EBU Technical Review

2009-Q2

Rollout of DAB+ in Australia

WorldDMB receiver profiles – silicon solutions

TV Displays – a progress report

TV Displays – small-area luminance uniformity testing

Why broadcasters should care about Home Networking

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Innovation — a core activity of public service media organizations

Innovation is for all times and ages. Over the centuries, innovation has been enabled by technological (r)evolutions – printing, radio waves, transistors, modulation, digitalization, etc. Innovation happens for us when ideas and technologies are combined to create a new media experience. If we look back on the innovations in media, their impact on society has been huge.

Today, innovation must be part of our daily routine. Innovation needs to take place in all core elements of the media experience: content, services, networks and devices. Today, we need innovation in all these domains. They have a major impact on our creative activities and economic models – indeed, on our survival.

New technological developments were an important part of the broadcasting organizations' work of the last century. By being at the core of technological developments, via their research centres, broadcasting organizations were "in control" of the evolution of broadcasting. They had, in short, an "insurance policy" for the future.

Today, most fundamental technological research is no longer carried out by broadcasters themselves. While some EBU members still have a team of experts with a strategic advisory role in technology, only a few EBU Members still have real research and development centres.

There are those who question the role of media organizations in technological development, and indeed, in media delivery. They see Public Service Media (PSM) organizations evolving to pure production houses. However we must never forget that the media of tomorrow will be defined by the total experience ... the combination of content, services, networks and devices (the media context). Perhaps it is understandable that the role of EBU Members in fundamental research must diminish but, in general, the role they need to play in innovation has grown.

Distinctiveness is a core asset of Public Service Media organizations. PSM organizations differentiate themselves from private broadcasters by their mission and by their action – not only by their content but also by the new service models they offer. PSMs serve as an "indirect investment organization" for innovative developments in society – a role that can be less readily played by fully commercial organizations.

PSM organizations have a key role in society to innovate and "test" new content, services and technologies. It is part of their remit as a public service organization, and it is important for their future. By taking innovation into our hands, we will make better decisions, and we will understand and control the future of (our) media. Public service broadcasters need to weight up all these things when their decide on how much to allocate to "innovation". It is an unwise man who has no insurance policy for the future.

Lieven Vermaele
Director, EBU Technical

22 June 2009

Editorials Archive

DAB+ — the Australian experience

Joan Warner
Commercial Radio Australia

Australia is just one of several countries now rolling out digital radio services based on DAB+ and other members of the Eureka-147 family of standards. In their case, it is Commercial Radio Australia which is leading the DAB+ challenge, unlike in many other countries where it is the public broadcaster that is to the fore.

This article describes the evolution of radio broadcasting in Australia and, in particular, stresses the importance for the radio industry worldwide to establish a foothold in the digital dividend *now* ... and control its own digital destiny. There are many technologies competing for the all-important spectrum required for digital radio and – whether broadcasters are thinking about digital radio now or in the future – they cannot just sit back and watch as other media technologies move over to digital platforms.

There are always doomsayers as you enter an exciting new era. They used to say that TV would kill radio and then it was the iPod and the internet and, more recently, podcasts. When you think about it – radio has defied generations of critics! It's a fluid, free-to-air medium that often ends up working brilliantly along with the very technology that is supposed to kill it off – including iPods, mobile phones and the internet.

Outlined below is radio's claim to a piece of the digital dividend and I'll use the Australian DAB+ rollout, and what we've learned so far, as a snapshot of the way in which radio broadcasters world-wide can secure not just their digital future but be leaders in the digital world.

So what is the digital dividend?

It is simply the situation that arises when spectrum is vacated, usually by television, in the move from analogue to digital. Bands of frequencies become available for other uses and I'll explain why radio has a right to benefit from this – at no cost to the industry.

Radio's evolution

Commercial radio has existed in Australia for 85 years and we've been assailed by and have integrated new technologies for years. The first AM radio broadcasts began in Australia in 1923. These were commercial radio broadcasts. Since then, we have seen the invention of the transistor radio – the first form of mobile entertainment. Then came our love affair with the motor car and the rise of in-car listening. Neilson Media Research figures from 2008 show that nearly 30% of listening to commercial radio in Australia is done in the car.

Talk radio started in 1967 and with it ... listener interaction, music quizzes and the start of live reporting from the scene of action. FM was embraced in Australia in 1980. More recently the emergence of the internet, iPods and mobile phones has seen radio streamed to PCs and downloaded as podcasts.

With each major development, radio has adjusted its content, format and style to meet the needs of the audience. At the heart of radio's continued success is the industry's ability to adapt to change. The next change – to digital – is just another exciting challenge. But in order to meet this challenge ... we need spectrum.

Australian Commercial Radio

There are 261 commercial radio stations in Australia: 42 serve the five major metropolitan areas while the remainder broadcast to regional and rural Australia.

Around 97% of Australians listen to the radio in an average week. Commercial radio is dominant – Australians spend 17 hours 2 minutes per week listening to commercial radio, which equates to two hours and 26 minutes per day. Breakfast is the most listened-to session, reaching nearly 80% of all people each week.

In Australia, the radio audience is growing, despite the wide range of technology choices and competition for listeners' time. Commercial radio revenue has been maintained while other traditional media are seeing revenues down by up to 30%.

Radio has been successful because it is free-to-air, accessible, and remains a trusted and important part of everyday life which keeps the listener in touch with what's happening both locally and globally.

Radio revenues

In 2008, the Australian radio industry proved to be very resilient in tough times, recording similar revenue to 2007 – despite a challenging global economic environment.

During 2008, metropolitan commercial radio stations recorded only a slight decrease of about 0.1% on the revenue generated in 2007. 2009 is obviously turning out to be even tougher for everyone. So this year, Commercial Radio Australia launched an on-air campaign promoting the need to trade through the economic crisis and to continue advertising.

Advertising budgets are often cut when overall budgets are tight, so the radio campaign has been developed to encourage businesses to keep a high profile through advertising. The advertisements highlight that people are still buying things, eating out and going to the movies and that radio is a cost-effective choice in tough economic times.

This campaign is another example of how the radio industry believes in itself and is prepared to invest in its future.

Digital radio

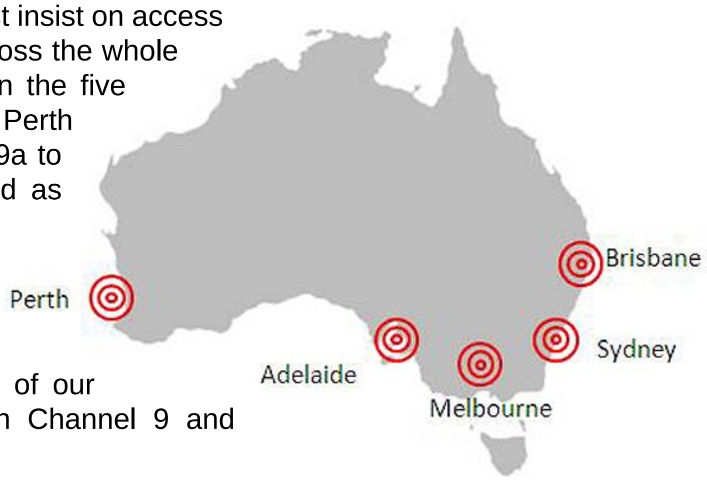
Digital radio is the next big step for radio. In Australia, and I would assume elsewhere, radio broadcasters will not sit back, with increasingly compromised spectrum, while other media move to digital platforms.

We have learned lessons from other digital radio rollouts throughout the world and we believe there are a number of key factors that will ensure a successful launch:

- the simultaneous rollout of digital radio by all major radio broadcasters in each market – that includes public and commercial;
- new and compelling content – whether it is audio or data;
- a range of affordable receivers in the market;
- major retailers to stock the new receivers;
- a good solid communication and public-relations campaign to actually tell listeners about digital radio the new services;
- a good robust coverage at high power across all of the licence areas or market;
- and, last but certainly not least ... guaranteed access to, and broadcaster control of, the right spectrum – that is, priority in the digital dividend decision-making process.

Australian launch cities

As radio broadcasters in any country, we must insist on access to spectrum that enables us to broadcast across the whole licence area at appropriate power levels. In the five launch cities – Sydney, Melbourne, Adelaide, Perth and Brisbane – we are using VHF Channel 9a to get access to what was previously regarded as "TV spectrum".



We had to put our case very strongly to the government. Cynics told us at the start that we would not be given access to Channel 9a as it sits between the transmissions of two of our powerful commercial TV broadcasters – on Channel 9 and Channel 10.

But we were determined to put radio's right to move to digital in the most appropriate spectrum and the government listened because we were certain, united and very very persistent!

Even though the five launch cities collectively cover nearly 60% of Australia's 21.5m population, we still have a lot of geographical territory to cover – and millions more people wanting digital radio services. The launch cities are just five of our 105 radio licence areas.

DAB+ ... digital future

When we move to digital and are allocated spectrum from the digital dividend, what will we do with it?

Australia has chosen DAB+ as its main digital radio technology. DAB+ is two to three times more spectrum-efficient than DAB and provides the Australian radio industry with a powerful technology which will enable a rich multimedia experience.

With DAB+, each commercial station has enough space to broadcast two digital-quality sound channels with small amounts of data ... or one very high-quality channel with a data channel.

Broadcasters have options allowing them to choose either more audio or data, or existing audio with new display features.

DAB+ is radio that can provide many new features ... not just for existing FM stations but also for AM talkback programmes (which obtain very high audience ratings in Australia):

- pause and rewind;
- extra information on-demand about advertised products;
- images;
- slideshows;
- real-time traffic advice and navigation;
- animation;
- bonus channels;
- digital-quality audio.

Australia is a sports-mad country and when you look what DAB+ can deliver in terms of sporting broadcasts – from a photo finish at a horse race, to a constant score update at a football match or cricket match ... it is impressive!

Listeners are keen to interact with their digital devices and DAB+ gives radio an opportunity to become even more interactive, with the results of live voting on a song, or issue, being shown on text and slides.

Most importantly, digital radio in Australia is free. Australians are reluctant to pay for radio!

The recent launch of a subscription satellite / internet radio service in Australia was hailed by its founder as the greatest revolution since FM radio. Just months later the organization had to down-size its workforce and is looking for additional funding to keep the service functioning.

Receivers and retailers

As mentioned earlier, one of the keys to the successful rollout of digital radio is a co-ordinated approach – not just from commercial and public broadcasters, but from retailers and receiver manufacturers as well. Consequently, many of Australia's leading retailers and manufacturers of digital radio products have joined forces as part of an advisory group to ensure a united effort in launching digital radio in the Australian market.

In addition, to encourage receiver manufacturers worldwide to test and trial their products using DAB+, Commercial Radio Australia produced a comprehensive Ensemble Transport Interface (ETI) file which contains recorded material from the Australian digital radio trial and includes up to 32 channels, slide show images, Portable Network Graphic (PNG) logos and scrolling text.

This ETI file was made available free-of-charge to receiver manufacturers all over the world to assist with the development of receivers that support the mix of audio and multimedia content and which fully showcases the capabilities of DAB+.

In addition to the ETI file, Commercial Radio Australia has also put together a DVD which illustrates broadcaster commitment and retailer support for the Australian DAB+ launch. Targeting key receiver-manufacturer decision makers, it is available in English, Japanese, Cantonese, Indonesian, Korean, Malay and Mandarin.

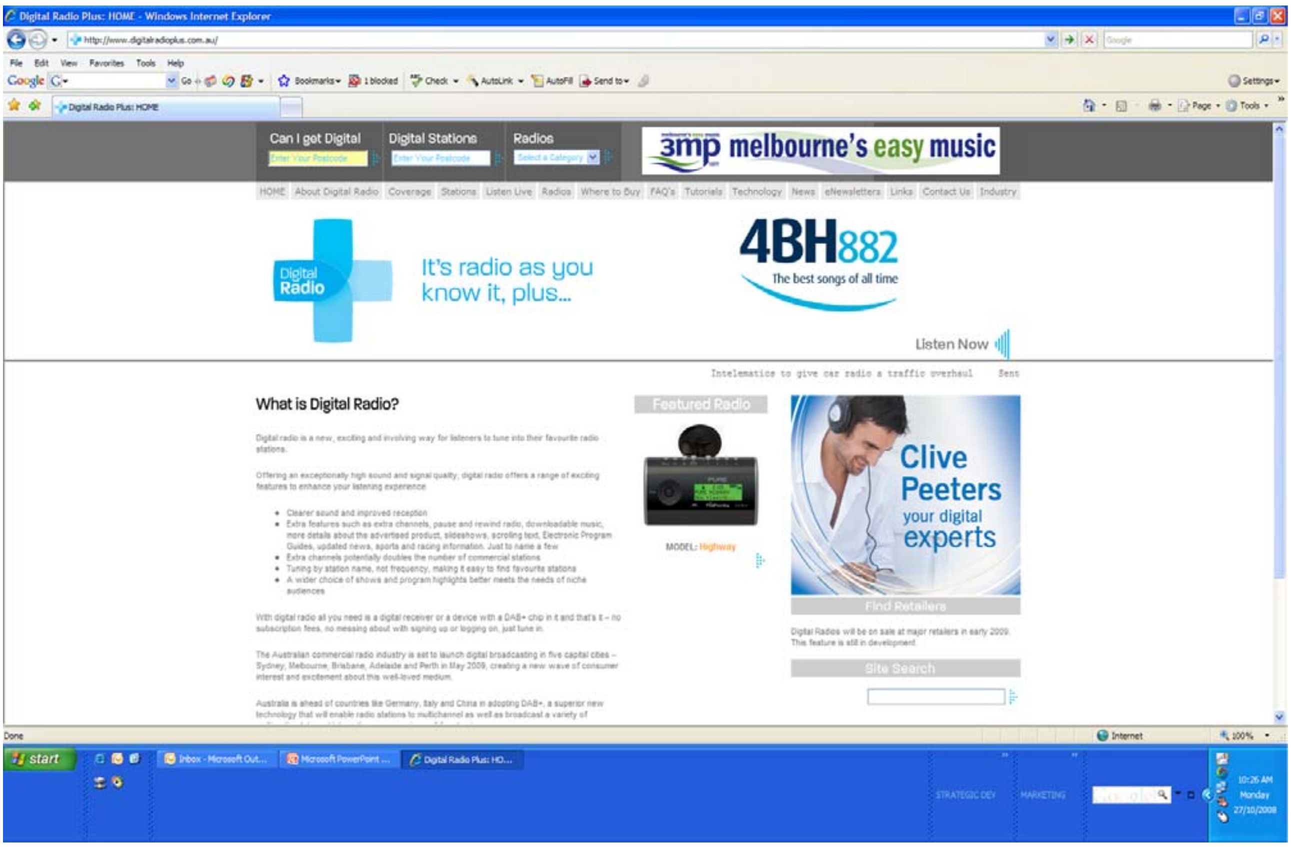
There are an estimated 50 million analogue radio receivers in Australia that we hope will be replaced over time by a new digital radio device. The receiver manufacturers are increasingly interested in supporting DAB+, as this is the standard already adopted in Australia, Switzerland, Malta and Hungary ... it is to be launched in Germany and Italy in 2009 ... and is likely to be the standard chosen in the Czech Republic, Malaysia, Indonesia, much of Scandinavia, possibly parts of China and other European and Asian markets.

Awareness campaign

The success of any new product is reliant on an effective awareness campaign. The timing of the campaign is critical. There is no use exciting the consumers about a new product until the new product is available and they can "buy" or sample it.

