DVB-SH — mobile digital TV in S-Band

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DVB-SH is the name of a mobile broadcast standard designed to deliver video, audio and data services to small handheld devices such as mobile telephones, and to vehicle-mounted devices. The key feature of DVB-SH is the fact that it is a hybrid satellite/terrestrial system that will allow the use of a satellite to achieve coverage of large regions or even a whole country. In areas where direct reception of the satellite signal is impaired, and for indoor reception, terrestrial repeaters are used to improve service availability.

It is planned to use frequencies below 3 GHz, typically S-Band frequencies around 2.2 GHz adjacent to the 3G terrestrial frequencies. DVB began work on the DVB-SH specification in 2006. The system and waveform specifications have recently been released in the form of DVB Bluebooks, and sent to ETSI for publication as formal standards.

Mobile TV is expected by many to become the next big mass-media market. There has been significant activity in this regard since the publication in November 2004 of the DVB-H standard, seen by analysts as a possible dominant system for the delivery of mobile TV services. Commercial networks are already being deployed in a number of countries and more than thirty trials have already been completed or are on-going. DVB-H is primarily targeted for use in the UHF bands, currently occupied by analogue and digital terrestrial television services.

In the same vein, DVB-SH seeks to exploit the less congested, higher frequency, S-band where there are opportunities for Mobile Satellite Services (MSS) systems, operating in conjunction with Complementary Ground Components (CGC). In particular, on 14 February 2007, the European Commission adopted a decision making 30 MHz of S-Band spectrum harmonized and available throughout Europe for hybrid satellite/terrestrial systems. DVB-SH also leverages on the experience gained by mobile telephone operators while delivering video streams over 3G networks in cellular terrestrial networks operating in the 1.9 to 2.17 GHz UMTS band, which is adjacent to the S-band (*Fig. 1*). This experience is particularly useful

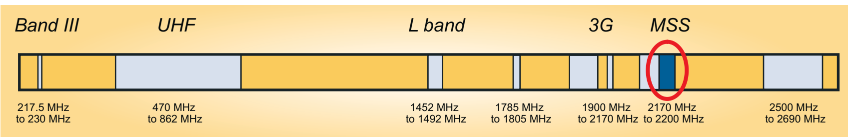

Figure 1
3G and S-Band spectrum

when planning the deployment of repeaters for good indoor coverage. And significant savings in deployment cost are expected wherever the re-use of cellular sites, including 3G antennas, will be made possible.

Figure 2
Prototypes of DVB-SH handheld terminals

DVB-SH services are aimed at providing IP-based multimedia services to mobile users. These services are targeted at a single user (owner of a personal terminal) or a restricted set of users sharing the same terminal. The user can access the services while on the move, e.g. walking or while travelling in a car or on a train. In particular, the required terminals have to be compatible with mobility in terms of size, weight and power consumption (*Fig. 2*). The main interest is in broadcast services. Typical applications may include:

- broadcasting of classic Radio and TV content;
- broadcasting of audio or video content customized for Mobile TV (e.g. virtual TV channels, pod-casts,);
- data delivery ("push"), e.g. for ring tones, logos;
- video-on-demand services;
- informative services (e.g. news) including location-based services;
- interactive services, via an external communications channel (e.g. UMTS).

Thanks to the long experience accumulated within the DVB project – in developing market-driven open standards for the provision of new services, and relying on the rich family of existing DVB standards (DVB-H, DVB-S2, DVB-IPDC, etc.) – the DVB-SH set of specifications allows the development of products and services for user terminals that can be easily operated in dual mode with other DVB-based similar services. In particular, making reference to the DVB-H case, DVB-SH allows the present UHF-based service offer to be extended to S-Band with a common cross-border allocation, a reduced total network infrastructure cost and an expansion of the offer in terms of number of channels/services. Hence, DVB-SH will benefit from the existing IP Datacast (IPDC) services, such as Electronic Programme Guides, Content Delivery Protocols and Service Purchase and Protection.

