greater the power used by the PAs, the greater the cooling power required and the higher the AC-DC conversion losses).

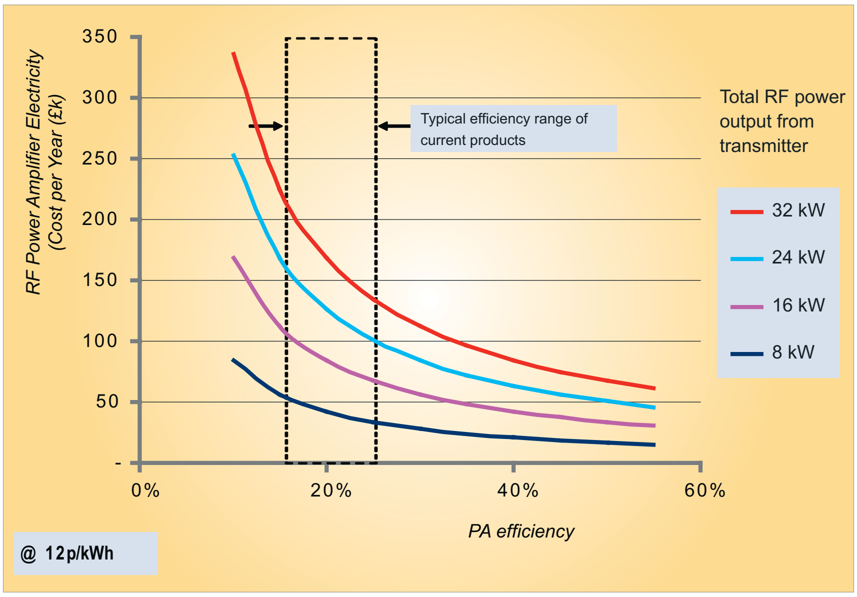

Figure 1
Annual cost of electricity required to power transmitter power amplifier(s), showing variation with PA efficiency

The power required for the PAs is directly related to their efficiency, which is relatively poor in current equipment. *Fig. 1* shows how the annual cost of electricity required to power (just) a transmitter's PAs varies with the PA efficiency. It can be seen that improving the PA efficiency produces a substantial improvement in running costs.

Secondary effects of poor PA efficiency

Poor PA efficiency has a direct impact on the transmitter's cooling requirements. With a PA efficiency of 20%, the remaining 80% of the electrical power supplied is wasted as heat, requiring careful cooling design to reduce equipment temperatures and ensure reliability, a significant consideration when broadcasters have a public-service obligation to meet.

Although lower power transmitters can use air cooling (either with or without air conditioning), higher power (or less efficient) transmitters require liquid cooling, incurring further complications. Furthermore, as power density increases, a higher proportion of power is required for cooling.

Cooling is a major concern for broadcasters for a number of reasons. Firstly, all forms of forced cooling involve moving parts in one form or another (fans, pumps, etc.) and other items such as filters that require regular maintenance. Secondly, mechanical noise can be a concern in many urban transmitter locations: some countries are already starting to pass legislation to control noise levels at such sites. Finally, the cooling plant increases the equipment required on-site and hence the site rental costs.