In Australia we used a carefully-targeted public relations campaign during the long lead-up to our DAB+ digital switch-on. We revealed our Digital Radio Plus logo and website last year to establish the brand and created **www.digitalradioplus.com.au** as the information gateway for all digital radio information. It's at this website that Australians could enter their postcode to see if they could receive digital radio in their area and where they could buy a digital radio. The site also includes training modules, for retailers and the advertising industry, about what digital radio can deliver.

In April 2009, we rolled out the $10 million industry-wide Digital Radio Plus on-air awareness campaign during the switch-on of digital radio in the markets of Sydney, Melbourne, Brisbane, Perth and Adelaide.



We will also soon be promoting a national listener event planned for 6 August 2009, which will be one of the largest radio outside broadcasts ever staged. All key stakeholders will be involved in this event, bringing commercial and public broadcasters together to highlight digital radio to the all-important listeners.

Awareness, interest and knowledge are key to getting the consumer to buy a receiver and try digital radio.

Retailers and manufacturers

Following the switch-on, the co-ordination, promotion and communication with listeners, retailers and manufacturers continues. Manufacturers have effectively incorporated our Digital Radio Plus industry logo into their promotional displays and onto product packaging.

Retailers are running in-store digital radio display competitions and including digital radio features in their product sales catalogues. The industry continues to help them with ongoing training for their retail staff about the benefits of digital radio.

Commercial Radio Australia conducts regular Retailer and Manufacturer Advisory Group meetings to ensure that two-way communication continues in the lead-up to the key Fathers' Day and Christmas retail cycles.

New DAB+ programming

Major broadcasters in Australia have already announced two new DAB+ services: *Radar* – a new music station which plays undiscovered artists with a heavy focus on Australian acts – and *Pink Radio* – a station broadcasting for three months playing Pink music, interviews and her favourite songs in the lead-up to her sell-out concerts in Australia.

Pink Radio illustrates the flexibility of digital radio and the unique sales and promotional opportunities the technology can support.

Another commercial broadcaster launched a national 24-hour, 7-day-a-week dance music station – *NovaNation* – and a mood and lifestyle-driven, chill-out music station called *Koffee*.

The public broadcaster, the ABC, will simulcast all its current services on digital, plus new DAB+ stations *dig jazz*, *dig country* and an eclectic mix of music on *dig*. We expect further digital programming announcements in the coming months from other commercial broadcasters and the other public broadcaster, SBS.

Spectrum

The industry worldwide must exhibit a strategy and plan for digital radio before a government will take spectrum claims seriously. We all are aware that the sale of spectrum is a great revenue-raiser for many governments but, as an existing medium, the radio industry must stake its claim to the appropriate spectrum to ensure a digital future.

Since 1994, the US Federal Communications Commission (FCC) has conducted competitive auctions of licences for electromagnetic spectrum. One of the US government's most significant sales of wireless spectrum last year raised nearly $19.6 billion.

The UK regulator, Ofcom looks set to change the way it auctions spectrum which is freed up by the shift to digital TV. It plans to make a wider band of spectrum available for services, such as mobile broadband. Mobile broadband will become ever more spectrum-hungry as more people use it.

In Australia over the past few years, the federal government has auctioned off the last FM commercial licences with amounts of nearly $200 million being paid for one FM frequency in a major city. The radio industry welcomed our government's announcement of the progressive switch-off of all analogue television by 31 December 2013. This will free up valuable analogue spectrum and the radio industry is lobbying the government to allocate some of the vacated VHF Band III spectrum for digital rollout across all of Australia.

Although the International Telecommunications Union (ITU) has reserved L-Band for DAB+ and Australia is keen to keep this reserved until all markets have an allocation on VHF Band III, we do not see L-Band as a suitable spectrum for Australian DAB+ and would recommend other countries to reserve VHF Band III in preference to L-Band for DAB+.

Despite our efforts to encourage manufacturers to support Band III and L-Band, there are very few receivers that support L-Band as it increases the cost of receivers and requires dual antennas.

Furthermore, L-Band is in a higher frequency range and the coverage area is much smaller ... requiring many repeater sites for a country the size of Australia. DAB+ in VHF Band III will cover a much greater area and therefore will be a more cost-effective solution.

I believe that, in any government's consideration of the digital dividend, the radio sector must not be ignored or the industry allowed to be passed over. Governments must be made aware of radio's desire to move to digital broadcasting, in clear unencumbered spectrum that will allow the full suite of free-to-air digital audio and data services to be offered.

Governments need to provide guaranteed spectrum allocations for current radio broadcasters to migrate to digital broadcasting, as a priority, in any consideration of the digital dividend.

Easy-to-access and free-to-air media such as radio is valued by the greater population and should be given precedence over new subscriber services which will only be available to those who can afford the receivers and the ongoing monthly fee.

Radio broadcasters in countries looking at future needs for digital services need to make their case ***now*** to secure spectrum for their digital future.

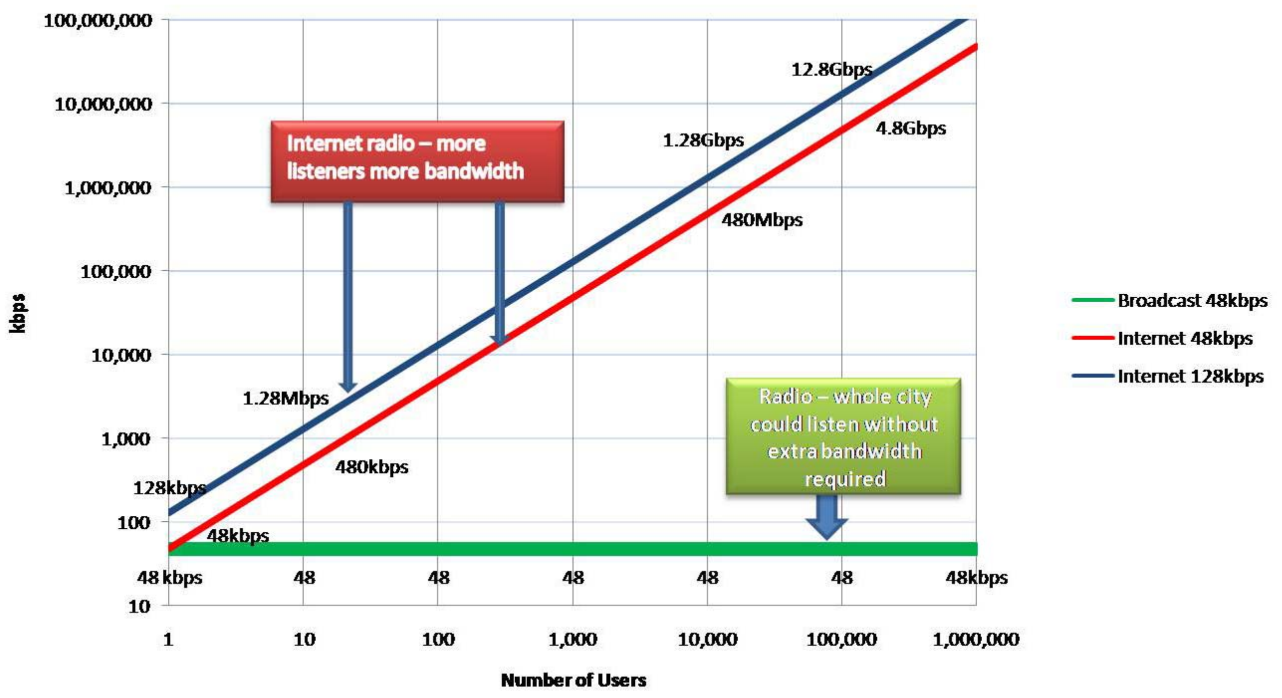
Internet radio

Spectrum is in demand from all areas and we keep being told that internet radio will overtake broadcast radio. In Australia, only 24% of the population (Dec-08 OECD figures) have broadband access and, while broadband take-up rates in homes are increasing, around 30% of radio listening happens in the car and a viable wireless internet car radio is not widely available.

The commercial radio industry acknowledges that radio and the internet are both instant, conversational media. Australian radio stations have long made use of the internet to engage and interact with their listeners and to offer additional information and interactivity.

The majority of Australian radio stations stream their free-to-air broadcast stations on the internet, as this presents another way of connecting with listeners. There are clear benefits in using radio and online together as a promotional and advertising combination but, in spite of the vociferous support from some quarters for internet radio as a *replacement* for broadcast radio, it is a fact that the internet – as a *one to millions* radio broadcast medium – requires far too much bandwidth.

The bandwidth requirements increase as the number of listeners increase, making it very spectrum inefficient. For example, 100 000 listeners @ 48 kbit/s requires 4.8 Gbit/s, while 100 000 listeners @ 128 kbit/s (i.e. Realplayer and other streaming audio players) requires 12.8 Gbit/s.



Joan Warner is the Chief Executive Officer of Commercial Radio Australia which represents 99% of all commercial radio broadcasters. She is responsible for planning for the rollout and implementation of digital radio for commercial radio broadcasters across Australia.

In her role as CEO, Ms Warner also oversees the whole of the industry marketing campaign, Radio Codes of Practice, audience survey contracts and industry copyright agreements. She is responsible for the annual National Commercial Radio Conference, Siren Creative Awards and Australian Commercial Radio Awards.

Joan Warner has worked at senior executive levels in the private and Government sectors and holds four degrees including a Master of Business Administration and a Master of Education.

Also, the internet radio infrastructure is built on a per-listener basis ... so more listeners = more servers = more cost! For example, you could support around 1000 listeners per server, in which case 100 000 listeners would require 100 servers! 300,000 listeners, a typical per-hour metropolitan breakfast radio audience in Sydney, would require 300 servers and a huge amount of bandwidth.

Digital radio, when broadcast to a city such as Sydney, requires only 48 kbit/s audio or 64 kbit/s for audio plus multimedia programme-associated data.

There are some views that digital radio is too late and we will be overrun by internet radio stations. Commercial radio in Australia disagrees ... not only for the reasons set out above but also because of its convenience, no cost and localism. We are yet to be convinced that internet radio is a threat: rather, it is supplementary to free-to-air broadcasts.

Radio as you know it ... Plus

I've outlined where radio is heading, why we must be in the digital space, how we can capitalise on digital radio and why radio broadcasters cannot afford to be overlooked by governments who are considering what to do with vacated TV spectrum.

Our job as radio broadcasters – who offer a robust, anywhere-anytime, free-to-air information and entertainment service – is to make sure radio does not miss the digital boat.

We must position radio to compete with other digital technologies and maintain radio's relevance in our listeners' lives. It's time to plan for the future and make governments aware of our right to a digital future.

That can only be achieved by the right policy settings, plus access to the right spectrum. Radio broadcasters must make sure they are beneficiaries of the digital dividend.

Implementing Receiver Profiles — the evolution of modules for digital radio

Mark Hopgood
Frontier Silicon

Since 2002, Frontier Silicon has shipped over 8.5 million DAB "solutions" (chips, modules, etc.) which are today used in more than 450 digital radio products.

This article describes how the company is implementing the new WorldDMB receiver profiles for digital radio in its latest generation of products, based on the Chorus chipset and Venice range of modules.

The UK's digital radio market has come a long way in the space of seven years, since Frontier Silicon shipped its first DAB module in July 2002. It was the Chorus FS1010 processor which even then was a super-integrated low-power system on a chip (SoC), aimed at delivering a highly flexible and efficient solution for multimedia and communication applications such as digital radio, portable music players, and home / in-car audio and multimedia.

This SoC was able to run multiple applications including the concurrent processing of digital radio and other multimedia tasks. Its processing power and programmability enabled it to be used for demanding application-specific functions such as surround-sound decoding, audio encoding or advanced data-service decoding.

Now we have now come to a point where the evolution of this first processor, through several generations of technology, allows us to springboard to the next generation of digital radio capabilities – beyond the original DAB standard for which it was designed.

In this article, we will outline the evolution of chips and modules for DAB digital radio and how this puts us in a position of being able to help define and implement the new standardized WorldDMB receiver profiles. The benefits and advantages of these receiver profiles were highlighted in the last issue of *EBU Technical Review* in the article "One Digital Radio across Europe" [1] by Quentin Howard, President of the WorldDMB Forum.

Taking this a step further, we will look at how the new receiver profiles allow us to deliver modules to address both the transition from DAB to DAB+ in the global take-up of digital radio, and the subsequent convergence to hybrid DAB, DAB+ and internet / Wi-Fi radios with full colour multimedia capabilities.

Behind the scenes – the technology ecosystem

The UK has been a model DAB market in which the whole ecosystem – from the content producers and broadcasters, to the brand manufacturers and technology providers – has worked together to

1. http://tech.ebu.ch/docs/techreview/trev_2009-Q1_DAB-Rx.pdf

build both a thriving industry as well as a range of products that the consumer (the listener) has come to appreciate and demand.

Right at the heart of this ecosystem is the enabling technology. This comes in the form of the chipset that provides the radio front-end, plus the baseband processor for decoding the incoming DAB signals; this combination of components can be packaged at a higher level as a complete module, comprising both hardware (the chipset) and software. At an even higher level, the module can be designed onto a complete reference platform which is available to manufacturers to use for quickly developing their own radios – with some level of customisation.

At the next level of the ecosystem is the audio system manufacturer – typically this will be one of many contract manufacturers in the Far East – who will take either the chips, modules or platforms, and then build a radio to a specification as laid down by their "customers" who are typically the consumer brands like Sony, Philips or Grundig.

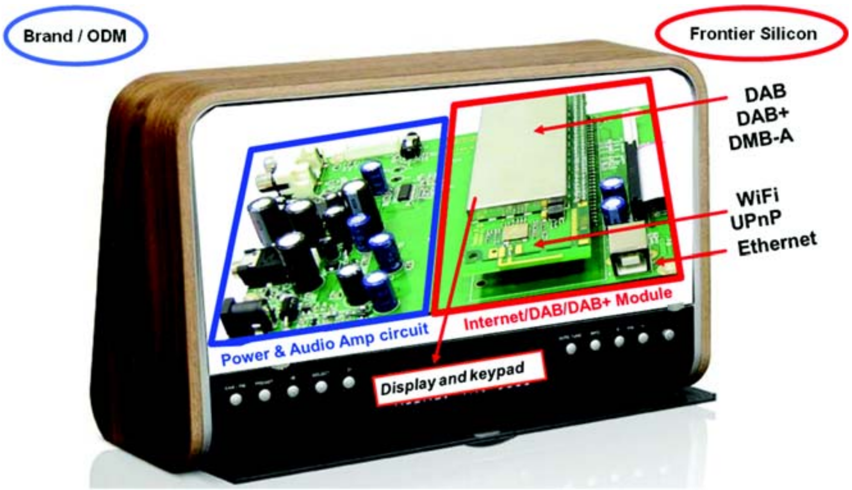


Figure 1
The building blocks of a typical digital radio

The highest level in this ecosystem is the retailer, who is the interface to the customer or end-user.

In *Fig. 1*, the areas bounded by the red line are effectively the section of the radio which Frontier Silicon's technology provides.

The chips and modules that powered the UK's DAB explosion

Frontier Silicon has to date shipped over 8.5 million DAB solutions in over 450 products. When we talk about 'solutions', this is a broad term covering several different forms of product available in the market – from chips, to modules, software and platforms.

The chip / chipset

The chip or chipset forms the basic building block and, in the case of Frontier Silicon, this is in the form of the Chorus baseband processor.

The first version of the Chorus chip started as a super-integrated, ultra low-power single-chip digital radio baseband IC (integrated circuit) with extensive on-chip peripherals, and the first generation launched in 2002 was optimized for Eureka-147 DAB decoding. It is programmable and flexible, based on the multi-threaded META™ DSP and general-purpose processor core from Imagination Technologies. The main benefit of this product was and still is the fact that, for a complete DAB implementation, all that was required to build a complete radio is an external front-end RF device, audio digital-to-analogue converter, FLASH memory to boot the system, and a keypad / display. Through the multi-threaded META™ DSP, the Chorus processor chip handles real-time radio demodulation and user-interface processing on the same processor.

