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SPECTRUM RESOURCES  
CONTENT ACCESSIBILITY

## Trends on the Horizon

David Wood Provides Some Forward Thinking on 3DTV



Ulrich Reimers Reflects on 20 Years Developing Digital Television



Nick Wells Looks at the Challenges & Opportunities Ahead for DVB



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# Reflections & New Horizons

## A Word From DVB

Twenty one years ago, in May 1991, six men met for a discreet meeting on the beautiful castle at Schönburg overlooking the Rhine River. They all shared the common concern that the broadcast industry in Europe was running into a dead end by following the D2-MAC and HDMAC route mandated by European Regulators. Multiplexed Analog Components (MAC) was still an analog system while at the same time digital television transmission systems were already being discussed in research labs. It was just a question of time before these solutions would be market ready.

This meeting was basically the birth place of the DVB Project and one of its participants was Ulrich Reimers, who at that time was with ARD/NDR and president of the technical commission of ARD/ZDF/ORF/SRG. Two years later, in September 1993, the DVB Memorandum of Understanding was signed marking the beginning of the extremely successful standardization work that led to the publication of DVB-S, DVB-C and DVB-T. All these specifications were developed in the DVB Technical Module (TM) under the chairmanship of Ulrich. These three standards and their second-generation successors are the technical basis for digital broadcast television worldwide and who could have predicted that more than 700

million digital receivers, representing 60% of the world market, would be based on DVB technology.

What were the reasons for this success story? First of all, DVB is a private association that includes those involved in digital television, such as broadcasters, network operators, manufacturers and regulators. It follows a market driven approach bringing together all relevant stakeholders to agree by consensus on the best solution. Another reason has to be the technical quality of the specifications.

The successful work of DVB will continue with Nick Wells (BBC) as the new TM chairman. Nick has been active within DVB for a long time. The enormous success of the second-generation terrestrial specification (DVB-T2) was achieved under his chairmanship of the TM-T2 module.

Interesting tasks continue to lie ahead of us. The latest progress in display technology combined with the upcoming new video coding standard will allow for resolution beyond HDTV. Already activities have commenced in DVB on Ultra High Definition Television (UHDTV) and we can expect more in the years to come. Another hot topic will be the subject of Companion Screens where we will work on multiscreen scenarios for the living room. At the last



**Peter Siebert**  
Executive Director

Steering Board meeting in July the go-ahead was given for this work. Work is also in the pipeline on a new form factor for CI Plus. Considering the high number of TVs equipped with CI Plus interfaces this will be quite a relevant activity. This short list shows that many interesting activities will be undertaken in the coming years and I have not even mentioned the new work items for satellite. I can only invite all interested parties to join us and take part in the development of tomorrow's broadcast standards

Finally, I would like to thank Ulrich for his marvelous cooperation with me over the last three years. I am also very much looking forward to working together on future DVB successes with Nick Wells as TM chair and Muriel Deschanel as the new vice chair.

## New Standards

EN 302 755: Framing structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2) (04-13-12)  
TS 101 600: GEM Profile for Plano-Stereoscopic 3DTV (05-03-12)  
TS 101 545-1: Second Generation DVB Interactive Satellite System (DVB-RCS2); Part 1: Overview and System Level specification (05-03-12)  
TS 101 545-3: Second Generation DVB Interactive Satellite System (DVB-RCS2); Part 3: Higher Layers Satellite Specification (05-03-12)  
TS 102 812: Multimedia Home Platform (MHP) Specification 1.1.3 (05-09-12)  
TS 101 211: Guidelines on implementation and usage of Service Information (SI) (05-16-12)

## New Members

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# GEM in 3D

## GEM profile for stereoscopic 3DTV

Michael Lagally, Chair TM-MUG



Michael Lagally, Oracle

DVB has recently published its specification for Frame Compatible Plano-Stereoscopic 3DTV (DVB-3DTV). It defines 3D extensions for video, signaling and subtitles to be able to transmit stereoscopic 3D movies via broadcast. The DVB-GEM Profile for 3DTV (GEM S3D) complements these specifications with stereoscopic enhancements for DVB's middleware specification GEM.

The new profile is available for the broadcast / IPTV and OTT targets of GEM and provides new display modes and 3D drawing functions. These enable the creation of applications that can draw 3D content in front of a 3D movie. (see fig.1)

### What is the problem with 3D graphics?

Assume you have a 3D movie, which is shown to the user via a 3D enabled TV. For each movie picture there is a Left and Right video frame that is displayed to the

respective eye of the viewer. If an application now just puts a graphics overlay on top of these two frames, there would be a collision between the graphics and the video. These collisions would corrupt the 3D presentation and lead to a broken picture. Consequently, the application needs to 'understand' that there is a 3D movie being presented, and needs to take precautions, to ensure that the graphics always appear in front of the movie. (see fig.2)

One challenge during the creation of the GEM S3D specification was to ensure that existing 2D applications can be easily made '3D aware', i.e., to be able to reuse them with only very minimal modifications.

### The GEM S3D profile

The stereoscopic profile defines several stereoscopic display modes and supporting APIs to resolve this problem and ensure that the graphics are always positioned in front of the movie. Conceptually the graphics can be seen as being rendered on virtual planes, which can be shifted along the z-axis via a horizontal offset between the image for the Left and Right eye.

The three new modes are using: (1) a single graphics plane; (2) two graphics planes with 2D drawing operations; (3) two graphics planes with OpenGL based 3D drawing operations.

The first 3D mode enables easy reuse of existing applications, which are always placed in front of the movie by using the video disparity information from the movie. There's no need to re-implement the drawing operations. An additional (global) disparity offset can be set by the application to shift the entire graphics plane closer to the user.

The second 3D mode allows an individual offset that will be used by consecutive graphics operations. This allows creating graphic scenes with 2D objects at arbitrary depths in front of the movie. This can be compared to a cut out paper diorama with flat figures at various depths. The graphics are synchronized and rendered on the Left and Right screen plane.

The third 3D mode allows creating a 3D scene that consists of 3D OpenGL ES objects. The scene is logically positioned in front of the video scene and is rendered to two graphics planes. It is based on the Java API for OpenGL ES, which is available as a JCP standard (JSR239). GEM S3D adds an API to enable the stereoscopic rendering of an OpenGL scene to two different viewports (one for the Left and Right eye). This is a straightforward and lightweight extension to the OpenGL model and allows reusing of existing OpenGL drawing code.

### Conclusion

GEM S3D complements the widely deployed GEM middleware platform with a new horizontal profile for stereoscopic 3D applications. This 3D GEM profile ensures that interactive applications and graphics are aware of 3D content and can handle drawing situations, where the application graphics are superimposed to 3D movie content. It extends the display model and drawing APIs and enables additional 3D display modes and drawing functions, with varying capabilities.

The GEM S3D specification (ETSI TS 101 600 V1.1.1) is available at: [http://www.mhp.org/specs/a159\\_DVB-GEM\\_3DTV-Profile.pdf](http://www.mhp.org/specs/a159_DVB-GEM_3DTV-Profile.pdf) or from ETSI.