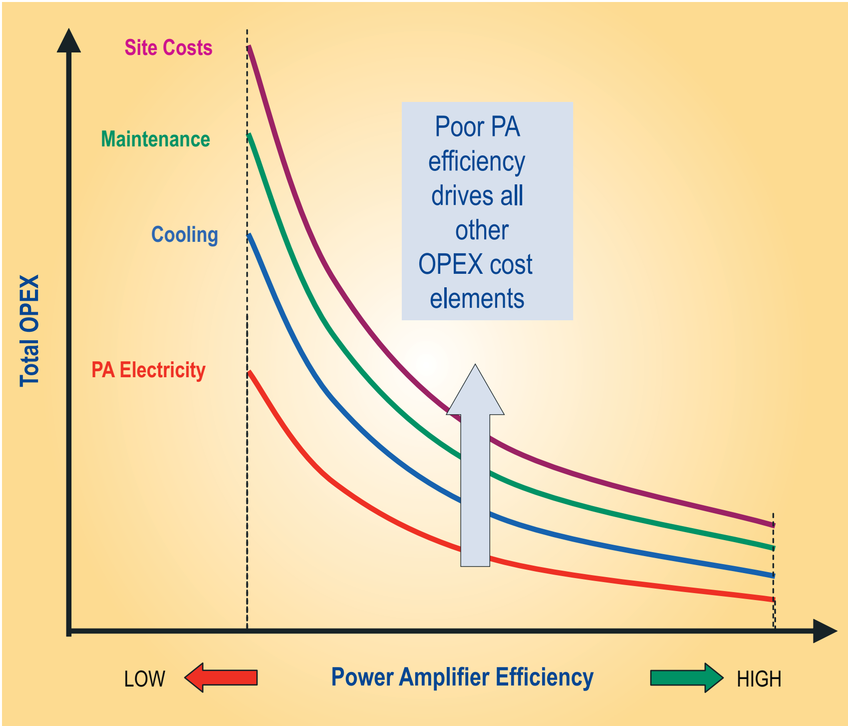

Figure 2
Effect of PA efficiency on overall network OPEX

Another impact of poor PA efficiency concerns the on-site backup power supply – higher transmitter power consumption necessitates either larger battery packs or larger diesel backup facilities, both of which again push up equipment and site costs.

It can be seen, therefore, that poor PA efficiency has a significant impact not just on the design of the transmitter itself, but also the cooling and backup facilities required on site, impacting both initial costs (CAPEX) and also long-term operational costs (OPEX). The overall impact on the total OPEX spend of poor PA efficiency is shown in diagrammatic form in *Fig. 2*.

RF Power Amplifier design

All DTV systems use OFDM (Orthogonal Frequency Division Multiplexing), broad channel bandwidths and complex modulation schemes to achieve high spectral efficiency. Unfortunately, the modulation accuracy, noise and spurious requirements effectively mandate the use of linear (Class AB) RF Power Amplifiers in the transmitter.

Fig. 3 shows a conventional Class AB amplifier as used in traditional DTV transmitters.

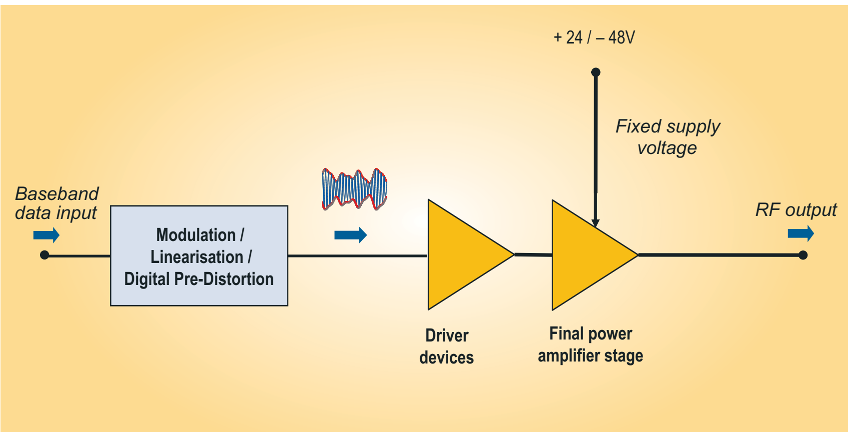

Figure 3
A conventional Class AB power amplifier configuration

Linear PAs can be very efficient when operating close to their peak power and, with careful design, this can be achieved over a relatively broad bandwidth. However, they are unfortunately very inefficient when handling real-world signals with varying amplitude components, such as OFDM signals.

OFDM signals are composed of a large number of individual components, the power of each varying with time. The resultant amplitude of the composite signal over time is therefore not constant but "peaky" in nature, and can be characterised by its "PAPR" (Peak-to-Average Power Ratio) or "Crest Factor". PAPR values for broadcast TV signals can in theory be quite large (> 35 dB) but in practice values of 11 - 12 dB are more commonly observed.

High PAPR signals make the design of PAs difficult for two reasons:

1) The amplifier must be linear over a wide dynamic range to preserve modulation accuracy and spurious performance. It is possible to use a technique called "Crest Factor Reduction" (CFR) to allow the PA to operate closer to peak power for most of the time, by limiting the peaks of the signal using DSP techniques. However this needs to be done with care to minimize distortion and maintain adequate signal EVM (Error Vector Magnitude). Typically, CFR will reduce the PAPR to around 8.0 - 8.5 dB.