The latest generation of this processor in development is the Chorus 3 processor, in which Frontier Silicon recently announced the initiation of a $10m investment to deliver an ultra low-cost and lowerpower device that will help drive the successful migration to DAB digital radio over the course of the next ten years, following the publication of the UK's Digital Britain report and the plans for other countries to migrate to digital radio over the next few years.

The chip is an advanced programmable baseband receiver, optimized for the WorldDMB profile 1 and profile 2 broadcast receivers, offering DAB, DAB+, DMB-A and FM-RDS, as well as being able to receive and decode internet radio streaming audio. It incorporates a number of mixed-signal system components as well as advanced peripherals previously only available as discrete additional components – providing significant space, cost and power savings (50 percent saving on both cost and power consumption). This offers a greener form of technology and it is expected to be the first of its kind to support all types of DAB radio – which means it is particularly suited to the car industry's plan for a pan-European receiver design.

The CPU provides the processing power to receive digital radio, decode internet media and operate the user interface in the system. It is powerful enough to be the master processor in any digital radio system. Frontier Silicon anticipates that this new chip will be shipping to receiver manufacturers by the second half of 2009.

The modules

Frontier Silicon has worked with radio manufacturers from the outset to enable digital radio solutions that they can easily produce and get to market quickly, based on defined consumer needs. The modules, based on the Chorus chips, are aimed at systems designers who do not necessarily work at chip level, and include all the interfaces necessary so that manufacturers can simply add a power supply, display, keypad, audio amplifiers and speakers to produce a fully functional DAB radio *(see Fig. 2)*.

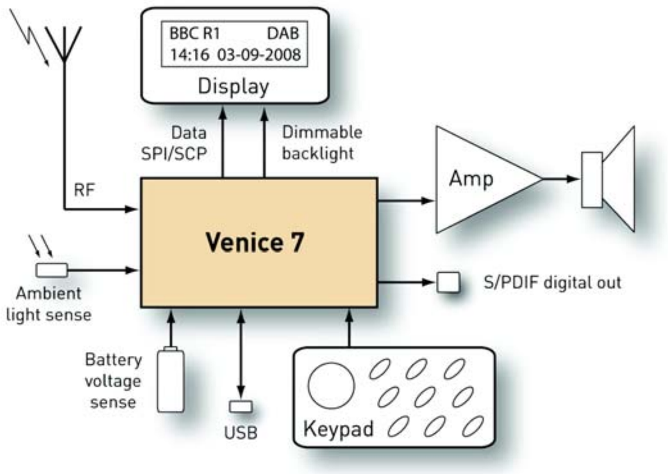


Figure 2
A complete digital radio can be build using Frontier Silicon's Venice digital radio modules

Throughout this evolution of modules, the products were always drop-in compatible with previous generation radios, which ensured that manufacturers could quickly upgrade existing models – adding, in succession, differing levels of radio capability from DAB to DAB+, DMB-A, FM-RDS, Wi-Fi, USB 2.0, mp3, WMA and AAC+.

The Venice range of modules developed by Frontier Silicon has met a variety of needs as the requirements for digital radio have evolved and as costs and power consumption of the technology has come down. For example, in June 2005, the Venice 3 module was introduced to enable up to 60 hours of battery life, and to drive greater penetration of DAB into portable digital radios. At the time, this was an ultra low-power tri-band DAB digital radio receiver module which also integrated an FM radio receiver with RDS in the same chip. The power consumption of Venice 3 was less than half of existing solutions, and manufacturers could significantly reduce system costs as no extra components were required to implement FM/RDS, and no additional microprocessor was required to implement high-end radio features such as the 'DABplus' electronic programme guide and rewind radio.

The Venice 5.1 module introduced in March 2008 was the first to enable the new DAB+ standard for emerging digital radio markets. The Venice 6 module launched in February 2007 was the first to offer a complete hardware and software module solution for Internet radio, network streaming, DAB/DAB+ and FM-RDS products. It provided the simplest and lowest cost solution for high-quality audio streaming from live Internet radio stations or network-based music collections. Several configurations were made available, with different combinations of integrated RF receivers for Wi-Fi networks, DAB Band III, L-Band and FM reception.

The latest generation of the internet radio module currently on the market is Venice 6.2 *(see Fig. 3)*, launched in October 2008, which provides comprehensive codec support plus enhanced music player functionality, bringing top-end Hi-Fi and audio system technology to a low-cost platform for use in mass-market connected audio devices.

Figure 3
The Venice 6.2 module provides a fully connected audio solution (internet radio), plus a DAB, DAB+, DMB-A and FM-RDS receiver

This module has moved to a full chip-down design to reduce the cost of implementing Wi-Fi radio and is a plug-in replacement for Frontier's Venice 6. Connectivity is also improved with this module, by delivering support for manufacturers wanting their products to meet requirements for home network and audio playback certification programmes, including iPod and iPhone interfacing. Venice 6.2 includes Wi-Fi antenna options and Digital Rights Management, in addition to optional DAB, DAB+, DMB-A and FM-RDS.

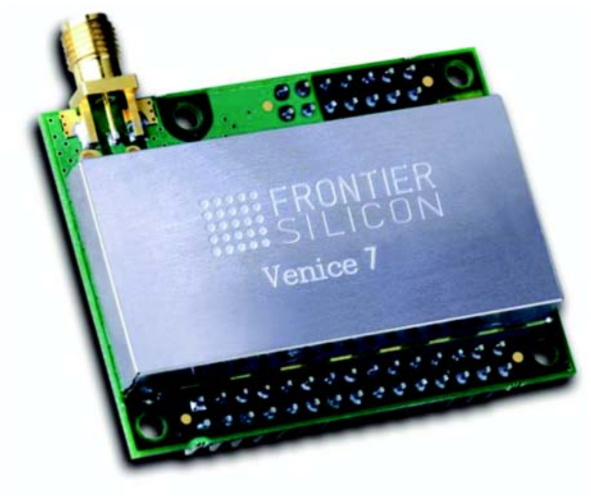


Figure 4
The Venice 7 module enables WorldDMB Receiver Profile 1 radios at the same cost as today's DAB radios

One of the most important aspects of the Venice 6.2 module in the migration to next-generation digital radio is that it conforms to WorldDMB Receiver Profile 1, with support for various digital radio broadcasting standards. Extended music player functionality – including trick play controls, gapless playback and metadata rendering – is also enabled on a graphical 128 x 64 pixel LCD display.

Another new module is Venice 7 *(Fig. 4)*, which enables manufacturers to produce Profile 1 receivers for the same price as today's DAB-only radios – it is the first in a new generation of digital audio products to provide additional features and enhanced performance in a plug-in replacement package for the world's bestselling DAB module, the Venice 5. The new Venice 7 is designed for worldwide application, to enable production of high-performance dual- or tri-band DAB/DAB+/DMB-A/FM receivers at low cost; it operates in master mode for stand-alone radios, or in slave mode under the control of an external microcontroller for more complex audio systems.

The Venice 7 module is electrically and mechanically compatible with Venice 5 *(see Fig. 5)*, and includes an additional connector for extra features and interfaces such as USB. Again, the module keeps up the principle of providing all interfaces necessary for a fully functional radio, needing only power supply, display, keypad, audio amplifier and speakers to complete a product.

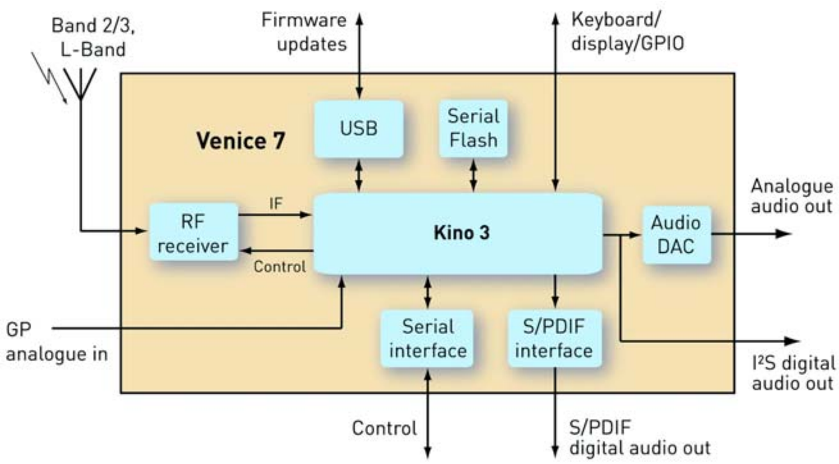


Figure 5
Venice 7 block diagram: the first in a new generation of digital audio products to provide additional features and enhanced performance in a plug-in replacement for the world's bestselling DAB module, the Venice 5

Abbreviations

CAD	Computer-Aided Design	**DMB-A**	DMB - Audio
CPU	Central Processing Unit	**DSP**	Digital Signal Processor
DAB	Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/	**ODM**	Original Device Manufacturer
		OEM	Original Equipment Manufacturer
DAB+	DAB using the AAC codec	**RDS**	Radio Data System http://www.rds.org.uk/
DMB	Digital Multimedia Broadcasting http://www.worlddab.org/	**SoC**	System-on-Chip

Software

The software on Frontier Silicon's modules is configured to customer requirements and is pre-installed in the module's Flash memory. Software builds are available for the module to be used as a host, or as a slave under control of a host microcontroller. A full suite of customisable application software on most modules includes software FM with RDS, clocks, multiple alarms/timers, presets, support for rotary encoders and support for a 2-line display with icons.

On the latest generation of connected audio modules (Venice 6.2), Frontier Silicon also provides the IR2.0 software, a comprehensive software stack for Internet radio and DAB, enabling network connectivity – either wired via Ethernet or wireless using IEEE 802.11b/g. The software also provides audio decoding in mp3, WMA, AAC and Real formats, an advanced user interface for control and content browsing, and a system management function that includes network discovery and system configuration. The user interface can be further customised for the OEM or ODM, in order to provide a unique appearance and to enhance the user experience.

Platforms

At the highest level in the digital radio technology ecosystem, Frontier Silicon provides digital audio reference platforms which manufacturers can use as a fast-track route to introducing brand new radio designs using the latest audio technology and with the lowest-possible bill-of-materials and time-to-market. These platforms are primarily available as complete CAD design data, and also as physical samples in small quantities (useful for evaluating the Venice modules). They may be used as-is, modified, or as a starting point to speed development of custom OEM products.

All platforms are production-ready, based on Frontier Silicon's Venice range of DAB/DAB+/FM modules (featuring Chorus-based chipsets and modules), and together cover a wide spectrum of audio system types, from low-cost DAB radios and CD players to the most sophisticated yet simple-to-use mp3, network and Internet streaming systems. Each platform design includes customisable software, and needs only a keyboard, display, case and power supply to finish off a complete high-quality audio system.

Matching module development to receiver profiles

As detailed in the 2009-Q1 edtion of *EBU Technical Review*, WorldDMB – the global standards authority for digital broadcasting – together with the European Broadcasting Union had last year published details of a standard set of digital radio receiver profiles that have been agreed with wide support from the industry (e.g. EICTA / Digital Europe). These profiles will ensure that digital radio and data services are common across Europe and will benefit receiver manufacturers, consumers and countries looking towards a digital broadcasting switchover.

In summary, Profile 1 is targeted at standard radio receivers and will represent the largest market segment for DAB/DAB+/DMB-A unified digital radios. Profile 2 provides additional rich-media capability for devices with a colour display. The third profile, the multimedia receiver, will demand a more sophisticated device that is capable of rendering video and is targeted more towards mobile phone and advanced in-car entertainment systems.

As the market-leader in digital receiver technology and a member of the World DMB Receiver Profile Task Force, Frontier Silicon helped define the profiles outlined by World DMB and fully endorses the categories of devices specified.

Frontier Silicon is aligned with both the standard receiver profiles as well as the major broadcast launches around the world. For example, prior to the publishing of the receiver profiles, the company had already developed its first DAB+ module (the Venice 5.1), to enable manufacturers to get ready with products for the Australian launch of DAB+ digital radio services. The next generation of this module (Venice 7) meets the Profile 1 requirements and is even more cost-optimized and features integrated memory, to provide a low-cost drop-in replacement for existing Venice modules – enabling a fast upgrade path for the majority of radios already on the market.

The next generation of connected audio modules – in other words, fully-featured DAB/DAB+/DMB-A radios with additional internet/Wi-Fi/streaming radio capability – has also been announced and is expected to hit the market later this year with full Profile 2 features. This will be in the form of the Venice 8 module, which will enable a completely new consumer experience from digital audio broadcasting technologies – it adds multimedia functionality and increased data information to digital radios.

This module is already being developed in a unique touch-screen full-colour audio-visual system that marks a major step forward in digital radio capabilities. The new “Touch Radio” is being developed by Frontier Silicon in conjunction with several leading broadcasters and manufacturers who are discussing how to adopt the system, known internally as “Advanced DAB”.

Once fully launched, Touch Radio will enable users to:

- access a media-rich electronic programme guide;
- view a slideshow depicting station ID and imagery;
- tag and store information on featured products via interactive advertising;
- tag and store information on favourite music tracks for purchase;
- watch real-time traffic information and receive updates on public transport.

The screen shots in *Fig. 6* show some of the typical user-interface images that can be displayed in the Touch Radio using the Venice 8 module.

Currently, Frontier Silicon is working in partnership with the BBC, Global and TrafficMaster to define the look-and-feel of Profile 2 radios. Utilising Frontier’s colour 320 x 240 display with touch-screen interface using the Venice 8 module, the current demo showcases features such as Slideshow, EPG and TPEG, as well as RadioTag to illustrate an interactive advertising application.

Figure 6
Screen shots showing multimedia capabilities of the new Touch Radio

Mark Hopgood is Director of Marketing at Frontier Silicon Limited, working at their headquarters in the UK. He has over 10 years of experience working in the semiconductor industry and is currently responsible for Frontier Silicon's product roadmap.

Prior to joining Frontier Silicon in 2005, Mr Hopgood was Strategic Marketing Manager at Sony Semiconductor, responsible for developing their European and US DVB-H strategy. He graduated from Brunel University in London with a B.Eng. (Honours) in Microelectronics Engineering, specialising in ASIC system architecture design. He is a regular presenter at industry forums throughout the world, providing a considered insight into the challenges facing the semiconductor industry today in the dynamic and highly motivated digital radio market.

One of the other areas that Frontier Silicon is working on is product development of a cost-effective single- and dual-tuner solution for car OEMs that meets with automotive Profile 1 and Profile 2 for in-car radios. The dual-tuner configuration enables uninterrupted reception of the TPEG data channel while listening to the radio.

Multimedia connected audio vision: taking radio to the next level

DAB is a proven technology already available in volume – and growing at around 2-3 million radio sets per year. In various forms it is being adopted by other countries, with Australia, France and Germany already having plans for the roll-out of DAB+ or DMB-A, and other countries like Italy releasing Band III spectrum for digital radio, predicated around the WorldDMB Profile 1 and 2. The latest Frontier Silicon modules enable receiver manufacturers to produce low-cost radios which are interoperable between countries in Europe as well as Australia.

The introduction of WorldDMB unified radio receiver profiles removes the roadblocks in providing a migration to digital radio in many parts of Europe, providing economies of scale through a set of standards that are adopted by a pan-European market. This helps to drive down the costs of manufacturing (for suppliers) and also the roll-out cost (for operators and broadcasters). The new profiles also enable the delivery of a wide range of receiver types to the consumer.