Fig. 1

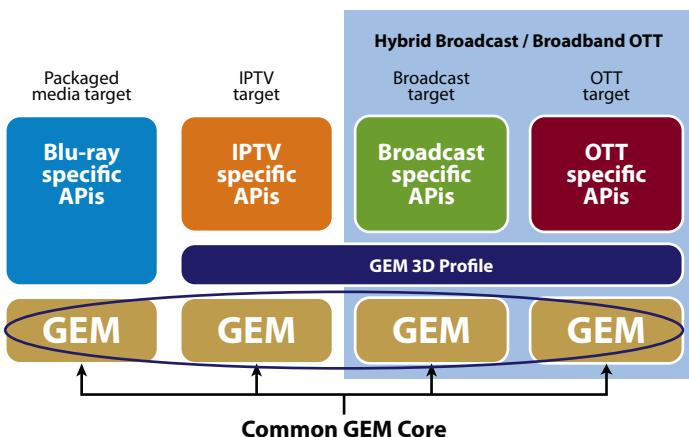
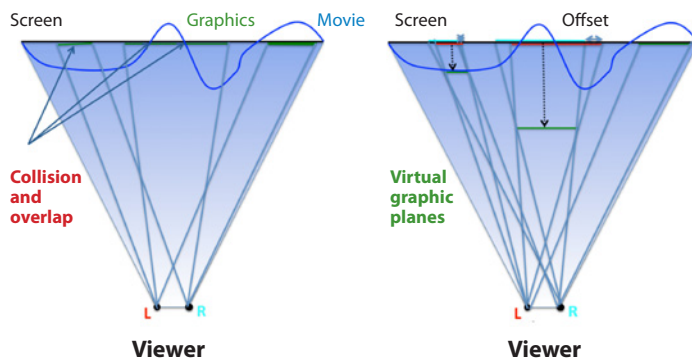


Fig. 2



# Quo Vadis

## Forward thinking for 3DTV

**David Wood, Chair CM-3DTV**

Even after the first DVB-3DTV specifications are available there are exciting new 3DTV challenges in the pipeline for DVB.

Let's face it - knowing where 3DTV will lie in future between a home fairground attraction and a major media art and delivery form is still a puzzle. 3D itself has shown waves of fashion over the past hundred years. But this in itself tells us something – that there is a hunger and attraction for 3D among the public that will never go away.

So, one thing we must do is to continue to move forward with the development of technical standards for 3DTV in DVB. For certain, 3DTV will never succeed even on a small scale, if everyone makes up their own different standards.

To meet the needs principally of Pay-TV operators, but also others, DVB first embarked on its Phase 1 3DTV system – the Frame Compatible system, where the Left and Right images are halved in resolution, squeezed and made to fit into either a 1080i or 720p frame. This is received by an HDTV set-top box, passed to the 3DTV display, where it is unraveled into separate Left and Right

images. This is the world's most successful 3DTV broadcast system.

This was followed by the Phase 2a system, designed to meet the needs of those who need to provide normal HDTV receivers with a 2D version of the 3D program from the same broadcast channel, and at the same time step up the bandwidth of the 3DTV images. The specification for Phase 2a is now completed and is in due process, which will lead to an ETSI standard. Phase 2a provides a 2D version plus an MPEG MVC top up signal. Although they are tailored to their different environments, both 3D Blu-ray and Phase 2a use MVC, so this may help receivers that want to include both capabilities.

Requirements for a Phase 2b system have also been agreed. In this case a 'top up' signal is added to a Frame Compatible broadcast, which will bring the resolution up to full HDTV resolution per eye. Work on the specification itself will start soon, with the expectation that it will be available in 2014.

The forward thinking about 3DTV has not stopped there. In some countries there is potential interest in broadcasting an HDTV form which would be '1080p/50,60' rather than 1080i/25,30 or 720p/50,60. Decoders of 1080p/50,60 would need to operate at twice the clock rate as 1080i, and need twice the storage. For some years they have been thought not practical for consumer products.

Today things are changing as 1080p/50,60 decoder chips become available without a price premium. If broadcasting is done with 1080p/50,60 there could be other options for 3DTV broadcasting. One of them may be to use a technique called 'Tile Framing' where the 1080p Frame is segmented to allow two 720p images to be included in it. Another might be to provide the Left and Right images as two 1080i signals in the 1080p Frame. No conclusions have been reached, except that if such systems are to be developed they should use the next generation compression



David Wood, EBU

technology - HEVC - for which first specifications should be available next year.

At the same time, the DVB Commercial Module discussion has opened on a whole new chapter of broadcasting, which will also probably use HEVC, with the agreement in the ITU of the two Ultra High Definition Formats – the '4K' level, which has about 8 million pixel images and the '8K' level, which has about 32 million pixel images.

'4K' cameras and displays have been available for several years, but now the fascinating concept of a 4K display that can also be used for 3DTV is emerging. The idea is that the 4K display is arranged with a surface (when called upon to show 3D) that allows 3DTV pictures to be viewed without glasses ('autostereoscopic'). The resolution of the 3D pictures would depend on how many 'views' are used – the 4K resolution has to be shared between the multiple views. Recent demonstrations were given at the NAB convention by Philips and Dolby.

Apart from systems like this, the community is asking how far the improvement in 'realism' with the 4K and 8K UHDTV will in some way substitute for the depth cues that the binocular disparity of a 3DTV system provides.

Further afield new phases of systems are being developed in the US and Korea which will use the internet to deliver a 'top up' signal synchronized by a time code with the broadcast program. The 'top up' signal is likely to be just the 'other image' of the stereo pair, and may be delivered in real time or downloaded before the broadcast takes place. We need to watch this space.

Clearly 3DTV is not going to lie still – it will just keep coming at us! (pun intended)

# 3DTV



# Stop Interfering

## Carrier ID technology

Vittoria Mignone, Rai



Vittoria Mignone

Radio Frequency Interference (RFI) highly impacts Quality of Service for satellite operators and their customers. This in particular applies to occasional use satellite transmissions and temporary feeder links, rather than to full time DTH services, often caused by failed equipment or by an improperly configured system due to human error.

With the objective to develop countermeasures against the so called 'rogue carriers', DVB has recently assigned to TM-S2 Ad-Hoc Group the task to define a satellite transmission system for Carrier Identification (Carrier ID).

As reported in the Commercial Requirements, Carrier ID is not expected to be a perfect solution to solve all RFI, but it will be a key technology in contributing to the rapid identification of RFI and reducing its negative impact to operators, customers, and the satellite industry as a whole. Furthermore, the Commercial Requirements state that Carrier ID is not required for transmitters that are fully controlled by a hub based network management system, since for these the interferer could be identified reliably by means other than an explicit Carrier ID signal. This is, for example, the case for low-cost VSAT equipment, for which the inclusion of a Carrier ID signal could be critical.

Carrier ID is meant to enable the operators and users to quickly identify interfering carriers and respond to RFI, reducing the duration of each event, improve Quality of Service and reduce operating costs. Also in the longer term, lower the number of RFI events and release

bandwidth being used to overcome current and ongoing RFI events. The availability of a DVB standard for Carrier ID will enable the industry to produce interoperable equipment and also will ensure an ongoing development and improvement of Carrier ID technology in a standardized manner.