2) The variation with time of the PA output power results in a poor overall power efficiency. The reason for this is shown in *Fig. 4*. A Class AB (linear) PA is at it's most efficient at peak power, but the drain (power conversion) efficiency, as shown by the solid line, drops off rapidly as the output power decreases. The probability distribution of instantaneous output power for a typical OFDM signal (dashed curve – not to a specific scale) shows that for much of the time the signal power lies well below the peak power and hence the device is operating at low (average) efficiency. Note that the PAPR value shown in this diagram assumes that CFR has been used to reduce the PAPR of the transmitted signal: without this, overall efficiency would be even lower.

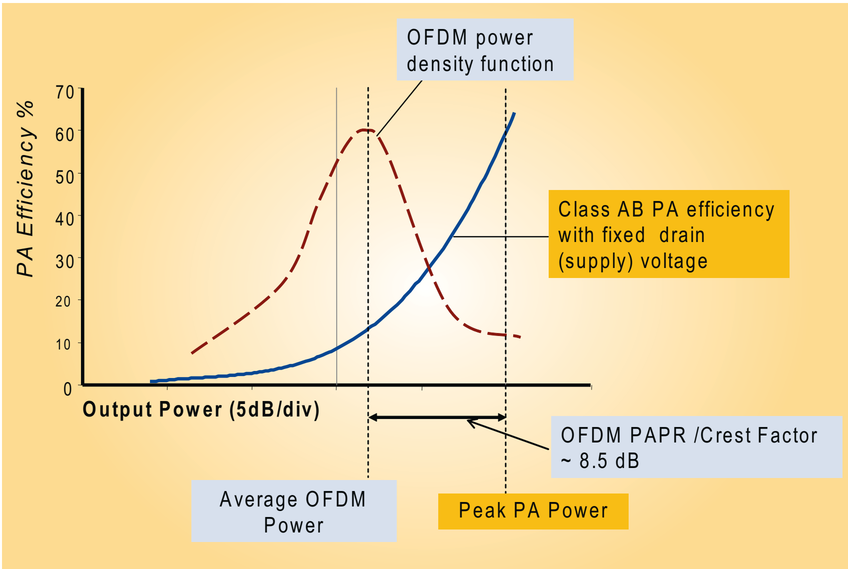

Figure 4
Comparison of drain efficiency vs. power output and probability distribution of the instantaneous output power value

It can be seen, therefore, that designing a linear PA to meet the system performance requirements, and to be power-efficient at the same time, is extremely difficult.

Possible solutions for improving PA efficiency

A number of techniques are now being used to improve PA efficiency. The majority of these have found their first use in the cellular industry, where the problems of high network power consumption and environmental impact have already caused many network operators to force the pace of change and to demand significantly improved equipment efficiency from their suppliers.

The major techniques are:

- Digital Pre-Distortion (DPD) and Linearization
- Envelope Tracking

DPD and Linearization

As already noted, Crest Factor Reduction can make a useful contribution to improving PA efficiency by allowing controlled compression of peak signals, effectively allowing the PA to operate nearer peak power and hence at a higher efficiency.

DPD and Linearization techniques build on this by compensating for non-linearities in the final RF output stage. In the process they also improve adjacent channel and EVM performance and, by allowing some compensation for the distortion caused by non-linearities near compression, the PA can be driven harder, resulting in an improvement in power efficiency.

The best improvements result when DPD and Linearization are used as part of a system architecture incorporating active sampling of the output signal as part of a feedback loop: only then can the system fully compensate for changes in amplifier characteristics with time, temperature and signal characteristics. This "adaptive" pre-distortion is in widespread use in the cellular industry but is more difficult to implement in the "corporate structure" PA architecture used in TV transmitters, and most systems in use today use simpler open-loop (predictive) DPD/linearization.

Envelope Tracking

Envelope Tracking (ET) uses a completely different technique: instead of the final RF-stage power transistor being supplied with a constant voltage, the supply is changed dynamically, in synchronism with the envelope of the modulated RF signal passing through the device. This ensures that the output device remains in its most efficient operating region (i.e. in saturation). The "modulation" of the supply voltage is performed by a Power Modulator device which replaces many of the features of the normal DC-DC converter that provides the supply voltage.