In addition, the rich media Profile 2 radios will take digital radio to the next level, with multimedia services delivered on colour screens. Frontier Silicon sees the future of digital radio being a hybrid of broadcast digital radio as provided by the various standards around Eureka 147 and the emerging internet radio which is becoming more popular. The union of broadcast and internet radio opens up exciting new possibilities and, with the availability of Profile 2-based multimedia features, this provides new rich-media features to listeners with services that sit somewhere between what they are used to with television, and beyond what has traditionally been possible with just radio.

This means that, with modules such as those that Frontier Silicon has planned for introduction between 2009 and 2010, there is great scope for a wide choice of radios that provide DAB, DAB+, DMB, FM and internet radio, and with enhanced levels of interactivity enabled by the Profile 2 features together with Wi-Fi.

For manufacturers, the availability of standardized modules which can be drop-in replacements for existing DAB radios means that they can assure broadcasters and operators that products can be rapidly deployed and therefore the listener base can also be quickly grown and developed.

Frontier Silicon's vision is that unified digital broadcast radio, in conjunction with internet streaming and interactive technology, will drive the growth of digital radio as countries migrate to digital in the next few years.

TV Displays

— a progress report

Richard Salmon
BBC Research & Development

In the 5 years since my first Technical Review article on television displays [1], we have seen the domestic TV environment change out of all recognition, as Liquid Crystal and Plasma displays have essentially displaced the CRT (Cathode Ray Tube) completely, in terms of sales.

This article covers the latest developments in the displays market, as we move into a world where manufacturers are prototyping a variety of different technologies and where 3D displays are also starting to appear.

In the domestic market, ***Liquid Crystal Display*** (LCD) and ***Plasma Display*** technologies have continued to evolve. Average screen sizes have now moved beyond 32 inches diagonal, and 37 or even 42 inches is foreseen as the biggest market segment in the very near future. Simultaneously, the largest practical sizes for domestic use have risen from 50 inch to 57 and even 65 inches over the past five years. The market has also evolved to provide higher resolution panels. Whilst most larger panels 5 years ago were 768-line devices, now no manufacturer can avoid the pressure to advertise “Full HD 1080” or some such wording.

Whilst the EICTA / DigitalEurope HD-ready logo had found widespread acceptance as a guarantee that a TV set would display an HD signal when the broadcasts started, the next step – the HD-ready 1080 logo – appears not to have achieved the same acceptance, which is unfortunate. Whilst a manufacturer’s own “Full-HD” logo indicates that the display has indeed got 1080 lines of pixels, it does not go as far as to guarantee that the TV will be compatible with 1080p50 signals from a set-top box or 1080p60 from a games machine.

Current trends

With plasmas also now tending to offer 1080-line resolution at most sizes, it might be thought that they would be well placed to compete with LCD in the larger screen sizes, but the plasma panel

1. R. Salmon: **The changing world of TV displays — CRTs challenged by flat-panel displays**
EBU Technical Review, April 2004
http://tech.ebu.ch/docs/techreview/trev_298-salmon.pdf
Also published as BBC R&D White Paper, WHP 089.

manufacturers are finding it hard to justify investment in the current climate: this year sees Pioneer (who had already absorbed NEC) and Fujitsu Hitachi pulling out of plasma panel manufacturing, leaving Panasonic as the only Japanese plasma panel manufacturer. However, Panasonic has made the investment required to bring the next generation of Plasma displays to the market, and the NeoPDP results in a big cut in power consumption, and thinner and lighter panels, all increasingly important factors.

But cutting the display power consumption has also been on the agenda for LCD manufacturers, and their massive dominance in the market remains, with recent investment in new plants now coming on line. With the ever-reducing manufacturing cost remaining the main focus for LCD panel producers, Sharp put a $3.2bn factory into production [2] in March 2009, which can produce eight 57-inch panels from a single 2.8m x 3m substrate, bringing still greater economies of scale. However, that will be Sharp's last Japanese factory; in April 2009 the company announced that, in the future, investment in new manufacturing capacity will be through partnerships outside Japan which, given the relatively high costs of both labour and land within Japan, can hardly be a surprise.

With the 42-inch market becoming increasingly competitive, manufacturers are introducing models in the 46 - 47 inch range – to bridge the gap below 50 inches. The inexorable rise in average screen size appears set to continue, which really is the main driver for broadcasters to invest further in HDTV.

Whilst the rear-projection TV was never a big feature of the European market, it was starting to achieve a small foothold about 3 years ago, thanks to its ability to offer large screens at low cost. With the flat-panel technologies having cut their costs, and the marketplace demanding flat panels to the exclusion of anything else, rear projection is now almost dead even in its traditional stronghold of North America.

A big growth market for displays has been in advertising panels, where the ability to have a moving or changing image is much more attractive to advertisers than a traditional poster, particularly in high-value locations. Whilst this has no immediate bearing on the TV market, it is another outlet for the manufacturers, enabling economies of scale in the larger display sizes, where the TV market has been constrained in the past by significantly higher prices.

The "new" technologies

A variety of new technologies have been shown in prototype form over recent years. Prior to the economic downturn, several of them looked set to give Plasma and LCD a run for their money. However, now that the money has itself run away, no company is really in a position to invest in new technologies on the scale required to make a significant inroad into the TV display market.

What has happened to TDEL and SED?

Thick-film Dielectric Electro-Luminescent (TDEL) technology looked very promising five years ago, with an impressive 34-inch full-colour prototype on show from iFire [3]. Capital investment was however not forthcoming to set up the planned pilot manufacturing plant but, towards the end of 2008, the iFire technology was sold by Westaim to a Canadian-Chinese joint venture, CTS Group. Further developments are now awaited.

Surface-conduction Electron-emitter Display (SED) technology also looked very promising until two years ago but patent/licensing problems caused the suspension of the Canon-Toshiba joint venture, and a loss of impetus. The legal wrangles are apparently now solved (in December 2008,

2. http://kn.theiet.org/news/jan09/sharp-LCD-centre.cfm
3. http://www.ifire.com/

Applied Nanotech announced that they would not be appealing against the court decision that ruled in favour of Canon in July 2008), but the opportunity to go into production has been lost and we wait to see whether this technology will eventually be able to fulfil its evident potential.

Abbreviations

1080p/50	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 50 frames per second
1080p/60	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 60 frames per second
CRT	Cathode Ray Tube
DLP	Digital Light Processing
EICTA	European Information, Communications and Consumer Electronics Technology Industry Association Now known as *Digital Europe* **http://www.digitaleurope.org/**
FED	Field Emission Display
LCD	Liquid Crystal Display
LTPS	Low-Temperature Poly Silicon
OLED	Organic Light-Emitting Device (Diode)
SED	Surface-conduction Electron-emitter Display
TDEL	Thick-film Dielectric Electro-Luminescent
VFD	Vacuum Fluorescent Display

The other new technologies (FED and OLED)

The last couple of years have seen a resurgence of interest in **Field Emission Displays** (FEDs) – similar in many ways to SEDs in that electrons are accelerated across a small gap to emit light from a phosphor. In particular, electron emission from Spindt tips has come to the fore again (FED has its origins in 1958, with Spindt emission dating from 1968, so maybe this does not really qualify as “new technology”!).

FET Inc [4], a spin-off from Sony, was set to purchase Pioneer’s old plasma display factory earlier this year, but lack of financial backing caused this development to be abandoned in March 2009. This is very disappointing, since Ikegami had demonstrated a very promising prototype monitor based on a prototype FET Inc panel.

Futaba [5], known for their Vacuum Florescent Display (VFD) modules (which are not a candidate for TV displays) have their own research into Spindt-based FEDs, and are reported to be continuing this line of development.

Although Samsung has demonstrated a 40-inch **Organic Light-Emitting Device** (OLED) display, and has hinted at a 50-inch version this year, the company does not expect OLED to become a mainstream product for 4-5 years. The major problem is how to create the larger screen sizes needed for TV. Because OLED is an emissive technology, the electrical current required to generate the light has to be supplied via the active matrix backplane technology. (In an LCD, the main power dissipation is in the backlight, not in the display matrix.) LTPS (low temperature poly silicon) is therefore the usual backplane technology, but is limited in the substrate sizes achievable to twenty-something inches, and larger displays have typically been made by “tiling” several panels together. However, OLED displays have recently been demonstrated on amorphous-silicon / micro-crystalline-silicon backplanes [6, 7].

The development of Organic LED displays has matured to the extent that OLED TV displays have made it into production. Marketed as 3mm-thick “Organic” panels, the 11-inch diagonal Sony XEL-1 is on sale in Japan *(as pictured in Fig. 1),* and in the USA with a low-key presence in the European market [8]. Also demonstrated as a prototype viewfinder for Sony's HD and CineAlta cameras, the

4. **http://www.fe-tech.co.jp/**
5. **http://www.futaba.com/**
6. T. Tsujimura et al: **A 20-inch OLED Display Driven by Super-Amorphous-Silicon Technology** SID Digest, Vol. 34 (May 2003), pp. 6 – 9.
7. F. Templier et al: **Development of nanocrystalline silicon thin film transistors with low-leakage and high stability for AMOLED displays** IDMC2006 Digest, p. 1705.
8. **http://www.sony.co.uk/product/tvp-oled-tv/xel-1**

Figure 1
Sony XEL-1 11-inch OLED on sale in Japan

OLED panels are impressive and attractive, but are still some way from making a major impact in the TV market.

Developments in Plasma Display Technology

Whilst the Panasonic NeoPDP design is aimed at ensuring a continued competitive position for Plasma, there is also a radical new plasma display from Shinoda. This display consists of an array of vertical tubes, each one acting as a column on a conventional display – but with better separation and greater flexibility, both in manufacturing and in the display configuration, thus enabling a semi-circular display to be formed in a continuous curve.

The demonstration so far has been of a 125-inch display, just 1mm thick. Not intended at present for TV applications, the initial market will clearly be for digital signage, but it is a very interesting development none the less. News of how the development of a product is progressing however has been hard to obtain, so this is another "wait and see" situation.

3D displays

Significant interest has been shown in 3D displays in a variety of configurations, with many stereoscopic 3D-ready back projection and plasma screens already sold in the US market, and 3D-equipped cinemas now using DLP projectors with, usually, polarizing glasses.

3D displays may be divided into a number of different categories:

1) **Volumetric displays** – a real image is formed in 3D space, providing an infinite number of simultaneous views. This avoids many of the issues with 3D viewing which are frequently experienced with other technologies, but is a very difficult technique to use for television.

   Wave-front reproduction (often called a holographic display) might be thought of as the ultimate form of 3D display, but practical implementations which are able to give high-quality images are some way into the future.

Integral Imaging is part-way towards this, and is essentially a multi-view display with a very large number of views, of which HoloVizio is one example [9].

2) **Auto-stereoscopic displays** fall into two varieties, both allowing the viewer to see "parallax" as the head is moved.

- **Head-tracking displays** which provide an image to each eye appropriate to the viewer's head position. Head-tracking displays for a single user are already feasible, and research on tracking and providing images for multiple viewers is advancing. Fraunhofer's Heinrich-Hertz Institut (HHI) [10] is heavily involved in leading the collaborative work in this area.

- **Multi-view displays** allow the users to move their head within a certain zone, and their eyes see different views depending on where they are within that zone. Until displays become available with vastly greater pixel counts than are available at present, multi-view systems suffer from relatively low resolution in each view. Philips has had a 9-view product [11] in this area, and has shown a 46-view prototype based on a 4k horizontal-resolution panel. However Philips has recently announced that it is ending commercial activity in this area, but is continuing with collaborative research projects in this field.

3) **Stereoscopic displays** present two views, one for each eye, and are the major market at present. There is a variety of different techniques.

- **Barrier or micro-lens based techniques**, essentially the same technology as multi-view displays, but with only two views, where the viewer is required to keep their head still, but does not need to wear special glasses.

- **Glasses-mounted micro-displays**, with individual displays dedicated to each eye.

- **Spectral separation with glasses**. The simplest form is the old-fashioned red/green anaglyph, but more sophisticated versions giving better colour reproduction are now being demonstrated. It is possible to obtain full colour reproduction by using two spectrally-separated primaries for each of red, green and blue, with notch filters or interleaved comb filters in the glasses matched to separate pairs of primaries. Currently the preserve of digital 3D cinema systems, such a technique could be applied to domestic installations.

- **Polarization separation** – either diagonally or circularly polarized for each view, with appropriate polarization in the glasses. Zalman [12] (in the games area) and Hyundai/Arisawa [13] (for TV) are the most readily-available polarizing displays. These are usually based on LCD technology.

- **Time-sequential with synchronized shuttered glasses**, such as those from LG, Mitsubishi and Samsung. Early displays of this type were back-projection DLPs, but now plasma is dominant in the domestic environment, with a substantial number (a few million) such displays sold in the USA.

The last two types of stereoscopic display, both with glasses, are the most common types in the market at present, although not yet widely marketed in Europe. In both cases the quality of the 3D effect depends largely on the level of perceived crosstalk between views (i.e. visibility of the right view to the left eye and vice-versa), and is dependent on the display and the glasses, in combination. If the display knows the characteristics of the glasses, then some cross-talk can, to an extent, be pre-corrected in the signal.

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9. http://www.holografika.com/
10. http://www.hhi.fraunhofer.de/
11. http://www.dimensionalstudios.com/philips_20_3d_4you_display.html
12. http://www.zalman.co.kr/eng/
13. http://www.arisawa.co.jp/en/product/3d.html

This present survey of displays cannot go into the many issues surrounding 3D TV. For more details on the challenges of bringing 3D to the domestic TV market, the reader is referred to BBC R&D White Paper 173 [14].

Aspect Ratio

Just as everyone is getting used to 16:9 widescreen, we have from Philips the launch of a "Cinema 21:9" [15] Ultra-widescreen 56-inch diagonal LCD screen (with the same height as a 16:9 screen of 45-inch diagonal), *seen in the publicity photo above*. It is understood that the intention is that TV material will be presented on it with a non-linear horizontal stretch (although the user will have the choice of how to display such images).

As screens get larger, it seems inevitable that TV formats in the future will continue the progression towards wider images since this better matches the human field of view and suits the horizon position for a screen occupying a significant proportion of a domestic room wall. However this new Philips model is not in the largest size category, and is clearly aimed at the home-cinema market, and so viewer reaction to its use for TV viewing, and the market reaction from other manufacturers, will be interesting.

Conclusions

The current economic conditions will probably result in a period of relative stability in terms of display technology. LCD appears secure in a dominant position. It is not only potential new entrants to the field which find it hard to match the huge economies of scale and market dominance which LCD has

14. BBC R&D White Paper WHP173: **The Challenges of Three-Dimensional Television**
    S. Jolly, M. Armstrong and R. Salmon, January 2009
    http://www.bbc.co.uk/rd/pubs/whp/whp173.shtml
15. **http://www.cinematicviewingexperience.com/press.html**

Richard Salmon is chairman of the EBU project group P/Display, which is producing guidance to broadcasters regarding the use of flat-panel displays in TV production environments, guidance to consumer display manufacturers on how the broadcasters expect the TV display to present their broadcast images, and defining the broadcasters' requirements for professional monitors. He has been involved in many different projects over the years, with a particular interest in displays, colorimetry, video compression, video watermarking, HDTV, visual perception and video systems engineering. He has also spent six months on attachment to NHK's Science & Technical Research Laboratories in Japan, working on Plasma Display technology.