The activities of the DVB-S2 group started in March 2012, with the conversion of the Commercial Requirements into technical ones, and the definition of a baseline system which is still undergoing refinements until the end of 2012. To allow for the Carrier ID to be virtually compatible with all carriers used in satellite today (to be considered unknown in terms of waveform and synchronization), and easy to be included in all satellite modulators, the baseline solution is based on the superimposition of a Spread Spectrum Meta-carrier (MC) to the main Data Carrier (DC). Two fixed values are proposed for the CID chip rate, 112 and 224 Kbit/depending on the DC symbol rate, in order to simplify acquisition/detection. To allow for a negligible degradation of the DC performance (typically below 0.1 dB), the MC will have a predefined Power Spectrum Density level, well beneath the DC level. At the same time, the adoption of Spread Spectrum technique, together with the Differentially Encoded BPSK modulation and a BCH FEC (Forward Error Correction) protection, allows for a very robust Carrier ID system. It should in fact

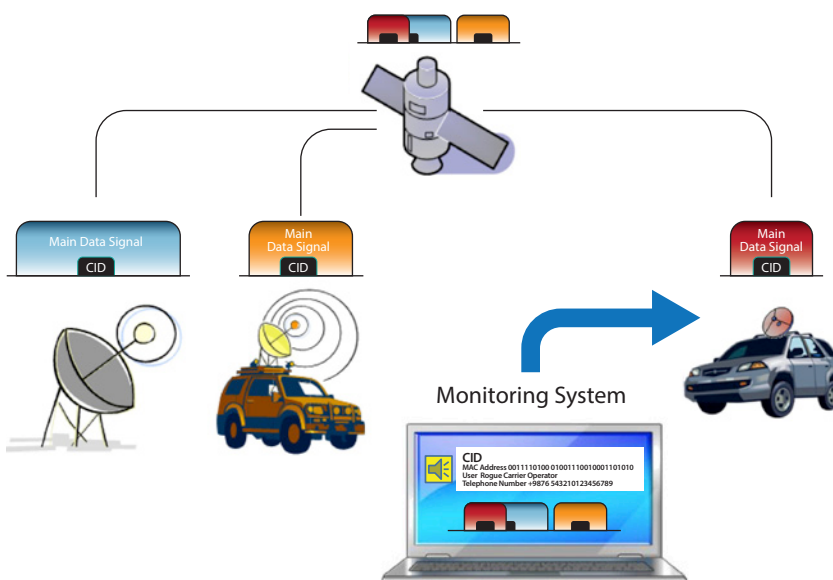
be possible, in the majority of practical cases, to identify the interferer without switching-off the wanted signal, as particularly required by broadcast services.

The message transported by the MC will include, at a minimum, the MAC address of the equipment and the Carrier ID format version (to allow for future extensions and improvements). Additional information can optionally be transmitted, configurable and editable by the user, which contains information such as uplinker name, contact phone number, etc., to help in the RFI identification. A common database is expected to exist, accessible by all satellite operators and possibly other authorized entities, which will contain all of the Carrier ID codes and the name of the satellite operator whose satellite is carrying each respective carrier.

The packet format allows for a rapid identification of the RFI: the MAC address is repeated every few seconds, so that it can be possible to identify the RFI in less than 15 seconds during line-up, and less than 1 minute during operation. The commercial requirements indicate respectively 1 minute and 15 minutes: the available margin can be used by receiver designers for reduced complexity algorithms that implement automatic detection with respect to massive parallel reception.

The standard is expected to be completed by the end of 2012.

### Example of satellite interference: CID allows the identification of interfering carriers



# Television Gets Social

## The TV set gets a companion

**Dietrich Westerkamp**

Director Standards Coordination, Technicolor

Is the TV display still the focus of the family room? Well, we see teenagers playing with their smart phones and chatting with their buddies, while dad uses his tablet to check the latest news from the stock market – and all of them sitting in front of a running TV show. Market research from the US shows that 70% of tablet and 68% of smart phone owners use their devices while watching television.

As market penetration of these personal devices grows rapidly, there is the risk that the TV program on the big screen loses its attraction, but there is also an opportunity: if the applications running on these interactive screens one way or another are related to the TV program, this would refocus the viewer's attention, turning the second screen into a companion of the TV set.

There are many ways a second screen application could support program viewership: apps could improve program search with a user-friendly EPG; could deliver background information about the show currently running; or could establish contact to buddies watching the same show so that they can exchange opinions and discuss. Even during advertisement breaks, the companion screen could offer direct access to e-commerce sites for purchase, or provide further information about the featured product. And we all know the quiz-shows where you can play along and compete with the person in the studio.

Many of us have come across check-in applications like Couchfunk (Germany), GetGlue (UK), or TVcheck (France) where one can get information from people watching the same TV show. The next level is applications that provide the user with access to and recommendations for TV shows such as BuddyTV, RendezVousTV, or M-GO. These applications combine recommendation, program access, and commerce for convenience of the user. For an even more immersive experience, content owners offer applications that run in sync with specific movies/shows and even work with

video delivered over different platforms, offering a deeper level of background or companion information and merchandise. Some example are CBC Sports (*Hockey Night in Canada*), Twentieth Century Fox (FX network's SOA Gear app for *Sons of Anarchy*), and The Weinstein Company (*The Kings Speech*). The latter works in sync with a Blu-ray Disc playback. Recently the German public broadcaster ZDF offered a thriller where you could be your own cop and help to solve the case. And as one might expect we finally also find the usual suspects here: eBay offers Watch with eBay.

There are different levels of companion screen applications: some work independently from and parallel to the running TV broadcast like the variety of social networking applications, while others are directly linked to a certain brand of TV device, since they also offer the functionality of a very comfortable remote control. And there are a rapidly growing number of new offers that is somewhere in-between. In the cases where an interaction between the two devices (main, companion screen) is needed, certain mechanisms must be in place:



**Dietrich Westerkamp**

(a) the devices must be paired to make sure that the companion screen works together with the right TV primary screen, (b) the running program must be identifiable, and (c) technology is needed for syncing any companion application if it evolves over time in parallel to content of the main video.

As can easily be seen, the fight over eyeballs is on, and every stakeholder is looking for a business model that fits. But in the end, technology must be in place to seamlessly enable these new offers. Otherwise, the growing multiplicity of proprietary techniques leads to market confusion and may finally be detrimental to the success.

And here DVB might have a role to play. A subgroup of the Commercial Module has put together a descriptive document on the Commercial Case for Companion Screen that shall serve as a starting point of the discussion in DVB. Stay tuned...





# Thank You DVB

## Prof. Dr.-Ing. Ulrich Reimers

Twenty years is a long time. Twenty years ago I chaired the first meeting of the Working Group on Digital Television Broadcasting (WGDTB) – the predecessor of the DVB Technical Module (DVB-TM). This first meeting took place more than a year after a small group of people had spent a weekend at the Schönburg, a beautiful castle overlooking the Rhine River. It was the meeting in which we tried to invent a ‘way-out strategy’ for the media industry of those years. This strategy was – we were convinced – required since we had recognized that the development of D2-MAC/HD-MAC would lead to systems that the European consumer would not accept. The idea we came up with was: ‘TV needs to go digital’. How naive we were in those early days. No one had a clue what the concept of digital television would entail. Nobody had thought about Service Information and there was no video coding available.