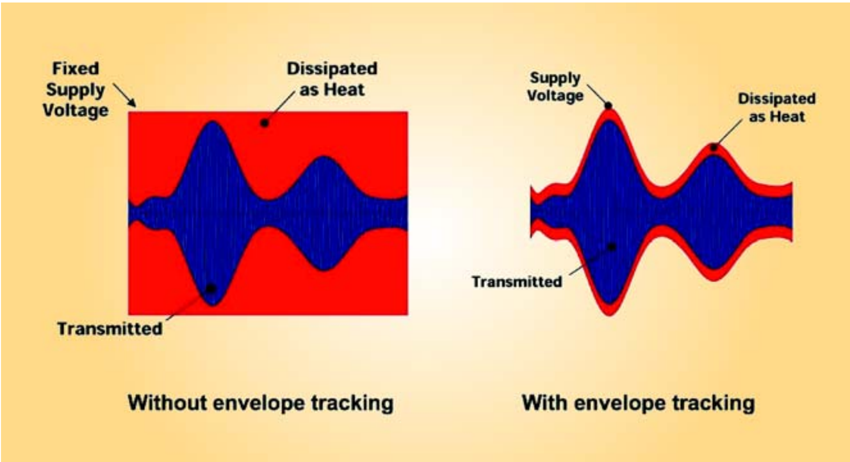

Figure 5
Envelope tracking reduces the voltage difference between the supply voltage and the signal envelope, dramatically reducing the energy dissipated as heat

Fig. 5 shows the Envelope Tracking system in operation: without envelope tracking, the difference between the fixed supply voltage and the required output waveform is dissipated in the RF power transistor as heat. With envelope tracking, the supply voltage tracks the signal envelope, dramatically reducing the energy dissipated.

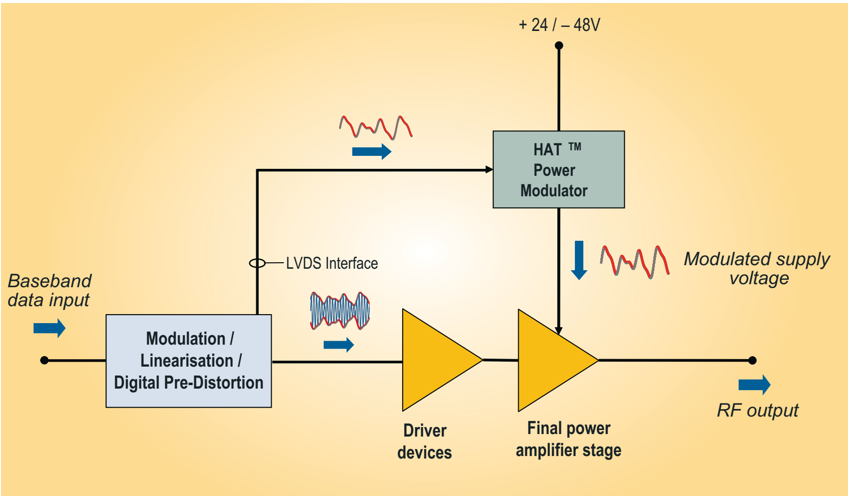

Figure 6
Application of Nujira's High Accuracy Tracking Power Modulator to a standard power amplifier

Although the principles of Envelope Tracking have been known for some time, the practical difficulties of implementing a working system have prevented the concept from being employed until recently. The first practical implementation is Nujira's High Accuracy Tracking (HAT™) technology.

Fig. 6 shows how Nujira's HAT Power Modulator is used in conjunction with a typical (single) PA. The only addition required to the standard PA architecture is an output from the DPD/Linearization function to drive the HAT Power Modulator with a digital representation of the modulation envelope.

Fig. 7 shows the Nujira HAT Power Modulator integrated with a typical PA.