System presentation

Overview

The DVB-SH standard provides an efficient way of carrying multimedia services over hybrid satellite and terrestrial networks, at frequencies below 3 GHz, to a variety of mobile and fixed terminals having compact antennas with very limited directivity. Target terminals include handheld (PDAs, mobile phones), vehicle-mounted, nomadic (laptops, palmtops…) and stationary terminals.

The DVB-SH standard provides a universal coverage by combining a Satellite Component (SC) and a Complementary Ground Component (CGC): in a cooperative mode, the SC ensures geographical global coverage while the CGC provides cellular-type coverage. All types of environment (outdoor, indoor) can then be served, either using the SC from its first day of service, and/or the CCG that is to be progressively deployed, building on the success of DVB-H. A typical DVB-SH system (see *Fig. 3*) is based on a hybrid architecture combining a Satellite Component and, where necessary, a CGC consisting of terrestrial repeaters fed by a broadcast distribution network (DVB-S2, fibre, xDSL…). The repeaters may be of three kinds:

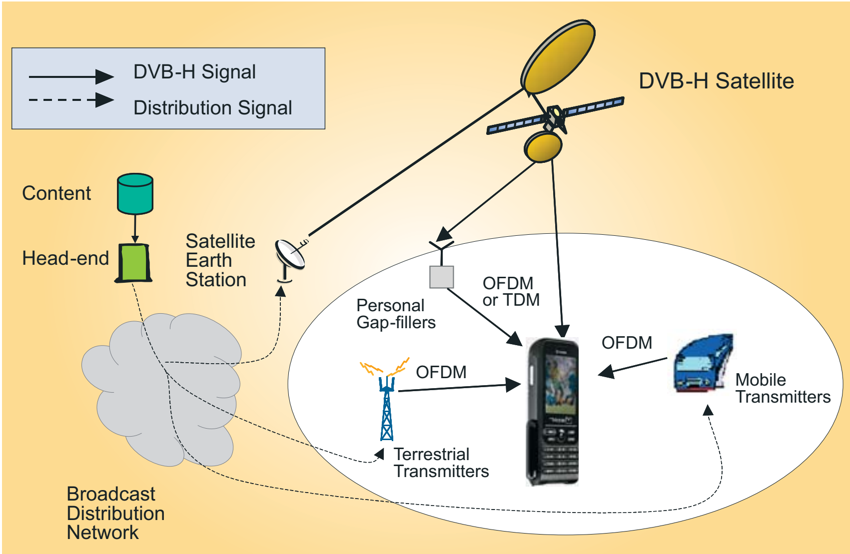

Figure 3
DVB-SH overview

- “Terrestrial Transmitters” are broadcast infrastructure transmitters, which complement reception in areas where satellite reception is difficult, especially in urban areas; they may be co-located with mobile cell sites or standalone. Local content insertion at that level is possible, relying on adequate radio-frequency planning and/or waveform optimizations.
- “Personal Gap-fillers” have limited coverage, providing local on-frequency re-transmission and/or frequency conversion; a typical application is indoor enhancement of satellite coverage; no local content insertion is possible.
- “Mobile transmitters” are mobile broadcast infrastructure transmitters creating a “moving complementary infrastructure”. Typical use is for trains, commercial ships or other environments where continuity of satellite and terrestrial reception is not guaranteed by the fixed infrastructure. Depending on the waveform configuration and radio frequency planning, local content insertion may be possible.

DVB-SH architectures

OFDM (Orthogonal Frequency Division Multiplexing) is the natural choice for terrestrial modulation and is the basis of both the DVB-H and DVB-T systems. DVB-SH introduces a second scheme, a Time Division Multiplex (TDM), leading to two reference architectures termed SH-A and SH-B:

- SH-A uses OFDM both on the satellite and the terrestrial link;
- SH-B uses TDM on the satellite link and OFDM for the terrestrial link.