The WGDTB met eight times until it was able to present the ‘Report to the European Launching Group on the Prospects for Digital Terrestrial Television’ in November 1992. The European Launching Group was the predecessor of the DVB Steering Board which started its work after the official launch of the DVB Project in September 1993. The title of the report reflected the political constraints of those early years. A number of consumer electronics manufacturers and the European Commission were still pushing for the use of the MAC systems on satellite and cable and we therefore had to find a niche for digital TV which seemed politically correct – terrestrial broadcast. Behind the scenes the WGDTB had already started working on technical solutions for digital TV over satellite and cable – waiting for the DVB Project to start and be acknowledged by the European authorities as an organization allowed to work on the whole digital ecosystem.

In those early days, the DVB Project was strongly influenced by Pay-TV companies and satellite operators who were convinced that only digital signals would allow for affordable multichannel offerings over satellite and for secure scrambling. In

consequence, DVB-S was the first ‘broadcast’ specification which the DVB Technical Module approved in November 1993. In the course of that meeting I came up with the idea of ‘traffic lights’. At the end of each meeting of the DVB-TM we ask Members of the DVB Project whether they found issues with the DVB specifications – technical, economic, political – which would lead their organizations to switching on yellow or even red traffic lights. I am still convinced that this idea led to a special atmosphere in the DVB-TM: everybody knew that there would come a moment when they would be heard.

In January 1994 the DVB-C system for transmission over cable was approved and endless discussions about digital terrestrial television became the focus of the work. The Commercial Module of the DVB Project separated into one which looked after cable and satellite and a second Module just discussing the prospects of terrestrial transmission. It took nearly two more years until in the course of the 14th meeting of the DVB-TM in November 1995 we could approve DVB-T.

When I wrote the first edition of what was later called the ‘DVB Cookbook’ (ETSI TR 101 200) in 1996, we had already finalized 26 specifications and implementation guidelines – including the ever so important Service Information, the guidelines for the use of MPEG audio and video in DVB systems (yes, MPEG had delivered), interface specifications both for professional and consumer equipment, implementation guidelines for the Common Scrambling Algorithm (CSA), etc..

This was when the age of interactive television, and of what in those days was called multimedia services began. So DVB developed a specification for the broadcasting of data which was approved in January 1997 and a long list of solutions for interaction channels via telephone lines, mobile phone channels, cable, satellite and terrestrial broadcast networks. DVB-RCT (Return Channel Terrestrial) is the name of the system which enables a communication between a TV household and the



**Prof. Dr.-Ing. Ulrich Reimers, Chairman DVB Technical Module from September 2003 to June 2012. Prior to that he chaired the WGDTB (Working Group on Digital Television Broadcasting) starting in June 1992.**

broadcaster via the same frequency spectrum in which DVB-T is operated. Ireland and France were said to be in need of such a system. The technology we developed was beautiful – and never used in practice. The idea of providing multimedia services accompanying TV programs led to the start of the development of the Multimedia Home Platform (MHP) in June 1997. About 32 months later we proudly presented this complex solution. I had founded an ‘MHP Implementers Group’ outside of DVB since the MHP was such a complex beast that I was convinced we would need a lot of interoperability work which DVB was not prepared to support. This grouping grew to nearly 100 member companies which presented operating MHP solutions in 2000 for the first time in the course of a conference in my home town Braunschweig, Germany.

To the surprise of many, an American satellite operator approached the DVB Project in 2001 and requested a new and more bandwidth-efficient solution for broadcasting over satellite. The new system was to provide at least 30% more data rate in a given channel than DVB-S. In June 2003 we approved the DVB-S2 specification as the first member of the DVB second generation family. DVB-S2 was so convincingly good that in August 2006 the ITU recommended it to be the one and only second generation system. DVB-S2 was followed by DVB-T2 (June 2008), and DVB-C2 (March 2009).

### Timeline of highlights of the Technical Module under stewardship of Ulrich Reimers





Technology had continued to provide new challenges. Mobile phones had started to be equipped with color displays and the data rates on internet access networks had grown so significantly that TV over the internet no longer seemed unthinkable. We embarked on the development of transmission systems targeting mobile phones and similar devices and we started to develop solutions for TV over the internet (IPTV). DVB-H was the first system for delivering video to handhelds. The specification was approved in January 2004. The first version of the DVB-IPTV handbook was finished on the same date. A few months ago the 5th version was completed – an incredibly complex and powerful system. DVB-H was followed by DVB-SH which we finalized in January 2007. At the time of writing, DVB-NGH (Next Generation Handheld) is nearing completion.

The few systems mentioned so far are just a fraction of what the DVB Project was able to deliver - at the time of writing we count 148 different DVB-based ETSI documents. Among these are 14 documents related to the DVB Content Protection and Copy Management (CPCM) solution. A huge amount of work went into this fabulous system over a period of nearly 10 years between March 2001 and September 2010. In some future time a more detailed analysis of the achievements of the DVB Project may be published – with room for the description of such wonderful solutions like CSA3, DVB-RCS2, DVB Subtitling, IP Datacast, DVB-3DTV, the various audio-video-related pieces of work, etc..

A long time ago I had decided that I would resign as chairman of the DVB Technical Module either at the age of 60 or after 100 meetings of the WGDTB/ DVB-TM or after 20 years of service as the chairman of those wonderful groups. In the summer of 2012 all these criteria were fulfilled at the same time. I therefore resigned from my position. The new management team of the DVB Technical Module will be Dr. Nick Wells (BBC) as the chair, and Muriel Deschanel (Microsoft) as the vice-chair. Both will continue to be supported by Dr. Peter Siebert and the able members of the DVB Project Office.

I wish the DVB Project all the best for the future and I say 'thank you' to those great guys in the DVB-TM, to the Members of the DVB Project, to the chairs of the Steering Board, Modules, and Ad-Hoc Groups, and to the members of the DVB Project Office for their support and for a great time.



The television industry has been fortunate to have the visionary leadership of Ulrich Reimers. Ulrich's leadership of the DVB Technical Module has been exemplary. His strategic outlook coupled with practical management skills have been key elements to the success of the DVB Project. Through his numerous lectures, presentations and papers, he has helped our industry advance its understanding of digital television. I have had the pleasure of knowing Ulrich for over twenty five years and look forward to future collaboration.

**Mark S. Richer,**  
President, Advanced Television Systems Committee, Inc.



As Ulrich Reimers is still the co-founder and father of the DVB Project, it is virtually impossible to provide a tribute to Ulrich for his work in the DVB Technical Module. His unparalleled knowledge of the technologies involved, paired with his ability to reconcile diverging member interests, has made DVB into what it is today: the most successful standardization venture ever. It was a great privilege to work with Ulrich for so many years.