Mr Salmon is a Senior Research Engineer, and has worked at Kingswood Warren (BBC Research & Development) since graduating from the University of Cambridge in 1987. He is active in the UK DTG's HD displays and professional monitors groups, and is a member of the Society for Information Display, the SMPTE and the IET.

achieved, but even plasma display technology finds itself under pressure, following the effective demise of back-projection displays from the TV market.

OLED technology appears the most likely challenger for the future, but is unlikely to seriously challenge LCD for some 5 or even 10 years to come.

Display measurement

— a simple approach to small-area luminance uniformity testing

Felix Poulin and Maxime Caron
CBC / Radio-Canada Technology

To address the need for a more exhaustive luminance uniformity test for video displays, this article proposes a small-area uniformity method. In addition to the benefits of the currently recommended large-area uniformity, a small-area uniformity test can help identify sudden changes in luminance and also identify problematic areas and patterns.

Scope of the test

Under pressure from the discontinued CRT display market, the broadcast industry has had to define new specifications for the upcoming generation of professional displays. These specifications define what would be considered minimal acceptance values for different grades of display (based on their usage). Once the specification had been defined, it came upon the broadcast industry to verify the display's performance. Consequently, many broadcasters are investing in both the measuring equipment and the technical expertise required for such work.

Most specifications for a display can be quickly and easily verified with a general-usage Light Meter Device (LMD). On the other hand, there are a few specifications that require more sophisticated equipment and complex testing procedures such as black level measurement, viewing angle dependency, motion artefacts and luminance uniformity.

Large-area uniformity

Large-area uniformity (LAU) is obtained from the measurement of a limited number of luminance samples. For flat-panel displays, EBU Tech 3320 [1] already defines a large-area uniformity performance goal of no less than 95% of the centre values for each sample, while Tech 3325 [2] recommends a method at just 13 measurement points *(Fig. 1)*. Such measurements already give a general idea of the uniformity of a display but the relatively few measurement points could easily miss problems such as sudden level changes, and periodic or fixed pattern non-uniformity.

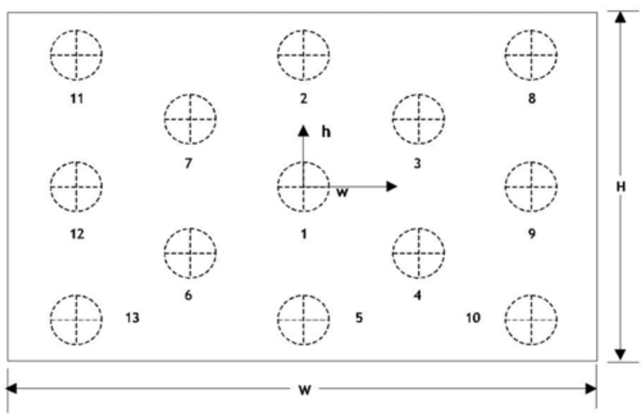


Figure 1
EBU Tech 3325 measurement points

Small-area uniformity

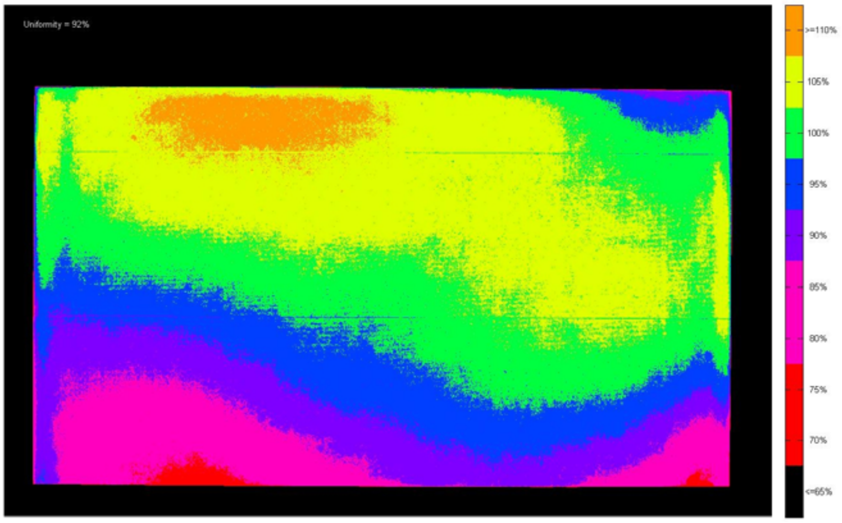


Figure 2
Visual representation example

Small-area uniformity (SAU) is computed from high-resolution luminance data, measured over the entire display surface. With the use of an array LMD, all the luminance information is captured in a single snapshot. This data can be used to identify more non-uniformity problems and to calculate a more precise uniformity score than for a LAU method.

This article proposes a SAU measurement method that is simple and not expensive to implement. The results are in the form of a visual representation *(Fig. 2)* and a computed uniformity score. The concepts of the method are presented first. Then, an analysis of its performance is given and some result examples for different display technologies are shown. Finally, further improvements are considered.

Proposed method

Description

The proposed approach *(Fig. 3)* is to use a commercial digital single-lens reflex (DSLR) camera and lens as the array LMD, i.e. a reduced-cost alternative to a scientific CCD sensor or other specialized equipment.

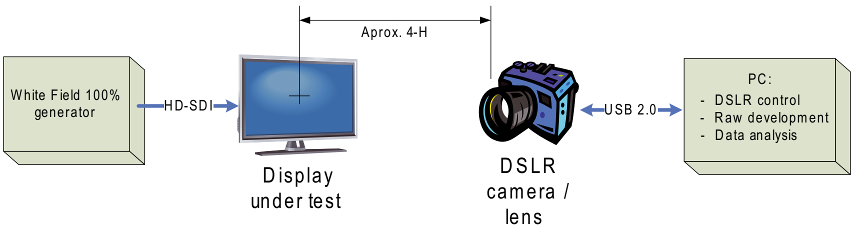


Figure 3
Proposed small-area uniformity approach

The camera is positioned in front of the display at a distance of 4-H (4 times the screen height). This provides an angle of view which is representative of an average viewing situation, while not being too close to minimize the effect of angular dependency in the case of some display technologies.

A 100% white field test pattern is provided to the display under test (DUT). The brightness of the DUT is adjusted to obtain a certain reference level of operation – e.g. 80 cd/m^2 – at its centre. The room must be dark with no reflective surfaces.

The picture is captured as a raw file and transferred to a computer for raw development and data analysis.

Image acquisition

DSLR camera

The resolution of the camera is chosen to cover approximately twice the resolution of the display under test, to minimize the spatial aliasing effect that can arise from the grid structure of the display.

For instance, with a 1920 x 1080 pixels matrix display, acquired using a 3:2 sensor, the minimal required resolution would be 10.0 megapixels. A DSLR camera includes a built-in anti-alias filter *(Fig. 4)* that removes most of the remaining aliasing.

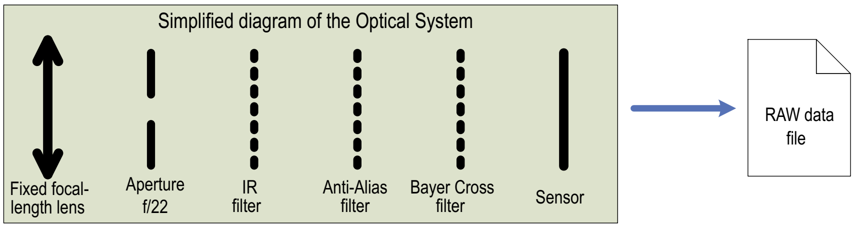


Figure 4
Data acquisition process

A DSLR camera also has a built-in infrared (IR) cut filter. A test was conducted to verify that the measurement is not influenced by the heat generated by the displays to be measured.

Lens and viewing distance

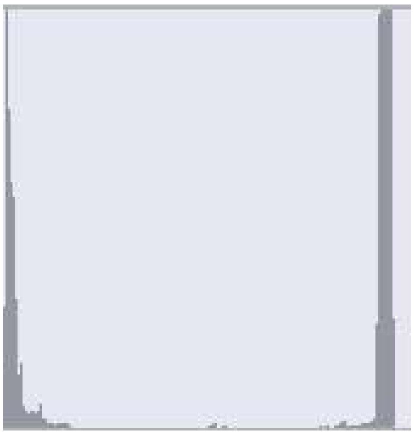


Figure 5
Histogram example given by a good exposure adjustment

A simple fixed-focal lens is preferable in order to minimize the different aberrations and distortions. The focal length was chosen to provide an angle of view for a viewing position of about 4-H, perpendicular to the centre of the display. Thus, for a 16:9 display and a 22 mm wide sensor, the lens' focal length should be 50 mm.

Exposure

The aperture is closed enough to reduce some undesirable aberrations and vignetting [3]. The ISO speed is kept low to minimize the noise, and the shutter speed is adjusted to optimize the exposure. The camera histogram view is helpful in maximizing the exposure while ensuring that there is no clipping *(Fig. 5)*. For instance, for a display at 80 cd/m^2 and with an aperture of f/22 and 100 ISO, the exposure time is about 4 seconds. This gives enough integration time for a scanning display (e.g. CRT).

Image processing and data analysis

Raw development

The camera's picture is saved as a raw file to prevent any image processing done by the camera. Commercial cameras are designed primarily to produce good looking images and skin tones, and this may involve some processing not suitable for flat-field measurement.

The colour reconstruction and conversion to the sRGB colour space rely on the manufacturer's matrix coefficients that are specific to the colour filters of the camera model.

The white balance is done manually on the raw development software at the centre of the display area. This operation removes the effect of colour temperature adjustment of the display, although any colour temperature non-uniformity (i.e. primary colour non-uniformity) is caught by the luminance uniformity measurement.

The usual sRGB gamma curve must be cancelled because the measurement is done on linear-light information captured by the sensor [4].

The output is a standard 24-bit colour (e.g. tiff format) file, coded with the sRGB primaries and D65 reference white.

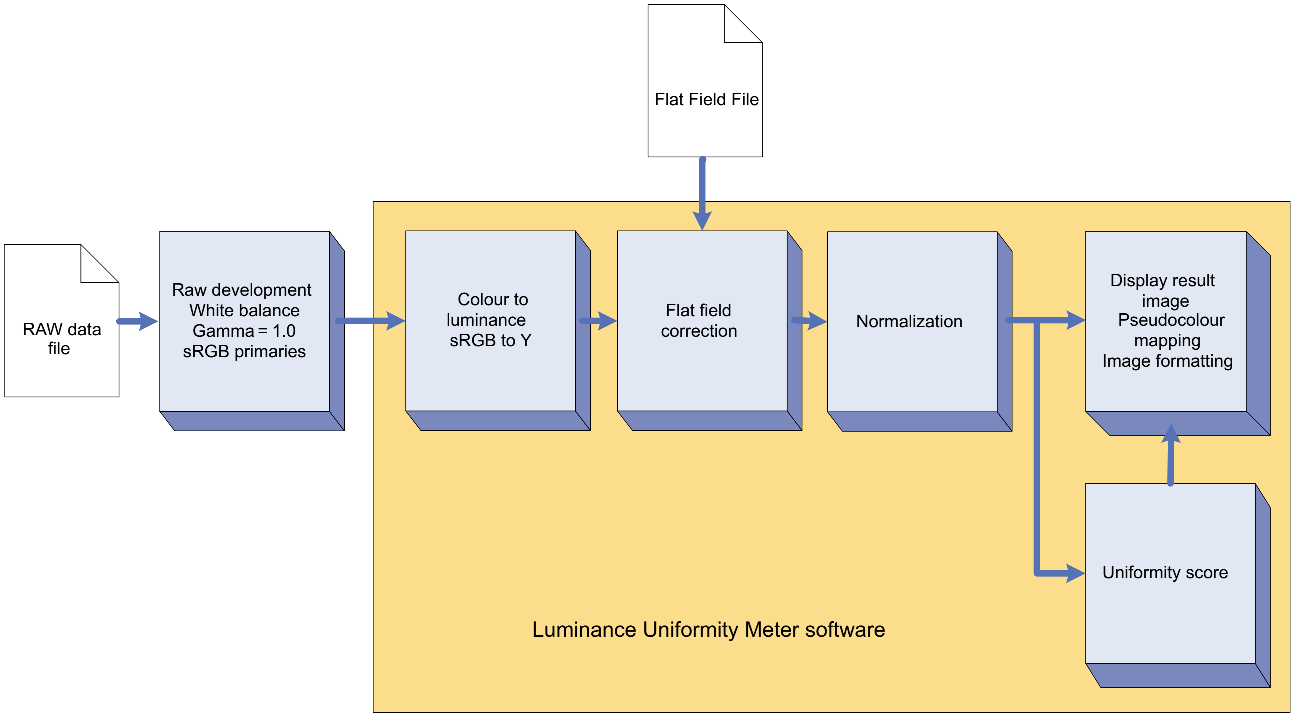


Figure 6
Image processing and data analysis blocks

Relative luminance

Luminance is the measure of light intensity, weighted by the spectral sensitivity of human vision [4]. It is computed from the developed colour image using the sRGB to XYZ conversion matrix [1]. This gives a monochromatic image with sample values proportional to the luminance.

Flat fielding

A flat fielding operation is needed to calibrate the opto-electrical system and to remove the effect of the lens cosine 4^{th}-power law [5] that causes an attenuation of light at the edge of the image compared to the centre.

This is the most challenging and potentially expensive step of the method, although it must be done only once for a given camera/lens configuration. An integrating sphere was used to create the flat field image. The image is developed and converted to luminance following the same procedure mentioned above for the display image. It is normalized to its average value and applied to the developed display image.

Normalization

The image is then normalized to the average of the area at the centre of the screen.

Pseudo colour map

The relative luminance image is scaled and converted to a colour map, with each different colour representing a 5% step.

1. $Y_{image} = 0.2126 * R_{image} + 0.7152 * G_{image} + 0.0722 * B_{image}$

Uniformity score

The large number of samples is useful to calculate a score that can be used to compare the performance of different displays and to verify its conformance to an eventual standard target.

In this implementation, the score is calculated from the standard deviation which gives a measurement of the degree of spread of luminance around the mean. The use of the standard deviation has also the benefit of being not very sensitive to a small quantity of extreme values that could be present at the edges of the display.

Uniformity score = 100% - STDEV(*relative_luminance_data*)

This calculation could easily be adapted to any other that might become accepted.

System components

This table lists the components chosen for this prototype system.

DSLR camera	Canon 40D, 10.1 Megapixels CMOS
Lens	Canon EF 50mm F/1.8 II
Camera control and Raw development	Canon software
Integrating sphere	Esser LE 6 (transparency illuminator)
Spectroradiometer	Photo Research PR-705
Image processing	Matlab-based custom software

Analysis of the performance of the method

In order to verify the performance of the method, a comparison with a LAU method at the 13 measurements points specified in EBU Tech 3325 was performed on a 24" LCD monitor. However, to compare equivalent quantities, the spectroradiometer measurements were performed at the same viewing point as the SAU method (4-H from the display and centred) while the Tech 3325 method indicates making the measurements perpendicular to the surface of the display at each point.

Abbreviations

CCD Charge-Coupled Device
CCFL Cold Cathode Fluorescent Lamp
CIE *Commission Internationale d'Eclairage*
http://www.cie.co.at/index_ie.html
CMOS Complementary Metal-Oxide Semiconductor
CRT Cathode Ray Tube
DSLR Digital Single-Lens Reflex (camera)
DUT Display Under Test
IR Infra-Red
ISO International Organization for Standardization
http://www.iso.org
LAU Large-Area Uniformity
LCD Liquid Crystal Display
LED Light Emitting Diode
LMD Light Meter Device
SAU Small-Area Uniformity
sRGB standard Red Green Blue (colour space)

Next, from the SAU method, the values for the 13 measurements points were obtained by computing the average over the same measurement area as the spectroradiometer *(as shown in the next table)*.