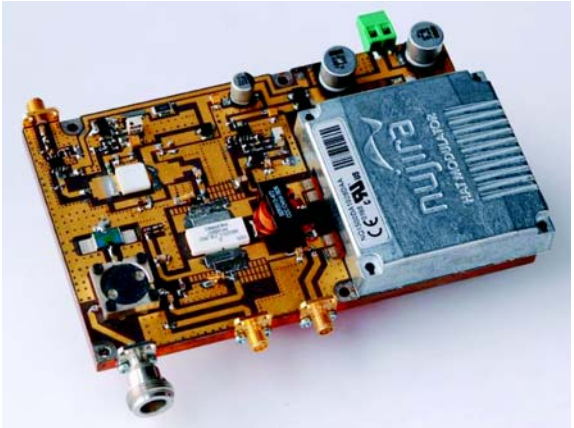

Figure 7
Nujira HAT Power Modulator integrated with PA

The practical implementation of Envelope Tracking is critically dependent on the design of the Power Modulator, which has to track the rapidly-varying envelope of the (wideband) RF signal with very high accuracy, in order to achieve the OFDM specifications. Accurate time synchronization between the signal passing through the device and the modulated drain voltage is also critical. Finally, the Power Modulator itself must be able to supply high peak power levels and at the same time have a very high power-conversion efficiency in order to achieve a high overall system efficiency.

Envelope Tracking can be used with a variety of transistor types – the main one for the broadcast industry being LDMOS.

Benefits of Envelope Tracking

The primary benefit of employing Envelope Tracking is the substantial gain in PA efficiency. Efficiencies of 40 - 45% are already possible with this technology, with higher levels expected in the future when RF devices optimized for ET operation become available (the major change required here is to optimize the RF device efficiency for the target PAPR value instead of peak efficiency at maximum output power).

Even at the conservative figure of 40%, an improvement in efficiency from the current level of 23% results in approximately 50% less heat dissipation in the PA, reducing and simplifying the cooling requirements, and increasing the threshold at which water cooling becomes necessary.

Other benefits include smaller equipment size, reductions in maintenance costs and improved equipment reliability, plus lower site installation and rental costs.

Despite the additional cost of the Power Modulator, the overall impact on transmitter manufacturing cost is expected to be minimal, due to the reduction in heatsinking and other metalwork, and from the overall reduction in size that is possible once power densities are reduced.

Abbreviations

AC	Alternating Current	**ET**	Envelope Tracking
CAPEX	Capital Expenditure	**EU**	European Union
CFR	Crest Factor Reduction	**EVM**	Error Vector Magnitude
DC	Direct Current	**LDMOS**	Laterally-Diffused Metal Oxide Semiconductor
DPD	Digital Pre-Distortion	**OFDM**	Orthogonal Frequency Division Multiplex
DSP	Digital Signal Processor / Processing	**OPEX**	Operational Expenditure
DTV	Digital Television	**PA**	Power Amplifier
DVB	Digital Video Broadcasting http://www.dvb.org/	**PAPR**	Peak-to-Average Power Ratio
		RF	Radio-Frequency
DVB-T	DVB - Terrestrial	**UHF**	Ultra High Frequency

The other significant advantage of ET is that Envelope Tracking amplifiers are inherently broadband and work with all modulation schemes. One power amplifier design can be used for all UHF frequencies, and future enhancements to DVB-T and other systems can be easily accommodated without further hardware changes.

The financial and environmental benefits arising from the use of this technology are discussed in a later section.

Application of Envelope Tracking to typical UHF transmitter architecture

Fig. 8 shows how envelope tracking is applied to a typical multi-element UHF transmitter using a number of PAs connected in parallel to achieve the required output power. Each PA is equipped with a Nujira HAT™ Power Modulator which dynamically varies the supply voltage in line with the signal envelope, all driven in parallel from the envelope signal generated by the exciter.