**Theo Peek,**  
Chairman, DVB (1996 - 2008)



We all know Ulrich as the chairman of the Technical Module, however for some he is also the Director of the renowned Technical Institute at the University of Braunschweig where he is extremely popular with employees, students and academic colleagues alike. Surprisingly, he still finds time for his hobbies such as taking photos of orchids and bird watching. I am always impressed how he manages all these activities. I am equally impressed by his warm and friendly personality, and for me it has been a great pleasure and inspiration to work with Ulrich. He is a truly remarkable individual.

**Peter Siebert,** Executive Director, DVB



I met Ulrich in 1993 when I was chairing an EBU subgroup setup to design the first digital satellite TV system. He has since gone on to enjoy a prolific career. His vision and ingenuity have made DVB a major force in the media community worldwide. Through our years of cooperation I have learned much in terms of technology, but more importantly the capacity to reach consensus via transparency and mutual respect. He always offers clear and insightful advice. He made it possible for European Broadcasters to select their delivery technologies by just picking the DVB solution, as it was always the best. And for all of us, DVB is synonymous with Professor Reimers.

**Alberto Morello,** Head of Rai Research Centre, Turin, Italy and Chairman, DVB-S2 Technical Module



"From discord, find harmony. In the middle of difficulty lies opportunity": the advice of Albert Einstein. Ulrich Reimers personifies these words. As the chairman of the DVB powerhouse, the Technical Module, he has shaped the world's broadcasting. He understands the technology. He listens to all sides. He finds solutions where everyone wins. He writes the reports on the meetings before his train pulls out of Geneva station. What a remarkable guy!

**David Wood,**  
Chairman, DVB-3DTV Commercial Module and former EBU Deputy Director, Technology & Development



The name Ulrich Reimers will always be synonymous with digital television. Ulrich's experience in manufacturing, broadcasting and academia made him uniquely equipped to lead the Technical Module in the most important development in broadcasting in half a century, the DVB Project. His utter dedication to the Project earned him the admiration of all associated with television and indeed inspired many colleagues and students alike to participate in the work of developing digital television. His retirement will leave a gap in our digital world but I am sure that with such an active intellect he will continue to provide guidance and advice.

**Dr. George T. Waters,** former Director General, RTE and former Director, EBU Technical Department



For the TM's many successes and achievements under Ulrich's leadership we congratulate and thank him. We should also add our sincere appreciation for the way Ulrich has gone about this. As CM Chairman, it's been a pleasure to work with Ulrich. His commitment to consensus, using the infamous 'coffee break' to overcome obstacles, his desire to see a market-led approach and his contribution to DVB's vision has ensured DVB's 20 year lifespan. Ulrich, you are a living legend in the industry. Thank you for your immense contribution to DVB.

**Graham Mills,**  
Chairman, DVB Commercial Module



Yes, it has been great and sometimes a lot of fun working with Ulrich on the DVB Steering Board since 1993. He is unique not only in his skills, but also in the way of solving hiccups in the technical work through diplomatic coffee breaks. As a German professor he is of course thrilled by numbers ending in zero, so he was eager to end his work in DVB with the 100th Technical Module meeting following his 60th birthday. What could be better than having the freedom to decide to start new challenges whilst still being young enough to enjoy new horizons? Good luck Ulrich!

**Helmut Stein,**  
Chairman, DVB Promotions & Communications Module



Congratulations Ulrich on a most successful 20 years steering the technical activities of the DVB Project. The impact on the global status of digital TV broadcasting has been immense, with the standards developed under your guidance now in use around the globe. It was a pleasure to work alongside you for well over half of those 20 years, and I wish you continuing success and happiness in your future career.

**Ian Childs,**  
Vice-Chairman, DVB Technical Module (1993 - 2006)



I met Ulrich 20 years ago when semi-digital standards like D2-Mac and HD-Mac were being discussed. We, along with many others, concurred that the future for broadcasting would be digital. However gathering all the players around the table, productively working together, looking for and accepting compromises and convincing the political side – this was the real challenge. With all his abilities and personal charm Ulrich took on the challenge and in doing so he became the father of DVB. Here in Germany, as in so many countries around the world, broadcasters have switched to digital and this is a credit to Ulrich. We all owe him our gratitude.

**Peter Kahl,** Chairman, DVB (1993 - 1996)



A role model in many ways: the leader of one of the most dynamic standardization groups at a critical time for television. In so many ways, Ulrich was a DVB-compliant individual. More than this his humanity and integrity shone through his many dealings with DVB Members and those implementing and using the technology. DVB remains a model for all industry organizations in the media technology domain. From a personal perspective, I arrived in DVB as a young engineer and Ulrich was the biggest influence on my career in the business of digital television.

**Peter MacAvock,**  
Head of Media Delivery and Platforms, EBU Technical and Executive Director, DVB (1994 - 2008)



First impressions of people are often misleading. After I first met Ulrich Reimers more than 20 years ago, I described him to a colleague as 'impressive'. Over the years, I have also learned that he is erudite, precise, punctual, articulate, highly-motivated, calm under pressure, generous and supportive to his colleagues. In other words, my initial judgment proved to be uncannily accurate. On behalf of the entire DVB Project, I can only say 'Thank you, Ulrich!'

**Phil Laven,**  
Chairman, DVB



# On the Horizon

## Challenges and opportunities ahead

**Dr. Nick Wells, Chair DVB-TM**

I have been asked to write a short article about what I see as the direction and challenges for DVB in the future.

Firstly, one of the major strengths of DVB is its organizational structure with a Commercial Module working alongside the Technical Module, overseen by a Steering Board. This structure helps to ensure that the work of the TM is concentrated on systems and specifications that are commercially relevant and that are required by several members of the DVB Project. Also, another reason for the success of DVB is its collaborative, consensus-building culture together with the excellence of the technical expertise contributed by member companies and individuals. One of our ongoing challenges is to foster and to maintain this excellent spirit of collaboration for all the work done within DVB.

A fundamental future activity for the TM is the maintenance of existing DVB standards in the areas of satellite, terrestrial, cable and IP-network distribution. This maintenance includes extending existing standards to meet new requirements that always continue to appear just as, for example, the DVB-S2 standard is currently

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**...the potential to continue to contribute positively to new developments and new standards in a way that maximizes the benefits to all players in the industry.**

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being extended to cover wide bandwidth satellite transponders.

In addition to maintaining existing standards, there are many new challenges and opportunities in the rapidly changing world of TV distribution (and contribution). DVB has the potential to continue to contribute positively to new developments and new standards in a way that maximizes the benefits to all players in the industry.

For example, in the case of terrestrial

broadcasting there is huge (and growing) pressure on limited spectrum resources. This pressure is coming from an ever increasing demand for TV services that require higher bitrates such as 3DTV and HDTV (and beyond), whilst the mobile telecom industry is now also competing for parts of the broadcast spectrum. Inevitably, there will be pressure on all spectrum users to make the most efficient use that is possible of a limited spectrum resource.