EBU Tech 3325 measurement point	LAU (Spectroradiometer)	SAU (Computed at EBU points)	Discrepancy
1	100.0%	100.0%	0.0%
2	99.8%	100.1%	0.3%
3	96.6%	96.9%	0.3%
4	102.6%	101.6%	–1.1%
5	94.7%	93.5%	–1.2%
6	101.0%	100.9%	–0.1%
7	104.8%	105.6%	0.8%
8	86.0%	86.7%	0.8%
9	93.3%	93.8%	0.7%
10	87.3%	86.7%	–0.5%
11	100.5%	100.6%	0.0%
12	103.8%	104.1%	0.2%
13	96.1%	94.5%	–1.5%

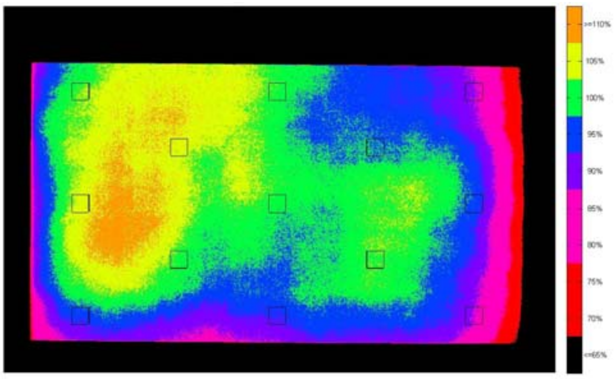


Figure 7
SAU representation with EBU measurement points

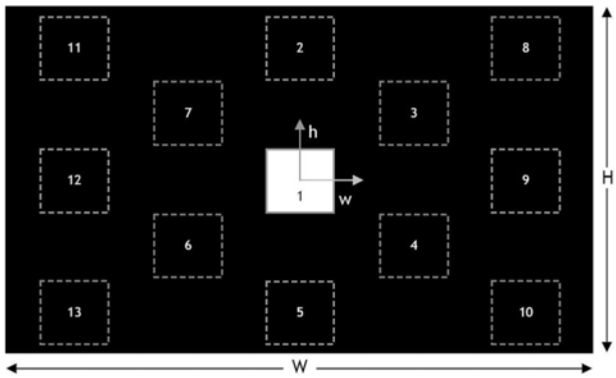


Figure 8
EBU Tech 3325 Test Pattern 3 series

The maximum discrepancy between the two methods is +0.8 / –1.5%. This includes the uncertainty of the spectroradiometer for ratio measurements in the order of ±0.1% [6]. The main contribution to the error of the SAU method is given by the flat field non-uniformity that was measured to be 1.0±0.1%. The repeatability error for computing the 13 EBU points from the SAU method is approximately 0.4%.

Example results

A few examples of the results obtained with the small-area uniformity test are shown in *Figs 9* to *14* for different display technologies and manufacturers.

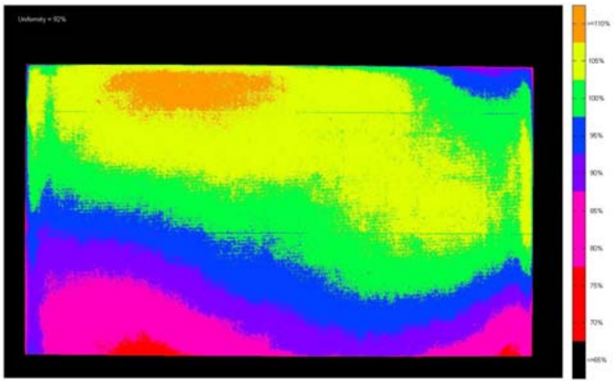


Figure 9
Professional HD CRT — 92% uniformity

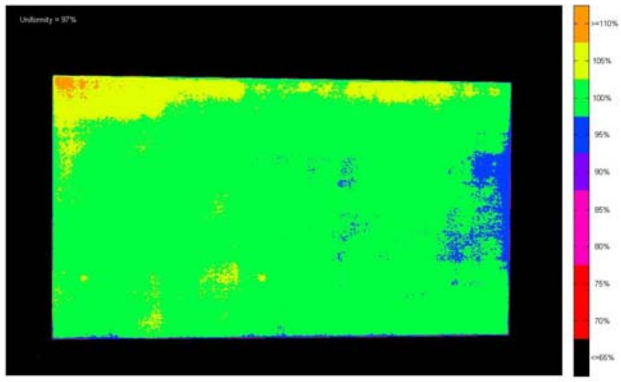


Figure 10
Professional plasma — 97% uniformity

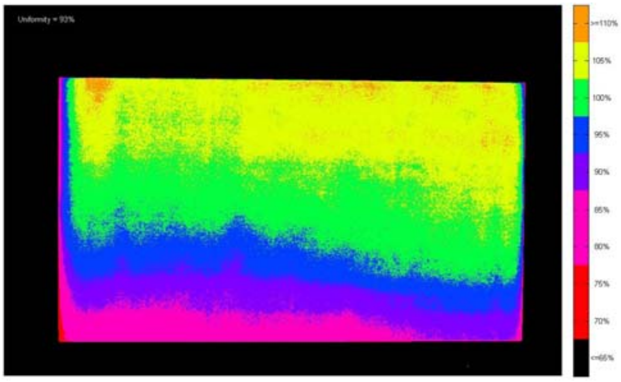


Figure 11
LCD with CCFL backlight (Mfg. A) — 93% uniformity

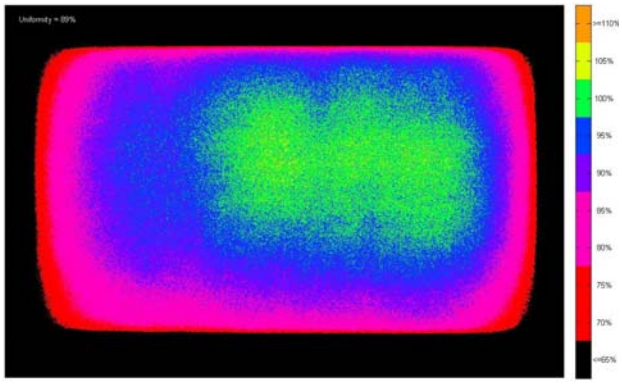


Figure 12
LCD with CCFL backlight (Mfg. B) — 89% uniformity

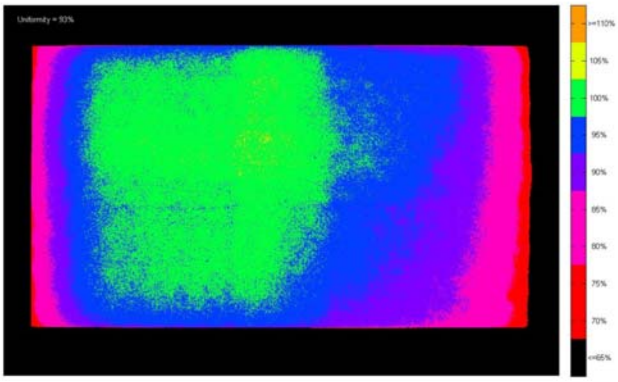


Figure 13
LCD with LED backlight — 93% uniformity

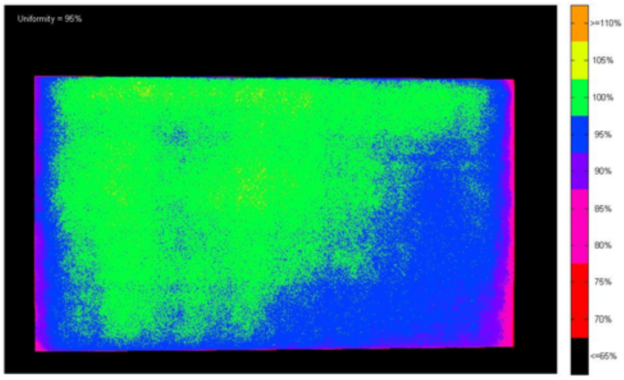


Figure 14
LCD-LED with uniformity correction — 95% uniformity

These examples demonstrate the impact on uniformity of different display-manufacturing technologies. The rate of change in the luminance level is clearly visible and the information gathered from the test can be very informative.

Future improvements

Lightness measurement

Lightness is a measurement of the visual perception of luminance. The CIE L* is an approximate lightness function and was standardized in 1976 [7]. This measurement should give a better representation of the perceptibility of the defects: a step of 1 unit of lightness is just perceptible (for 2 large uniform patches) giving additional information on the perceptibility of the non-uniformity defects. Therefore, this measurement is more dependent on the intensity of the display and the ambient lighting, making the comparison between different results more difficult.

Reduced angular dependency

By using a lens with a bigger magnification factor, it would be possible to move the camera back from the display, reducing the effect of the angular dependency of some display technologies. Otherwise, it would also be possible to remove the angular factor from the measurement by applying a function obtained from a separate angular measurement.

Grey and Colour uniformity, Luminance Meter

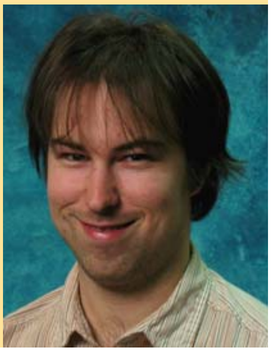
Other similar measurements could be derived from the picture data, such as grey and primary colours uniformity. More experimentation would be required to calibrate and verify the linearity of the colour measurements. It could also be possible to use this method to measure the absolute luminance (or Lightness) level (e.g. in cd/m^2) assuming it is calibrated for a certain camera configuration.

Conclusions

This article has presented a small area uniformity display measurement method using a commercial DSLR camera as the array LMD. The method outputs a colour representation of the display uniformity and, combined with a computed uniformity score, it yields very detailed information when compared to a large-area uniformity test. The method was tested on many display technologies and correlates well with spectroradiometer measurement at the points used in a large-area uniformity method.

Maxime Caron received a degree in electrical engineering from *École de technologie supérieur*, Montreal, in 2005 and also holds a technical college degree in telecommunications. His experience in broadcasting is extensive and covers most transmission and production technologies, including High Definition Television and digital archival platforms. He has been with CBC/Radio-Canada since 1999, initially working with transmission services before joining New Broadcast Technologies in 2004. He is a member of the Society of Motion Picture and Television Engineers (SMPTE).

Félix Poulin graduated in electrical engineering at *École Polytechnique de Montréal* in 2002 after having completed his final year of study at the Massachusetts Institute of Technology, USA. He previously worked as a sound and radio-frequency system designer for Solotech and Cirque du Soleil. He joined the New Broadcast Technologies team at CBC/Radio-Canada in 2007 where he developed his expertise in production equipment, including cameras, lenses and video quality assessment. He is a member of the Society of Motion Picture and Television Engineers (SMPTE).



With the described method, there is also room for improvements and added features. In the long run, it could provide a valid addition to a complete test procedure for television displays.

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[7] Charles Poynton: **Digital Video and HDTV Algorithms and Interfaces**
Morgan Kaufmann Publishers, San Francisco, 2003, p.208.

Further reading

Flat Panel Display Measurements Task Group: **Flat Panel Display Measurement Standard, Version 2.0**
VESA, 2005.

Why broadcasters should care about Home networking

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This article describes some important issues relating to home networking. It addresses the issues of interoperability and connectivity of networked devices and then discusses the standardization progress in DLNA, UPnP and DVB. It briefly lists some proprietary home networking solutions and outlines some findings of the German research project, WiMAC@home.

Finally, the article provides some guidance to the broadcast community, to ensure that evolving solutions adopted by the market will meet their technical and operational requirements.

The importance of home network connectivity

People's homes are becoming a place where members of the family use an increasingly large variety of different media devices. Traditional radio and TV sets are now being complemented by a myriad of gadgets such as iPods, mobile phones, DVD recorders, PCs, gaming consoles, storage devices and many others. All these devices used to be isolated and unaware of each other. Today, however, they are becoming connected through a home network, allowing the users to: share content regardless of where it originated or is stored; control delivery and access; allocate band-width ... and integrate new devices automatically.

A home network may use different physical infrastructure but generally users may like to replace their old coax cables with more modern Wireless Local Area Networks (WLAN), Power-Line Communications (PLC) or even Gigabit-Ethernet cabling. Regardless of the physical layer, Internet Protocol (IP) is used for transporting the files and streams. *Fig. 1* depicts a typical home-networking scenario with several content sources and playout devices located in different rooms. Using a simple control device, any content (live TV and pre-recorded video, radio, mp3 music, photos, EPG data, etc) could in principle be reproduced on any device in the home.

In practice however, users may experience tremendous problems with interconnecting the available commercial devices successfully. The reasons are multiple. The most obvious is that many device manufacturers commercialise their own proprietary solutions, which are not interoperable and do not comply with the Universal Plug and Play (UPnP) standard. Broadcast content is particularly disad-vantaged, as very few commercially-available television and radio devices today provide IP connec-

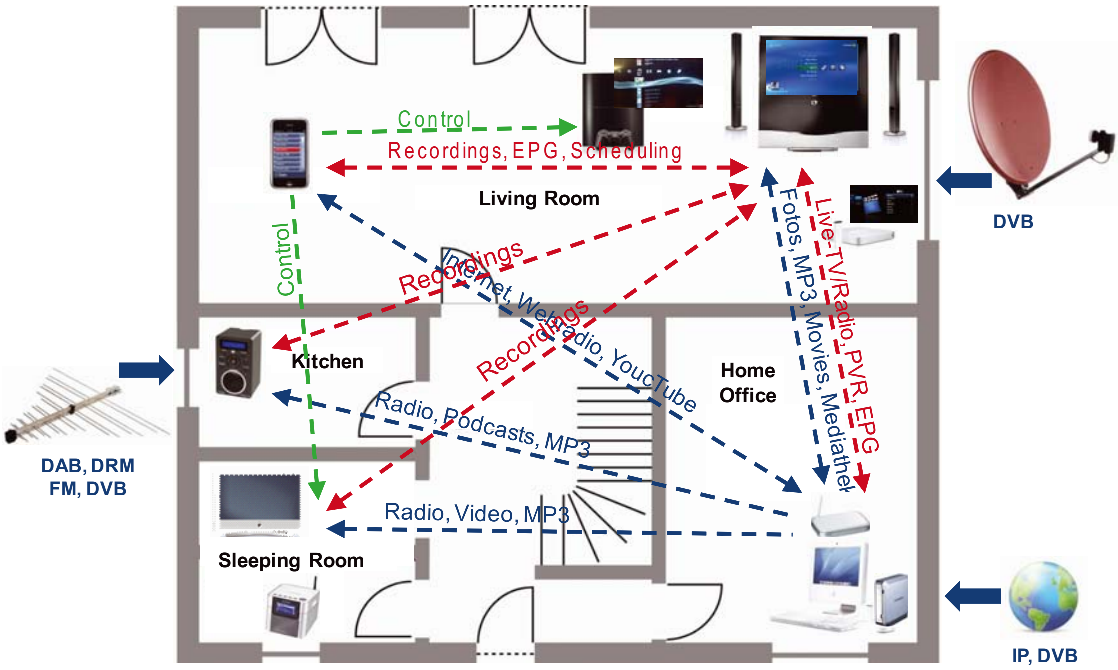

Figure 1
Typical home-networking scenario

tivity (which is required for the sharing of video recordings and live DVB signals over residential networks). Furthermore, most of today's IP-connected devices are still incapable of processing programme-associated data, teletext, MHP, EPG, subtitles and multi-language audio and other broadcast services that accompany TV broadcast programmes; they simply discard the data packets carrying these services before transferring the TV stream to another networked device.