When assessing whether SH-A or SH-B should be selected, two main classes of satellite payloads may be considered:

- Single DVB-SH physical layer multiplex per high-power amplifier (HPA);
- Multiple DVB-SH physical layer multiplex per high-power amplifier. This is the case with a multi-beam satellite with reconfigurable antenna architecture, based on large-size reflectors fed by arrays (*Fig. 4*)

In the case of a single-carrier per HPA payload configuration, exploitation of the SH-B (TDM) configuration reduces the signal envelope peak-to-average factor, thus allowing HPA optimum operation close to its saturated power. SH-A is instead penalized by its intrinsic multi-carrier (OFDM) signal nature that requires a higher optimum HPA back-off. However, in the case of a multi-carrier onboard HPA operation, there is little or no difference between the performances obtainable with the SH-A or SH-B configurations.

In summary, SH-A requires satellite transponders operated in a quasi-linear mode, whereas SH-B targets satellite transponders operated at full saturation.

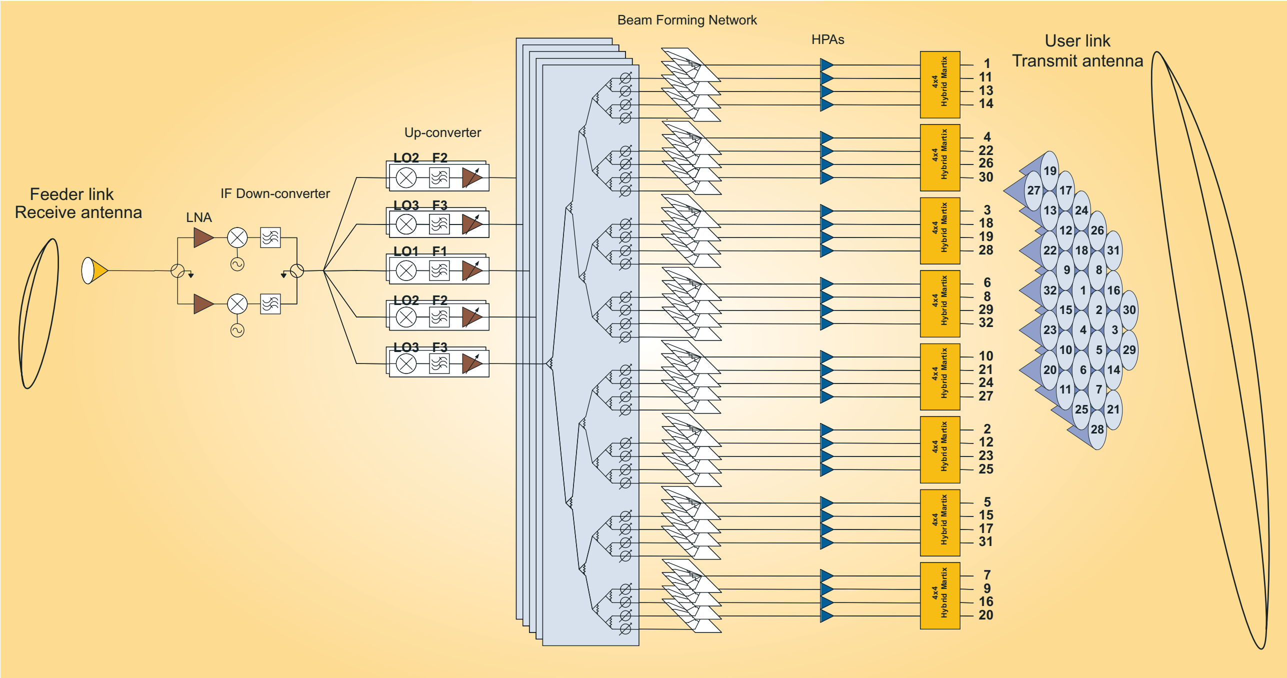

Figure 4
Multi-beam satellite payload

DVB-SH network configuration

Considering spectrum allocation, SH-B needs a dedicated sub-band for satellite transmission, completed with a part of the sub-band available for the terrestrial local component to re-enforce reception of the satellite programmes. Conversely, SH-A allows on-channel terrestrial repetition of the satellite content in the same sub-band as the satellite transmission, leaving all the remaining sub-bands available for terrestrial-only transmission.

On the other hand, for the SH-A case, not only the modulation type (OFDM vs. TDM) is re-used between satellite and terrestrial links, but also the sub-carrier's modulation and coding are strictly identical to allow a repetition at the same carrier frequency in an SFN mode. For the SH-B variant, the carrier's parameters are independent; only the content of the satellite carrier should be repeated on the terrestrial one.