Similarly, there will inevitably be a requirement to use terrestrial spectrum to broadcast TV to handheld devices. Broadcasting TV to mobiles cannot be said to have been a commercial success, yet it seems inevitable to me that there will be an unstoppable future demand to receive broadcast / multicast TV content on portable and handheld devices as the proliferation of smartphones and tablet computers increases. New solutions need to be agreed so that traditional broadcast and mobile applications can coexist in the most effective and efficient manner.

Another area that I think that DVB could definitely add value is in the specification of open interfaces that enable improved 'accessibility' to delivered content. For a significant minority of people, the current methods for accessing content through a traditional program guide and conventional remote control are far from optimum. Many different ways to provide tailored solutions to improve accessibility are possible and these would be aided by standardized and open interfaces in TVs and STBs. DVB is well placed to define such interfaces.

There has been much talk about 'companion screens' or companion devices. These could be used not only to provide a means to improve accessibility but also to provide simultaneous access to material that supports broadcast or streamed content. I think that this is an exciting and important area for development that could really enhance our viewing experience. There are several aspects of such a network and system that could profitably be standardized and again DVB is well placed to write helpful and relevant specifications.

Finally, the distribution of TV content over the internet and IP distribution



**Dr. Nick Wells is the new chair of the DVB Technical Module. He studied physics at Cambridge University and then obtained a Ph. D. from Sussex University for studies of radio wave propagation in conducting gases.**

**In 1977 he started working at BBC Research and Development in a variety of fields including image compression in production systems and digital terrestrial transmission systems. He has played a leading role in several large European collaborative projects. He chaired the Professional MPEG Forum which played a major role in the creation and promotion of MXF which is a key standardized file format for the exchange of programme material in the professional environment. He chaired the DVB-T2 technical working group. He previously served as vice-chair of the DVB Technical Module.**

networks is becoming ever more prevalent and important. DVB needs to constantly review where it can actively and effectively contribute in this area. In summary, I think that there are many continuing opportunities for DVB to serve the TV industry through using its very effective organizational structures, intellectual resources and culture to define standards that support all means for TV distribution and consumption.



# Digital Future

## FoBTV - What's it all about?

### Phil Laven, Chairman, DVB

Does terrestrial TV have a future? Your answer to that question probably depends on where you live. If you come from a country that is very heavily-cabled (e.g., The Netherlands or Belgium), you might feel that terrestrial TV has no future. On the other hand, if you come from France, Spain, Italy or the UK, you are more likely to say that terrestrial TV is important.

In many countries, the use of cable and satellite delivery systems has been dramatically increased by the advent of digital TV. In an era when TV programs are often viewed via the internet, you might conclude that terrestrial delivery is about to disappear. However, there are many contrary examples: for example, the arrival of digital terrestrial TV in Germany actually increased the number of households using terrestrial TV. Similarly, a recent study from GfK Media indicated that 17.8% of households in the US now rely exclusively on terrestrial transmitters to get their TV (compared with 15% in the previous year). Figures from the UK regulator Ofcom show that, despite very strong competition from cable and satellite services, digital terrestrial TV became the UK's dominant delivery platform in 2007 and is projected to hold 40% of the primary TV set market in 2020 – with an even higher share of secondary TV sets.

Such figures cast doubt on the idea that terrestrial TV is a dwindling market. But TV viewing is no longer restricted to 'TV sets'. Delivering TV signals reliably to mobile and portable devices is a huge challenge – especially to millions of such

devices simultaneously. In fact, it is impossible for mobile phone networks to cope with the projected demand for video delivery – even if they divert most of their users to Wi-Fi networks.

Terrestrial broadcasting (i.e., 'one-way' 'one-to-many' transmission) is the best possible way of delivering live TV to massive audiences – and, therefore, we need to enhance digital terrestrial transmission systems to meet the needs of mobile and portable devices. Consumers would welcome the ability to watch free-to-air TV services on such devices (without incurring substantial charges for downloading of data), but it is unreasonable to expect manufacturers to incorporate all of the various standards for digital TV (e.g., ATSC, DVB, ISDB-T, DTMB, etc.). The obvious solution is a single global standard. The multiplicity of regional standards for delivery of digital TV could, perhaps, have been excused when TV sets were rarely moved between countries. However, the increasing availability of high-quality portable displays in the form of smartphones and tablets dramatically changes the environment. Although achieving a single global standard is undoubtedly 'easier said than done', it would be disappointing if the next-generation of digital terrestrial TV perpetuated the existing fragmentation of standards. A unified standard is an important goal that would offer huge benefits for broadcasters, manufacturers and, above all, consumers.

One of the most important developments during the last year has



Phil Laven

been the emergence of the FoBTV (Future of Broadcast TV) initiative following the declaration agreed in Shanghai on 11 November 2011 (at the propitious time of precisely 11.11.11 on 11/11/11). Television broadcast organizations from around the world have signed a landmark memorandum of understanding (MOU) to officially form the global FoBTV Initiative.

The fact that FoBTV is supported by organizations that have long been involved in the development of the various standards used for digital TV around the world suggests that this is the start of a new era in which 'global collaboration' will be the key principle.

FoBTV is a voluntary, non-profit association that is open to any organization that signs the MOU which is available at [www.fobtv.org](http://www.fobtv.org).

### Founding Members

Advanced Television Systems Committee (ATSC)  
Canadian Broadcasting Corporation (CBC)  
Communications Research Center (CRC)  
Digital Video Broadcasting Project (DVB)  
European Broadcasting Union (EBU)  
Electronics and Telecommunications Research Institute (ETRI)  
Globo TV Network  
IEEE Broadcast Technology Society  
National Association of Broadcasters (NAB)  
National Engineering Research Center of Digital TV of China (NERC-DTV)  
NHK Science and Technical Research Laboratories  
Public Broadcasting Service (PBS)  
Brazilian Society of Television Engineers (SET)

### Management Committee

**Chairman:**  
Mark Richer (President, ATSC)

**Vice-Chairman:**  
Phil Laven (Chairman, DVB)

**Technical Committee Chairman:**  
Dr. Wenjun Zhang (Chief Scientist, NERC-DTV)

**Technical Committee Vice Chairs:**  
Dr. Yiyan Wu (Principal Research Scientist, CRC),  
Dr. Toru Kuroda (Director of Planning and Coordination Division, NHK)  
and Dr. Namho Hur (General Director, Department of Broadcasting System Research, ETRI)

# The Big Switch

## Russia's migration to T2

### Alexey V. Malinin , Deputy Minister of Telecom & Mass Communications of the Russian Federation

Almost a year ago, in September 2011, Russia adopted DVB-T2 as the standard to build the most innovative broadcasting networks throughout the country.

For many years terrestrial television broadcasting has remained one of the most accessible and called-for sources of information for the people of Russia. That is why it is so important to keep the terrestrial platform up to date.

The transition to digital offers great opportunities not only to improve coverage and provide better quality of sound and pictures but also to introduce new services. Since 2009 when the national program of transition to DTT started, digital television has come to many remote districts of our country and everywhere people are very interested and enthusiastic about the new services.

The current digital terrestrial offering consists of four social and political channels as well as a news service, sports, culture and children's channels transmitted within the first multiplex. After the transition to DVB-T2 two more channels will be accommodated in this multiplex: a regional and a public channel.