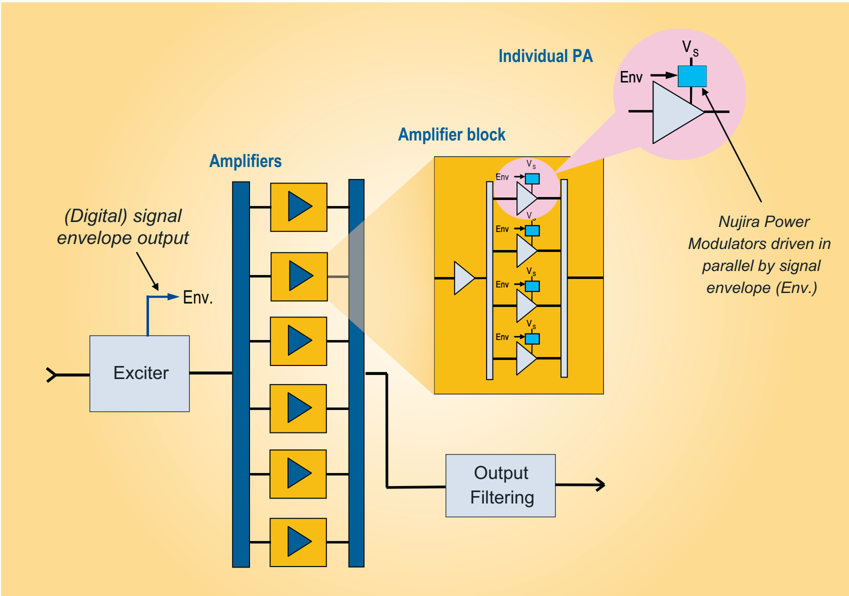

Figure 8
Typical transmitter architecture using Envelope Tracking power amplifiers

Economic and environmental benefits of using Envelope Tracking

Table 1 shows the potential savings in energy costs and environmental impact that are possible using Nujira's HAT technology as applied to a typical digital terrestrial television network. As can be seen, the savings in both energy cost and environmental impact are substantial. Note that these savings are based on a conservative value for the PA efficiency using Envelope Tracking, and electricity costs typical of long-term contracts negotiated before the recent price rises, so actual savings with ET-enabled transmitters are likely to improve on these figures.

Applicability to Mobile TV

Although this article has focussed on digital terrestrial television systems, the same problems (and benefits of adopting Envelope Tracking) apply equally to Mobile TV systems such as DVB-H and MediaFLO.

The key differences between Mobile TV and terrestrial broadcasting systems are mainly concerned with the network topology and transmitter power levels. Since much of the usage is expected to be in-building, it is likely that Mobile TV systems will be more "cellular-like", with a much greater number

		Current Technology	HAT™ Technology	Saving
	PA efficiency:	20%	40%	
Transmitter (32 kW)	Total transmitter power consumption:	239 kW	117 kW	122 kW
	Overall transmitter efficiency:	13.4%	27.3%	
Network (1.6 MW)	Total network power consumption:	12.0 MW	5.9 MW	6.1 MW
	Total yearly consumption:	105 GWh	51 GWh	53 GWh
	Yearly energy cost:	$ 12.6 M	$ 6.2 M	$ 6.4 M
	CO2 emissions (Tonnes per year):	45,040 t	22,040 t	23,000 t
			overall saving:	51.1%

Key Assumptions:
RF power per multiplex: 8.0 kW
Number of multiplexes: 4
Number of transmitter sites: 50
Electricity cost: 12 ¢/kWh

Table 1
Operational savings through the use of Nujira technology

of lower power transmitters. The total aggregate power required is likely to be of the same magnitude as current terrestrial systems (with in-building coverage in major centres of population only), although it could be several times higher if better coverage is required.

The business case for Mobile TV remains a major issue, delaying adoption of the technology: the significant reductions in direct operating costs possible with transmitters equipped with high-efficiency PAs will make a strong contribution to improving this. Envelope Tracking systems are ideally suited to this environment, since they are already being adopted for 3G and WiMAX cellular base stations.

Summary

As digital TV networks (both terrestrial and mobile) grow to support the digital switchover and bring new services to customers worldwide, the energy required to run these networks will substantially increase. The power efficiency of the RF power amplifiers within the transmitters is the critical issue in reducing this energy usage and the associated environmental impact.

Bringing more than 20 years of experience to the Nujira management team, **Keith Pruden** was most recently the Global Vice President of Networking Sales with Agere Systems Inc. and prior to that held sales leadership positions with Agere in both Europe and Asia.

Prior to joining Agere, Mr Pruden ran the Wireless and Multimedia business unit for Cadence Design Systems and this followed on from his role as Northern European Sales leader for VLSI Technology. Prior to moving into sales, he worked as an ASIC and DSP Field Application Engineer and received his engineering training and degree whilst employed by the Royal Air Force in the UK.

There are several techniques that can be used to improve power amplifier efficiency: of these, Envelope Tracking (e.g. Nujira's High Accuracy Tracking technology) provides the best improvement in efficiency, combined with inherently broadband operation, and has the potential to reduce the overall power consumption of a digital TV network by 50%. This technology is expected to play a large part in helping to improve both the economics and the environmental impact of new digital TV networks.