Taking the example of a 15 MHz MSS band, split into three sub-bands of 5 MHz, there would be three satellite spots allocated to three countries, with each country able to reuse two sub-bands of 5 MHz for terrestrial-only transmission.

In SH-A systems, the terrestrial repeaters strictly generate the same carrier symbols as the satellite, in the same 5 MHz sub-band. Each transmitter is synchronized with its neighbours and with the satellite. This synchronization is based on the transmission of a "SHIP" packet, very similar to DVB-T's MIP, which allows SH-frames to be synchronized together at the output of transmitters, the terrestrial ones being slaves of the satellite signal. The feeding network includes compensation for the earth-space delays and the signal regeneration at the terrestrial level, thus producing an overall earth-space SFN broadcast network. Two full sub-bands of 5 MHz remain available for terrestrial-only transmission.

In SH-B systems, a different 5 MHz sub-band is used to transmit the satellite content via a terrestrial network in areas where it needs to be re-enforced. Since the receiver can make use, at the physical layer level, of both the symbols received from the satellite and the terrestrial transmitters, the same synchronization technique is applied as for SH-A. Hence information symbols from a given programme are close enough in time to be combined at the decoder input to improve the overall link performance. Furthermore, terrestrial transmission – because of its higher signal-to-noise ratio –

allows higher spectrum efficiency than the broad satellite transmission. Therefore, the terrestrial carrier can convey additional local content in the same 5 MHz terrestrial sub-band which repeats the satellite content. As a result, out of the 15 MHz MSS band, there is one full 5 MHz sub-band plus a portion of a second 5 MHz sub-band available for terrestrial-only transmission.

DVB-SH receiver classes

A typical phenomenon of satellite reception with mobile terminals is long interruptions to the line of sight, resulting for instance from the shading effects of buildings and bridges. Depending on the manner in which they cope with such interruptions, two types of receivers have been identified:

- The Class 1 Receiver is able to cope with rather short interruptions and mobile channel fading using appropriate mechanisms on the physical layer but supports the handling of long interruptions using redundancy on the link layer.
- The Class 2 Receiver is able to handle long interruptions (around 10 seconds) directly on the physical layer (PHY). This is made possible via the use of a large memory, directly accessible to the receiver chip.

It is up to the service and network operators to allocate the protection between the different layers, depending on the targeted quality of service, service categories and commercialized classes of receivers. The combination of both system architectures and these two receiver classes leads to the four terminal configurations listed below:

Terminal configurations	System architecture	Receiver class
Configuration A-1	SH-A	Class 1
Configuration A-2	SH-A	Class 2
Configuration B-1	SH-B	Class 1
Configuration B-2	SH-B	Class 2

DVB-SH physical layer outline

3G networks have raised market expectations for indoor coverage to a level that needs to be matched. Good indoor coverage with an infrastructure that is lighter than 3G networks entails a selection of new tools for enhancing the signal robustness. For example, a state-of-the-art forward error correction (FEC) scheme, 3GPP2 Turbo code over 12 kbits blocks, is used. In addition, DVB-SH uses a highly-flexible channel interleaver that offers time diversity from about one hundred milliseconds to several seconds, depending on the targeted service level and corresponding capabilities (essentially memory size) of the terminal class.