One of Russia's 4900 Transmission Stations

The first T2 test transmissions were performed in Russia in August 2011. Up until then the national program for the transition to DTT had started with most of the frequency and network planning work done and several DVB-T networks already rolled out. Thus, the re-use of existing infrastructure and operating within planning constraints became the primary goal when determining the optimum transmission mode for the T2 network. It was a really challenging task given that in order to provide coverage to the entire population it was necessary to build more than 4900 transmission stations.

Existing DVB-T network parameters are set in order to reach a bitrate of 22 Mbps, which in combination with MPEG-4 coding allows the transmission of 8-9 channels within 8 MHz band. Field measurements of T2 signals performed in several Russian regions proved a 50% gain in a bitrate compared to DVB-T. With the same transmission mode (64-QAM, FEC 3/4) and coverage, a T2 transmission provides 33 Mbps. It means that 20-24 free-to-air channels can be accommodated in just two multiplexes instead of three as was previously planned.

Another positive result of the trial was that the coverage area of a T2 transmitter had doubled when compared to DVB-T while keeping the same transmitter characteristics, reception mode, video quality and number of channels.

DVB-T2 transmissions are now on air in several regions of the country including Moscow, St. Petersburg and Kazan. It is expected that the number of people who can potentially receive T2 signals will increase to 70% by the end of this year. Coverage for the entire population will be achieved by 2015.

The additional capacity provided by T2 in the first multiplex is allocated for an emergency warning system and e-government programs. Pilot projects have already been launched in St. Petersburg and Kursk. HD services are expected to be introduced in the third T2 multiplex.

It is also planned to use one of the most essential innovations of the T2 standard, Multiple PLP mode, for the insertion of local and regional services. Given that 83 regions of the country are spread out in eight time zones, traditionally five



Alexey V. Malinin

time-shifted versions of national channels are created and delivered by satellite to the terrestrial network. As well, local information blocks are inserted in national channels in every region. The Multiple PLP mode will provide improved regional programming, while at the same time ensuring more efficient use of satellite bandwidth.

As DVB-T tuners do not support reception of T2 services, migration to DVB-T2 becomes a complicated task for countries that have already launched DVB-T networks. However, Russia has a unique opportunity to use the latest standard for digital terrestrial television broadcasting almost from the very start. Several existing DVB-T networks will be modified to DVB-T2 by 2013 and very few people in Russia will have to replace their STB.

The DVB-T2 standard ensures extremely efficient spectrum use allowing transmission of up to 15 SD channels in 8 MHz. Therefore after the switchover to DTT, a good deal of spectrum will be released. To meet the growing demand for wireless broadband services, mobile operators are eager to acquire the upper UHF band (790-862 MHz). However, broadcasters also have plans for the digital dividend to expand their services and introduce HDTV, 3DTV and interactive programs. Now the aim of the regulator is to promote a balanced use of the digital dividend between broadcasting and wireless broadband services to enable the introduction of advanced technologies and innovative services.

I believe that DVB-T2 will have a long life and our experience will be valued and appreciated by countries that are planning to start their transition to DTT as well as those considering migration from DVB-T to T2.



# Life after ASO for DTT Set-Top Boxes



**Myra Moore** is the chief analyst of DTC, a market research firm that analyzes the digital TV market. DTC recently formed the Digital TV Transition Group which provides planning, consumer education, research and technical design for countries making the analog-to-digital TV transition.

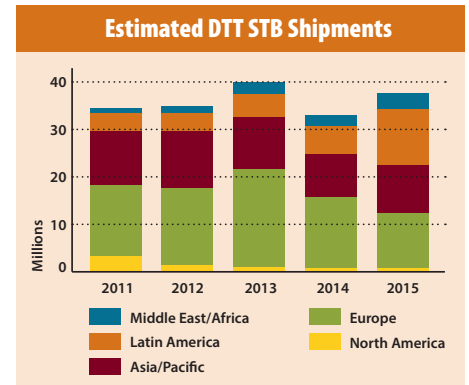
For more information, please see: <http://dtcreports.com/dtv.aspx>

The evolution of the digital terrestrial TV set-top box is rather circuitous. In the beginning it was the only way to receive over-the-air DTT signals. Over time the DTT tuning and video decoding migrated into TVs where most of today's reception occurs. Intermittently a market for digital-to-analog converter boxes surges as the boxes bridge the gap of digital transmissions to analog TVs.

Does the DTT STB have a life beyond the ASO era? DTH satellite operators will likely continue to install satellite/DTT hybrid boxes to accommodate simultaneous program recording for PVRs. We also believe that there may be other life after ASO as most consumers will benefit from a greater number of Over-the-air (OTA) channels that can be supplemented with other entertainment programming sources (internet streaming offerings and/or pared down traditional Pay-TV offerings).

But the ASO era won't be over for some years and several large markets (Russia, Mexico, and South Africa) are scheduled to shut down analog transmissions in the next few years. For makers of DVB-T2 STBs, Russia will become a critical market. The timing of its shut-off is somewhat fluid since Russia decided to switch from DVB-T to DVB-T2 networks. Shipments in 2013 spike as 2013 is the date that the Russian government announced the switch to DVB-T2 will be complete. In 2013 DTC forecasts that about 40 million DTT STBs will ship worldwide representing an estimated 15% increase over 2012.

South Africa and the southern Africa region should also bring an increase in DVB-T2 STB shipments. A strong foothold in Africa will bode well for DVB-T STB makers past the 2015 date as the rest of the continent is only beginning planning or implementation of analog to



digital transitions. Africa's analog to digital transition is already impacting market share for DTT STB suppliers. Altech, for example, is slated to make low-cost STBs for the South African government. It will likely leverage the South Africa contract to supply STBs to other African countries.

Mexico, in ATSC territory, is also expected to contribute greatly to the overall DTT STB category as it has a large population dependent on OTA transmissions. Later in the forecast period and beyond, Latin America will heavily dominate the market with almost all DTT STBs falling under the ISDB-T transmission standard.

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# MARKET WATCH

[www.teamcast.com](http://www.teamcast.com)

The TeamCast Vyper modulator is DVB-S, DVB-DSNG and DVB-S2 compliant, and meets all requirements for contribution, distribution and DTH satellite broadcast applications. It offers a maximum throughput of 68 Mbaud, which when combined with its optimized roll-off characteristics, means it can transmit data rates up to 306 Mbit/s over a 72 MHz transponder, while still remaining 100% compliant. With standard ASI and IP interfaces, it has an embedded web browser and user-friendly front panel controls.



[www.digitaltv-labs.com](http://www.digitaltv-labs.com)

Digital TV Labs, the official CI Plus LLP Approved Test Centre, has released the CI Plus v1.3 Test Suite, which became mandatory in August 2012. The Test Suite and accompanying Test Tool provide diagnostic conformance testing of the new Host resources and enable comprehensive testing of the complete CI Plus CAM interface. Manufacturers can minimize time to market by using the Tool to validate CI Plus Hosts before the certification process.