There is some evidence that the present-day home networks are less then friendly with broadcast content. And yet, more and more people are using home networks to enjoy broadcast programmes, both live and on-demand. Therefore, there is a common agreement among broadcasters that their content needs to be part of this new "home networking" paradigm.

In order to integrate broadcast content with other media sources – such as music collections, local video libraries and holiday photos – broadcasters should make sure that their standards are fully taken into account in emerging home-networking specifications. To "stay in the loop" with future products of the digital life-style, broadcasters should endeavour to establish horizontal markets of interoperable and interconnectable home-networking devices, including all kinds of receivers from digital radios, PCs or handhelds up to set-top boxes and iDTVs.

Interoperability of CE and IT devices

A home network is a *"wired and wireless interoperable network where digital content such as photos, music and videos can be seamlessly shared through personal computers (PCs), consumer electronics (CE) and mobile devices in and beyond the home"*. This quote is taken from the vision statement of Digital Living Network Alliance (DLNA) [1]

Set up in 2003, this industry organization now comprises more than 250 partners including Philips, Sony, Samsung, Sharp, Microsoft, IBM, HP, Loewe etc. The EBU and IRT are among its members. The DLNA provides *"sustainable implementation guidelines based on existing technologies that are open to all manufacturers and which should satisfy the user's needs"*. A minimum set of media formats is mandatory, including (i) JPEG, LPCM and MPEG-2 for stationary devices, and (ii) mp3, AAC and H.264 for mobile devices. Other optional formats can additionally be integrated *(Fig. 2)* .

Connectivity between devices is provided using IEEE standards of the 802.11 family or Bluetooth for wireless connection (WLAN), and 802.3 standards for wired Ethernet.

Multimedia-over-Coax (MoCA) can be used for existing cables [2]. Although any power-line network that supports IP will generally work with DLNA, it is not yet part of the standard. The higher layers of the DLNA Stack (1.0) make use of IPv4, DTCP-IP, HTTP 1.0/1.1 and UPnP-AV 1.0.

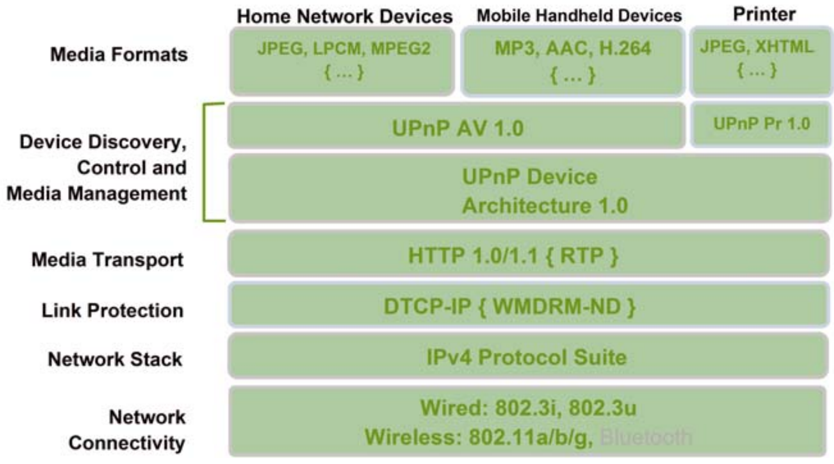

Figure 2
DLNA device interoperability stack *(Source: DLNA)*

The principal DLNA technology ingredients are given in *Table 1*.

Version 1.5 of *"DLNA Networked Device Interoperability Guidelines"* was updated in October 2006 and introduced mobile devices and Link Layer Security *(Fig. 3)*. The next version, 2.0, is intended to be released in the third quarter of 2009. For these guidelines, support has been announced for some important broadcast features such as electronic programme guide (EPG), AV recording, content synchronization, digital rights management and remote user interface.

Table 1
Principal ingredients of DLNA technology

Functional components	Technology ingredients
Connectivity	Ethernet, 802.11 and Bluetooth
Networking	IPv4 Suite
Device Discovery and Control	UPnP Device Architecture v1.0
Media Management and Control	UPnP AV v1 and UPnP Printer:1
Media Formats	Required and optional format profiles
Media Transport	HTTP (mandatory) and RTP (optional)

To benefit from the interworking of various devices, the DLNA has specified precise use cases for different scenarios. Support for all the technical requirements should be guaranteed by an international product certification programme [3]. During implementation, the compatibility can be verified at Plugfest events and with conformance test tools, offered on the DLNA homepage for members. A lower-level UPnP certification is required in advance of DLNA certification. Test certificates, indicating the functional features of each individual device, can be found in the public area of the DLNA website [4].

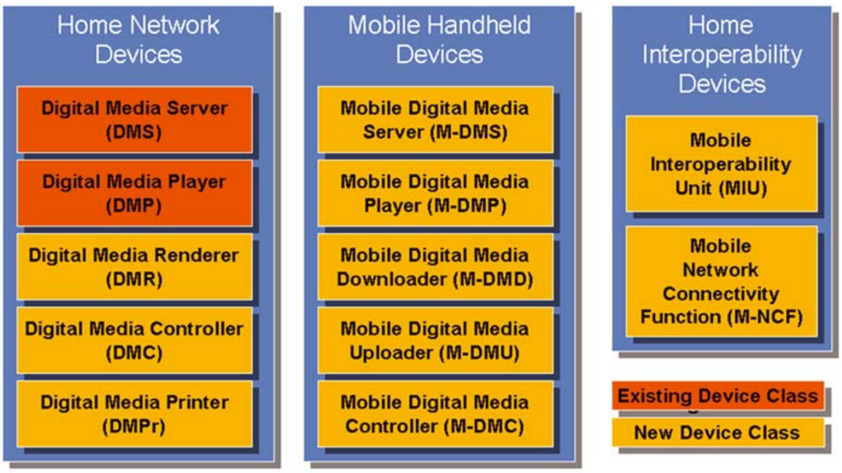

Figure 3
Device classes in DLNA Expanded Guidelines 1.5, October 2006
(Source: DLNA)

Plug-and-Play networking with UPnP

In a heterogeneous home network – where many telecom, mobile, IT and broadcast devices may share audiovisual content and where new devices may come and go at any time – plug-and-play networking, embodied in the UPnP family of standards, is essential. The UPnP-enabled devices are able to communicate with each other, discover any changes in the network (for example, a new device joining the network), describe their features and expose them to the network. UPnP-based home networks are self-configurable and autonomous.

According to UPnP, networked devices are divided into categories and classes. Devices of one particular category are used within one specific usage scenario. For example, there are categories for audio/video, home automation, networking, printers, remote control and scanners. Additional categories are being regularly specified by the UPnP Forum [5].

A device class, on the other hand, represents a dedicated combination of services and functions [6]. It can, for example, be an internet gateway, a media server or lighting control.

With UPnP, the user is able to browse, search and select content and remotely control the network-attached devices. The look-and-feel of a user UPnP interface is vendor-specific and may be applied to all products of a given vendor, regardless of whether local or remote services are accessed on these devices.

The UPnP-AV architecture defines device categories such as Renderer and Server which are operated by a Control Point [7]. The Content Directory Service (CDS) is most important for multimedia devices, as it exposes the physical media of a server to the network in a container structure which can be browsed and searched.

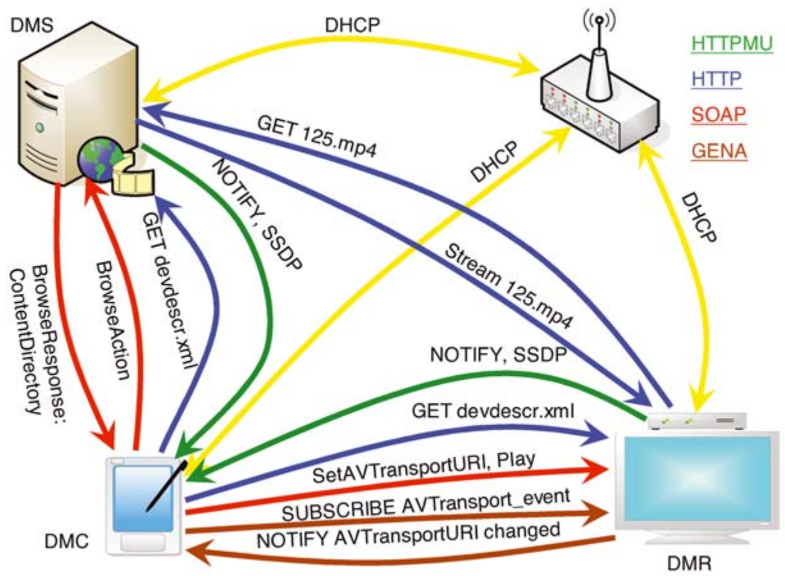

Figure 4
3-Box model in the UPnP-AV architecture, version 0.83
(Source: University of the Saarland)

The Media Server, Media Renderer and Control Point can reside in one physical appliance or they can be distributed across the network. It is essential to understand that playback on UPnP devices without DLNA compliance can fail if both do not support the same media formats, although the device capabilities are exchanged prior to the transfer.

If a UPnP-enabled device follows the DLNA guidelines, it is called a "Digital Media Player" (DMP) or "Digital Media Server" (DMS) depending on the supported functionalities *(see Fig. 4)*.

Chip vendors such as SMSC (**http://www.smsc.com**), Broadcom (**http://www.broadcom.com**) and FreeScale (**http://www.freescale.com**) have already developed system-on-a-chip solutions which contain a DLNA stack for integration in CE devices.

Home networking in DVB

DLNA, mainly dominated by American and Asian corporations, has initially focused only on the exchange of pictures, music and videos. In contrast, the Digital Video Broadcasting (DVB) Consortium has been mainly working on broadcast delivery systems [8]. To achieve a sustainable develop-

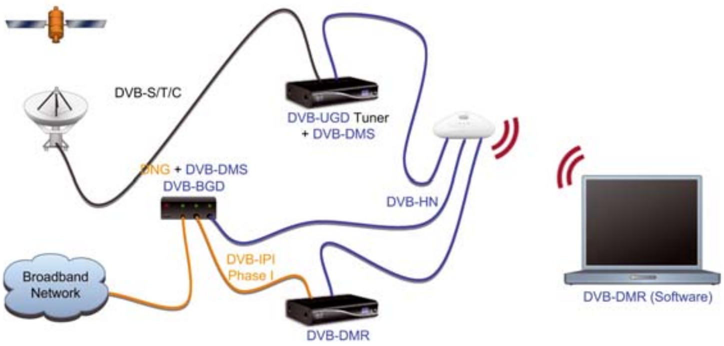

Figure 5
Home Network Reference Model *(Source: University of the Saarland)*

ment of networked devices for European markets, the DVB Consortium has liaised with DLNA through the DVB Home Networking Task Force of the IP Infrastructure group under its Technical Module (DVB-TM-IPI/HN).

It is now understood by DLNA that DVB-DLNA system integration may be the key feature for the mass-market success of media-networked devices in the long run.

The DVB specifications distinguish between a Home Network (HN) segment and the Delivery Network (DN). Both domains are connected via a Delivery Network Gateway (DNG). Each end point in the HN is called a Home Network End Device (HNED).

The DVB-HN Reference Model *(see Figs 5)* is based on UPnP-AV and defines how typical Radio and TV services, including teletext, subtitles, EPG and recording, can be shared across a Home Network [9] . Some media format- and transport-related requirements were not initially supported by the DLNA Guidelines but have now been successfully introduced into DLNA. In particular, the following DVB requirements have been taken up by DLNA:

- IP multicast RTP/UDP for the transport of DVB-IPTV;
- H.264 video coding in SDTV and 720p/50 for HDTV;
- mapping of DVB-SI, SD&S or BCG and TV-Anytime to UPnP-CDS (Content Directory).

Some requirements are optional in DLNA but are mandatory for DVB, and vice versa. For that reason, a Digital Media Player in DVB (DVB-DMP) has to implement some features differently to a player that fits in with the DLNA requirements (DLNA-DMP). A so-called commercial video player (CVP) profile is an attempt to harmonize both player specifications.

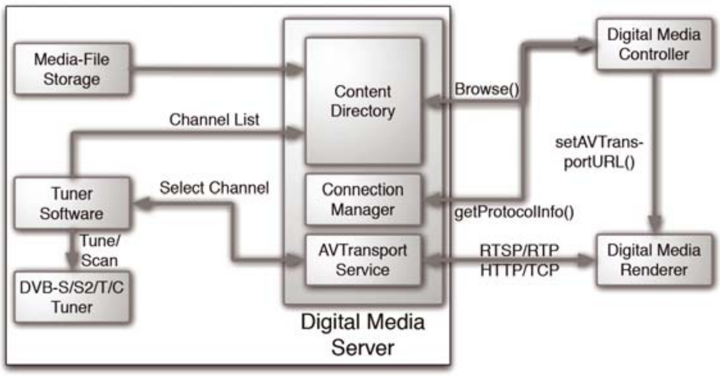

Figure 6
Digital Media Server Architecture *(Source: University of the Saarland)*

When the Digital Media Sever (DMS) concept *(Fig. 6)* was introduced, there was the possibility of realizing a broadcast receiver by means of the "tuner representation" given in Appendix B of the DLNA Guidelines. Depending on the type of broadcast network, DVB-HN defines two new device classes:

- Unidirectional Gateway Device (DVB-UGD) with a DVB-S/C/T tuner;
- DVB-DMS or a Bidirectional Gateway Device (BGD) which connects to a broadcaster through broadband access.

The representation of dynamic contents and their metadata is done through the UPnP-AV Content Directory (CDS) with a mapping of DVB-SI to the CDS container. After a channel search, each Radio and TV service is represented as a CDS item with programme-associated data from SI tables such as BAT, and with SDT or EIT being added as attributes.

Multiple languages or multiple audio tracks can be included as MPEG-2 Programme-Specific Information (PSI) or separately as multiple instances of one video stream. Depending on the number of tuners and the services inside each transponder, one DVB-DMS can serve multiple renderers (DMRs) concurrently [6]. For such scenarios, a DMS has to implement "collision handling" when limited tuning resources are allocated by multiple users, remotely and/or locally, at the same time.

If a DMR is not capable of parsing a Transport Stream, the DMS can re-multiplex a single service to an MPEG-2 Programme Stream. The DMS is found by means of DMC via SSDP. Its channel list can be found with a SOAP browse request. Using the command `setAVTransportURL`, a DMC can tell a DMR which service to decode. Depending on the streaming support of the DMS, a tuning operation is initiated with `RTSP PLAY` *(RTP/UDP)* or `HTTP GET` *(HTTP/TCP)* by the AV Transport Service from a DMC.

If more than one DMR is requesting the same service, a DVB-DMS which supports multicast is more efficient than a simple DLNA-DMS using unicast [6]. The MPEG-2 Transport Stream can furthermore be used to carry programme-associated interactive applications with MHP or CE-HTML. These added-value applications can be shared in the home network with UPnP devices either as part of the transport stream or from a separate IP connection to a web service on the internet, or to a locally-cached carousel in the HN.

A dedicated signalling of applications, such as in the German R&D project WiMAC@home [10] *(see Fig. 7)* is not yet standardized in UPnP. Nevertheless, it can be integrated on top of the DLNA stack, thus extending the UPnP device model.