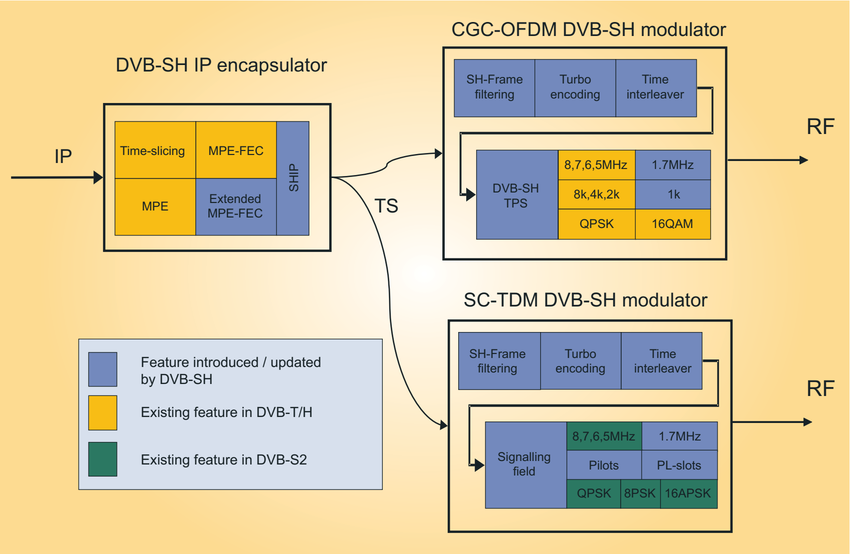

Figure 5
SH-B system architecture

A functional description of the components required on the transmitter side, in the case of an SH-B system, is provided in *Fig. 5*. It can be seen that there is a common part including forward error correction and interleaving, which could be called "Outer Physical Layer" (OPL). Then there are two different "Inner Physical Layers" (IPLs):

- IPL-OFDM: Inner Physical Layer with multi-carrier modulation (OFDM)
  The multi-carrier modulation concept is derived from DVB-T;
- IPL-TDM: Inner Physical Layer with single-carrier modulation (TDM)
  The single-carrier modulation concept is adapted from DVB-S2 technology.

For the OFDM part, the possible choices are QPSK, 16-QAM and non-uniform 16-QAM with support for hierarchical modulation. A 1K mode is proposed – in addition to the usual 2K, 4K and 8K modes – which does not exist in either DVB-T or DVB-H. The 1K mode targets mainly L-Band where the planned channel bandwidth is 1.75 MHz. For the TDM part, the choices are QPSK, 8-PSK, 16-APSK for power and spectral-efficient modulation formats, with a variety of roll-off factors (0.15, 0.25, 0.35).

An overview to the physical layer technologies of the DVB-SH system is given in the table on the next page

DVB-SH Upper Layer outline

DVB-SH is essentially a transmission system. It does not aim at defining transport protocols, audio and video coding solutions, an Electronic Service Guide (ESG) etc. As with all other DVB transmission systems, such "upper layer" issues are defined elsewhere. More specifically, the following link layer features are inherited from DVB-H (see *Fig. 5*):

- support of MPEG2-TS packets at the input, although the specification allows for the introduction of a Generic Stream at a later date;
- MPE encapsulation as defined in DVB-DATA [1] and support of MPE Time Slicing (power-saving) and handover between frequencies/coverage beams;
- compatibility with MPE-FEC (intra-burst FEC);
- GSE ready.

Abbreviations

3GPP2 3rd Generation Partnership Project 2
APSK Amplitude Phase Shift Keying
C/N Carrier-to-Noise ratio
CGC Complementary Ground Component
CRC Cyclic Redundancy Check
DVB Digital Video Broadcasting http://www.dvb.org/
DVB-H DVB - Handheld
DVB-S DVB - Satellite
DVB-S2 DVB - Satellite, version 2
DVB-SH DVB - Satellite to Handheld
DVB-T DVB - Terrestrial
ETSI European Telecommunication Standards Institute http://pda.etsi.org/pda/queryform.asp
FEC Forward Error Correction
GSE Generic Stream Encapsulation
IP Internet Protocol
IPDC IP DataCast
IPL Inner Physical Layer
MIP (MPEG) Mega-frame Initialisation Packet
MPE (DVB) Multi-Protocol Encapsulation
MSS Mobile Satellite Services
OFDM Orthogonal Frequency Division Multiplex
OPL Outer Physical Layer
PDA Personal Digital Assistant
PHY The PHYsical layer
PSI (DVB) Programme Service Information
PSK Phase-Shift Keying
QAM Quadrature Amplitude Modulation
QPSK Quadrature (Quaternary) Phase-Shift Keying
SC Satellite Component
SFN Single-Frequency Network
SI (DVB) Service Information
TDM Time Division Multiplex
TPS Transmission-Parameter Signalling
TS (MPEG) Transport Stream
UMTS Universal Mobile Telecommunication System
xDSL *(Different variants of)* Digital Subscriber Line