[www.harmonicinc.com](http://www.harmonicinc.com)

ProMedia Xpress file-based transcoder uses Harmonic's H.264 codec technology to deliver quality video without impeding transcoding speeds, thereby improving video workflows for content owners and service providers, enabling them to deliver an increase in content hours while adhering to processing timetables and video quality targets. Facilitating faster-than-real-time transcoding of broadcast-quality content for multiscreen VOD delivery to mobile devices, PCs, and connected TVs, it allows operators to launch new services efficiently without compromising quality.



[www.imgtec.com](http://www.imgtec.com)

Imagination Technologies' PowerVR D4500MP decoder and E4500MP encoder are the first members of the PowerVR Series4 multi-standard codec cores, including H.264 HP support. By providing up to 10-bit precision and 4:4:4 color resolution, the video cores provide the required fidelity for the latest generation of displays and offer the performance for enjoying super high definition at full 4Kx2K resolution, multistream channel browsing, high frame rate support for detailed slow motion footage and other rich multimedia content.

[www.agilent.com](http://www.agilent.com)

Agilent Technologies announced two new X-Series vector signal generators N5182B MXG and N5172B EXG that it claims provides unmatched performance in phase noise, output power, ACPR, EVM/MER and bandwidth. The systems, together with N7623B signal studio software provide real-time capabilities to create validated DVB-T/H/T2/C/S/S2 reference signals for receiver design, verification and performance testing. They extend ARB waveform memory up to 512 M samples, which are optimized and cost effective for component, transmitter and receiver testing.



[www.verimatrix.com](http://www.verimatrix.com)

Verimatrix has released version 3.1 of the Operator Management Interface, a core component of the Video Content Authority System, VCAS 3. Uniquely, while a single DRM may support a multi-device domain concept as such, VCAS enables cross-DRM domain management, i.e., VCAS super domains. When content is entitled to a subscriber's domain, as opposed to a device, it is automatically available to all the domain's devices, whether DVB, IPTV, Hybrid, HLS, PlayReady or Marlin DRM clients.

[www.t-vips.com](http://www.t-vips.com)

The T-VIPS CP524 TS Adapter performs multichannel MPEG-2 Transport Stream processing, multiplexing and interface conversion between ASI, IP/Ethernet and SMPTE 310. Capabilities include: multiplexing/filtering of services and components, demultiplexing of input TS, dynamic PSI/SI/PSIP updates and insertion of PSI/SI/PSIP data. Advanced features such as Hitless Switching with diversity reception are available as options and network performance data from the TS Adapters' built-in redundancy and monitoring features can be integrated with NMS systems for improved reliability.



[www.newtec.eu](http://www.newtec.eu)

Newtec has launched its next generation broadcast satellite modulator platform for satellite networks for delivering further bandwidth efficiency performance and help broadcasting businesses evolve through ongoing market and technology transitions. A new generation DVB-S2, DVB-DSNG and DVB-S modulator, it is designed for contribution of television and radio content, primary distribution and broadcast direct-to-home (DTH). It interoperates seamlessly with DVB set-top boxes, professional IRDs and satellite demodulators.



[www.ericsson.com](http://www.ericsson.com)

Today's broadcast environment must address an ever widening range of applications, often resulting in the deployment of a broad portfolio of compression equipment with hidden costs. With the emergence of new resolutions such as 1080p50/60 and 4K, the range of equipment is likely to further expand. Ericsson addresses these challenges with the Advanced Video Processor range of high density, multi-function, multi-application video processing products, designed for current and future requirements of broadcasters and network operators.



[www.myechostar.com](http://www.myechostar.com)

EchoStar recently launched the world's slimmest digital TV recorder on the Freeview network in the UK. The DVB-T2 Ultra Slim Box HDT-610R measures only 14mm deep and provides consumers with subscription free access to 50 high quality digital channels plus 4 in HD. Features include on demand and catch-up TV applications, the ability to pause or rewind live TV and record a complete series at the touch of a button using Series Link.





# After Digital, Now Analog!\*



\* After DVB-T and DVB-T2,  
MT2 now supports Analog PAL

## MT2-2200

### Rack Modulator



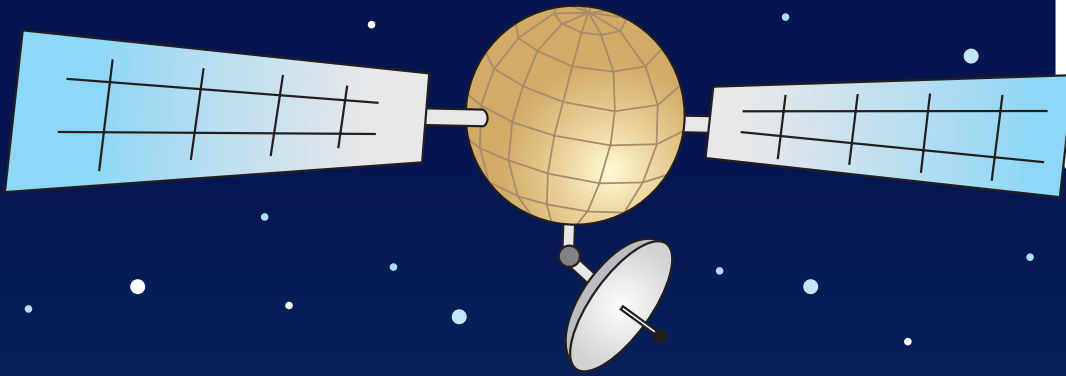
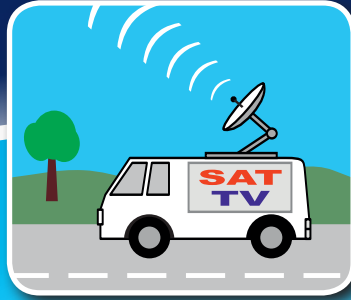
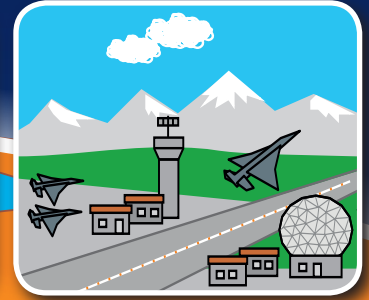
### OEM Modulator



“Be prepared for a smooth transition to Digital”  
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operation, releases as a worldwide first a Digital  
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Choosing MT2-2200 product is a guarantee for successfully  
performing a smooth transition from Analog to DVB-T  
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It especially meets broadcaster's requirements to purchase  
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ment, even after the DSO switch over.

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WORK Microwave's comprehensive range of DVB-S2 modems are the most reliable products for optimizing throughput and increasing the bandwidth efficiency on any communications network. Designed for service provider, corporate network, broadcast, telco, and government use, our advanced modem technologies are the ideal choice for a variety of applications.

Performance and cost-saving features include:

- Multi-channel ACM functionality (OptiACM)
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- Generic Stream Encapsulation (TS 102 606)
- DaVid Technology (multiple MPEG transport streams and IP data aggregated into a DVB-S2 multistream)
- Roll-Off factor down to 5% for reduced carrier spacing
- Power Supplies for BUCs