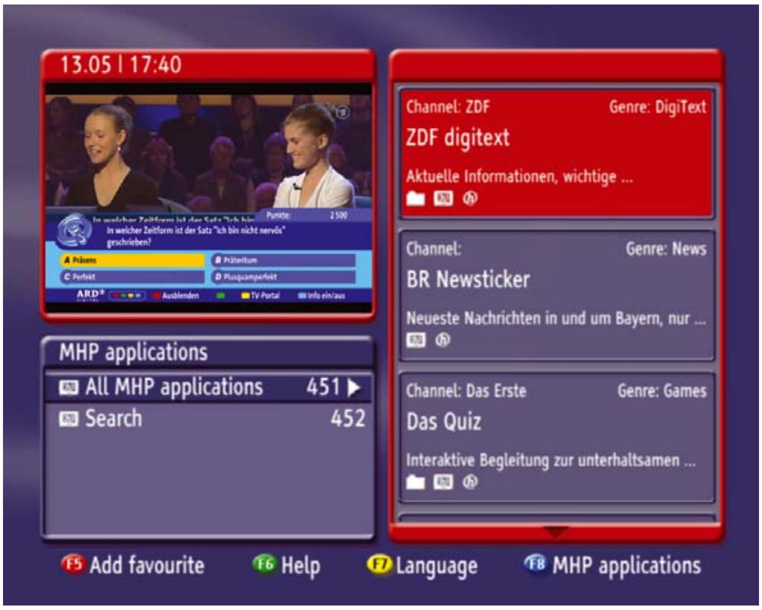

Figure 7
Reception of interactive DVB services with UPnP-AV in IRT middleware (m4iTV)

In order to make real-time streaming of broadcast signals within the home viable, special attention should be paid to the Quality of Service (QoS) mechanisms. A DVB-DMS uses RTP with connectionless UDP and without error protection on the transport layer. Multicast can cause problems when it is used over 802.11-based wireless links because there is no Automatic Repeat Request (ARQ) at the MAC layer level.

To avoid packet loss, the multicast stream can be tunnelled in a unicast session by the DMS or the DNG [11]. Alternatively, a Hybrid Error Protection can be applied, combining ARQ and Forward Error Correction (FEC) together with a strict delay constraint [12].

For a good Quality of Experience (QoE), a one-way delay of 100ms – caused by the use of too much buffering in the network interface and DMS/DMR application, including decoding and re-encoding – should not be exceeded. In addition, the channel-switching duration should not be longer than about 1 second including all UPnP communication, DMS tuning and DMR playback.

Content security in residential networks

As mentioned in the introductory section, the digital distribution of broadcast signals, recordings and webcasts over a LAN is, at the moment, supported by very few devices and requires an experienced user to set up the configuration. Several reasons for that have already been indicated but there is one which has not been mentioned so far: copyright. Content owners are concerned that their pay-TV content and Hollywood blockbusters may be uploaded to the open internet and thus evade payment. To this end, device manufacturers should implement the relevant DVB specifications such as CI (v2) and CPCM that are aimed at setting up systems to balance the interests of free-to-air (FTA) and pay-TV providers. In the meantime, the CI-plus Consortium specifies another system separately from DVB.

Technology is in principle available for the secure transfer of multimedia content from the provider to the end-user, independent of the local WPA- or WEP-based network security. For this purpose, Conditional Access (CA) systems such as Nagravision, Betacrypt or NDS Videoguard, which restrict general access, can be combined with Digital Rights Management (DRM) systems such as OMA, FairPlay or Windows Media DRM (WM-DRM). DRM systems can assign dedicated Usage State Information (USI) such as “Copy Once” or “Copy Never” to special content items. Encryption of the media transport link between two devices within the home can be performed by HDCP via HDMI or DTCP via IP. Both systems can also carry some basic USI flags. If the content owners cannot agree on a single system, an intermediate CA/DRM bridge can carry out an authorized translation of USI flags from a Nagravision-encrypted DVB-S transport stream to a secure WM-DRM container on the fly, to be playable on a PC.

Despite a potential re-distribution over the internet, these scenarios are not relevant for some public service broadcasters. For example, the German public service broadcasters ARD and ZDF declared the prohibition of any type of encryption on their content – whether for delivery, storage or connectivity. This demand is reflected in a free-to-air Content Management Descriptor which signals a “Do not scramble” bit to the receiver. However the users might not understand why they can stream the time-shifted broadcasts of ARD and ZDF from the living room to the bedroom while the same procedure does not work with content from German Pay-TV services.

Therefore it seems that a key to the adoption of IP interfaces in set-top boxes or integrated television sets (iDTVs, IRDs) for the mass market is to be found in the settlement of expectations around intellectual property rights (IPR), especially for movies and TV productions.

Products on the market

UPnP- and DLNA-enabled home-networked devices are becoming increasingly available commercially. Many routers and residential gateways can already be controlled by simple UPnP commands. Most operating systems like Windows and Linux are enabled to support the UPnP protocol. The exception is Apple which stays with its own protocol, *Bonjour*. This restricts Apple networking to devices which support the iTunes platform and Apple web services. Although some third-party suppliers offer iTunes-compatible media sharing with their devices, the client will always have to be an Apple product (e.g. an iPod, iPhone or Airport Express). Nevertheless, Apple seems to “tolerate” Elgato (**http://www.elgato.com**), a third-party UPnP software supplier whose applications are used on the iPhone.

In contrast to the Apple Media Centre Front Row and the “iPod for TV” (aka Apple-TV), some Microsoft editions of Windows come with native broadcast support. Even though Microsoft requires Windows Media Centre (XP/Vista Media Centre, MCE/VMC) as the host operating system to be remotely connected to their Extender (MCX), the next version of Windows (i.e. Windows 7) was announced to be DLNA-certified [13]. An additional Windows logo programme should make some more optional DLNA features mandatory. The latest public preview of Windows 7 beta [14] already comes with a UPnP Control Point in Windows Media Player and a partially implemented DMP in Windows Media Centre.

It can be expected that support for UPnP-AV in Windows Media Player and Windows Media Centre (in Windows 7) will enable the streaming of free-to-air recordings to various CE devices such as the PS3 or Loewe Connect. Microsoft will have to implement an on-the-fly transcoding from their new proprietary container (.wtv) to a DLNA-compatible MPEG-2 single-programme transport stream (SPTS) or a programme stream (PS).

The dLAN TV SAT system from Devolo (http://www.devolo.com), for example, bridges DVB-S signals for in-house distribution over PLC/IP. Another approach is offered by Reel Multimedia with their live streaming-enabled NetCeiver (http://www.reel-multimedia.com/en/dokumente/net-ceiver/NetCeiver.pdf), which resides in an enhanced set-top box, and an additional NetClient which is functionally quite similar to Microsoft's Media Centre / Extender technology.

Both the popular DreamBox and the open-source video recorder software LinVDR for Linux are able to stream a single programme to a PC. Experienced users can upgrade the missing UPnP support to these open-source operating systems. UPnP streaming clients with an integrated Renderer and Control Point came along with Loewe Connect HD, Playstation 3, XBox 360, some Blu-Ray disc players, a few set-top boxes and several streaming clients (digital media adapters), such as Popcorn Hour which is based on the Sigma 8635 chip. In some multi-radio appliances such as the Pure Evoke Flow, with WLAN/DAB and FM capabilities, UPnP support is added to the radio chipset by means of a so-called media player mode.

UPnP-AV servers are integrated in many Network Attached Storage (NAS) devices such as those from Buffalo and QNAP, in routers such as Fritz!Box or from Netgear, and in Windows Media Player, Windows Home Server and even Eye Connect on the Mac. Third-party Media Centre applications such as Myth-TV for Linux or MediaPortal, Sage-TV and TV-Central for Windows provide basic networking support in combination with Radio / TV recording.

The system architecture in the next release of MediaPortal, v2, is said to use UPnP-AV as a networking middleware [15]. The free Media Centre client, Xbox Media Centre (XBMC) also supports UPnP-AV and is now available for Windows, Linux and Mac.

Abbreviations

BAT (DVB) Bouquet Association Table

BCG (DVB) Broadband Content Guide

CA Conditional Access

CDS Content Directory Service

CE Consumer Electronics

CI Common Interface

CPCM (DVB) Content Protection and Copy Management

CRT Cathode Ray Tube

CVP (DVB) Commercial Video Player profile

DAB Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/

DCP Device Control Protocol

DLNA Digital Living Network Alliance http://www.dlna.org/home

DMP Digital Media Player

DMS Digital Media Server

DRM Digital Rights Management

DTCP Digital Transmission Copy Protection

DVB Digital Video Broadcasting http://www.dvb.org/

DVB-S DVB - Satellite

EIT (DVB) Event Information Table

IEEE Institute of Electrical and Electronics Engineers (USA) http://www.ieee.org

EPG Electronic Programme Guide

HDCP High-bandwidth Digital Content Protection

HDMI High-Definition Multimedia Interface

HTTP HyperText Transfer Protocol

iDTV Integrated Digital (or Decoder) TeleVision

IP Internet Protocol

IPR Intellectual Property Rights

IRD Integrated Receiver/Decoder

IT Information Technology

LAN Local Area Network

MHP (DVB) Multimedia Home Platform

MoCA Multimedia over CoAx

NAS Network-Attached Storage

OMA Open Mobile Alliance http://www.openmobilealliance.org/

PLC Power-Line Communication, also written PLT, BPL ...

RTP Real-time Transport Protocol

SD&S (DVB) Service Discovery & Selection

SDT (DVB) Service Description Table

SOAP Simple Object Access Protocol

SPTS Single Programme Transport Stream

SSDP Simple Service Discovery Protocol

UPnP Universal Plug 'n' Play http://www.upnp.org/default.asp

USI Usage State Information

WLAN Wireless Local Area Network

WPA Wi-Fi Protected Access

Research on home networking

WiMAC@home [10] was finalised in March 2009. The project was partially funded by the German Federal Ministry of Economics and Technology within the initiative "Next Generation Media". The consortium – consisting of Loewe, Fraunhofer-IIS, the IRT, Nagravision and Weinzierl Engineering – went a decisive step beyond the current state-of-the-art. In this project, a new iDTV was developed that can be used for archiving broadcasts, videos and photos, and for sharing them over a local wireless network.

Additionally, live TV services and premium Pay-TV content can be accessed securely across the network. DVB signals are exchanged with UPnP-AV-compliant devices following the guidelines of the DLNA. TH-Show can even follow the user automatically, using a UPnP-based context-awareness server, in combination with WLAN localization of devices.

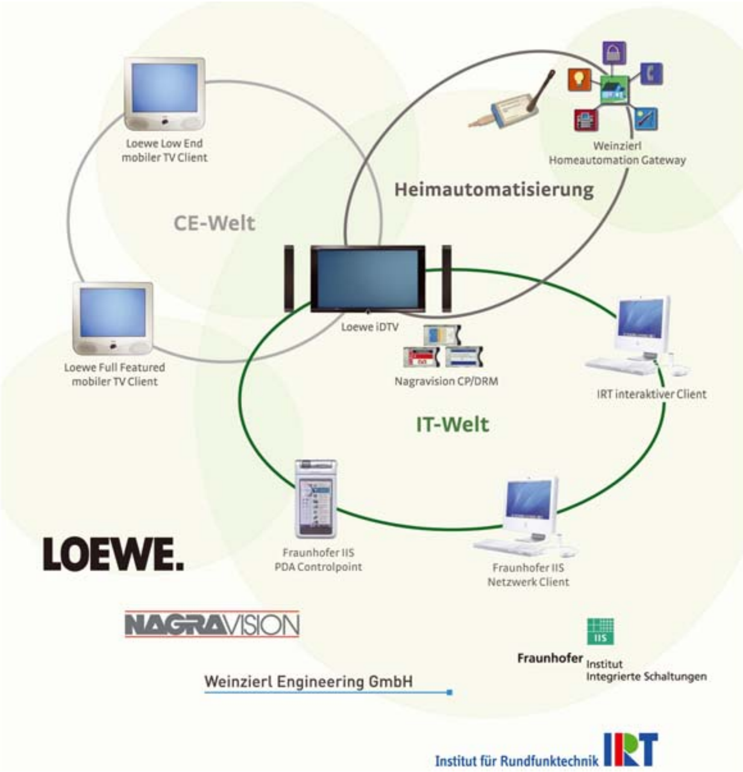

Figure 8
Interoperability in the CE and IT domains including home automation *(Source: WiMAC@home)*

Home Automation for building services, such as the control of shutters, lighting and heating, are other key aspects of the project. Every device shall be usable within the network, regardless if connected via WLAN, Powerline, Ethernet, Konnex [1] or DigitalSTROM [2]. Even interactive services can be shared through the network, when applications and programme-associated data within a DVB Transport Stream are exchanged from the Loewe iDTV Server to the portable IRT client using UPnP [16].

Other CE projects from the German NGM initiative, such as Homeplane and SerCHo, expand the functionalities developed in WiMAC@home, in terms of QoS optimization and deployment of home-centric services. WiMAC@home ended by staging a large Symposium for the public, including a demonstration of the system, at the IRT on 31 March 2009 [17].

Conclusions – what should broadcasters do?

This article shows that home networks have become an important means for delivering audiovisual content to multimedia, computer and broadcast terminal devices in the home. Their impact on the delivery of radio and television broadcasts to the general public will undoubtedly grow in the future. While several proprietary products are currently available in the consumer market, many manufacturers have already started to commercialize open-standard, interoperable and user-friendly UPnP and DLNA consumer electronic appliances. These are all very cheap and affordable, so that the market will be able to evolve quickly. DVB-HN-compatible CE devices will follow shortly. Only new IP-enabled iDTVs or set-top boxes can make home networking a success in the mass market place.

1. Introduction to Konnex: **http://www.weinzierl.de/download/Knx_Info.pdf**
2. DigitalSTROM: **http://www.digitalstrom.org/index.php?id=115&L=2**

Martin Schmalohr graduated in 1996 from the University of Applied Sciences in Munich with a degree in Electrical Engineering. He joined the Audio Systems group at the IRT in 1998, focussing on the subjective evaluation of audio and video coding systems. He is/was involved in the work of the European IST/ICT research projects P2P-Next, kuMobile, Savant, GMF4iTV and Sambits.

Since 2005, Mr Schmalohr has been leading the IRT activities within the national collaborative research project WiMAC@home (Wireless Media and Control at Home). He is also involved in the work of EBU, DVB and DLNA technical groups. In 2008, he became chairman of the EBU group D/CH (Connected Home) and, in 2009, he joined the IRT department "Platforms for Broadcast Systems".

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.

With the growing availability of broadband connections and bundled residential gateways or routers, many users already own a private home network (even though they might not even be aware of it).

There are several issues that need to be resolved in order to roll out home networks successfully. Stable firmware embedded in the home devices and easy-to-use handling of these complex devices may still be an issue. Content security issues are still not resolved and may adversely affect the users' acceptance of networked devices.

Like HDMI and HDCP today, DLNA and network interfaces might be the next criteria for consumer electronic purchases of tomorrow – especially when it comes to the replacement of old CRTs with new multifunctional flat displays. In the homes of tomorrow, services will be accessed through a residential IP network, regardless of their physical connection – whether it is by means of telephony, webcasting, mail, web or television.

Broadcasters should continue working actively in the various standardization bodies including DVB, DLNA and UPnP in order to assure that the broadcast requirements are duly met. The EBU Project Group D/CH (Connected Home), chaired by Martin Schmalohr (IRT), has already contributed significantly to these processes. The Group is in the process of developing a test bed in order to test QoS, latency, synchronizations and other technical parameters that are critical for the high-quality performance of home networks. The group has also contributed to the latest D/HDREC (HD Receiver) specification in terms of home networking.

Broadcasters should try to impact the market development. We should encourage the CE and IT industries to integrate open-standard, interoperable, horizontal market solutions, as opposed to the multiple proprietary solutions that are currently available in the market. Any home-networking technical solutions, in order to be future proof and acceptable to all actors in the value chain, must guarantee technical quality and content security.

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