The physical layer technologies of the DVB-SH system

Technology	Description	Related features
Pilot symbol aided OFDM (IPL-OFDM)	Nearly identical to DVB-T. Addition of 1K mode, 1.5 MHz bandwidth for L-Band channelization, specific use of TPS bits	OFDM demodulators, as already available for DVB-T/H, can be reused. The 1K mode offers additional flexibility for the parameter selection in case of narrow channels (e.g. 1.5 MHz channel bandwidth) or very high Doppler frequencies.
Pilot symbol aided TDM (IPL-TDM)	Single-carrier modulation scheme with QPSK, 8-PSK and 16-APSK constellations. The pilot symbol pattern is designed to support synchronization also at very low C/N values.	The SH-B architecture supports ❍ efficient use of satellite power ❍ independent selection of parameters for the satellite signal and CGC ❍ efficient support of local content insertion
Turbo code (OPL)	The 3GPP2 Turbo code has been selected as the FEC scheme	High power efficiency. The Turbo code also offers high flexibility for the time interleaver design.
Low (< ½) code rates (OPL)	The FEC used supports code rates between R=1/5 to 2/3	High receiver sensitivity. Low code rates together with time interleaver offer outage protection already at the physical layer, especially for satellite channels.
Block code (OPL)	The selected Turbo code uses a block size equivalent to 8 MPEG-TS packets at the input to the Turbo encoder. The framing of the block code is synchronized to the framing of the IPL.	Simplifies the diversity combining [a]. The synchronization required for hand-over or code-combining can be (partly) derived from the IPL.
Additional CRC (OPL)	For each MPEG-TS packet, a CRC is added by the PHY	Detection of erroneous data packets to allow efficient error mitigation techniques or to support the upper layer FEC.
Link layer FEC	Using a technique similar to DVB-H, additional MPE sections containing redundancy can be transmitted, in separated bursts	This FEC can be exploited either by the terminal controller or the receiver, depending on the memory architecture and form factor requirements.
Time interleaving (OPL)	Time interleaving is applied at the physical layer to improve the performance in fading channels	Very high performance for mobile reception
Configurable interleaver length (OPL)	The interleaver length can be selected according to the channel characteristics or available memory. Two receiver classes have been defined: ❍ Class 1: Reduced memory size (and limited interleaver length) ❍ Class 2: Long interleaver	Trade-offs between memory size (receiver cost) and system performance are possible. Also, depending on whether a physical layer or link layer FEC is used, adaptation of the waveform to the receiver constraints is more progressive.
Long interleaver (OPL)	Interleaver lengths of several seconds are supported.	Signal blockages of some seconds, typical in the case of mobile reception of the satellite signal, can already be handled efficiently by the physical layer.
Uniform/late interleaver profile (OPL)	For the trade-off between zapping time/recovery after signal losses, and the performance for blockage protection, non-uniform interleaver profiles are supported. The feature is especially useful in combination with low code rates. For code rates ½ or higher, a uniform interleaver profile is recommended.	At the expense of a slightly lower protection, short (e.g. 1 second) zapping times are feasible whereas the interleaver length spans over several seconds.

a. Diversity Combining: Exploitation of the low mother code rate to transmit complementary punctured streams (e.g.: via TDM and OFDM) and combine them into an un-punctured stream instead of simply using maximum ratio combining.

However, the longer fading experienced in the satellite context tends to require longer protection than provided by MPE-FEC. Therefore it is currently foreseen that an MPE-FEC extension (inter-burst FEC) should be supported. This MPE-FEC extension is expected to combat the deep and long shadowing encountered in some satellite channels by providing additional time diversity.

Furthermore, DVB-SH benefits from the set of IP Datacast specifications, which were originally defined to turn the DVB-H transmission system into an end-to-end solution. IP Datacast will now be amended – if necessary – in order to act as the “higher layer” of DVB-SH. Audio and video formats will be defined by what DVB calls “A/V implementation guidelines” [2].

Finally, DVB-SH signalling is done via either TPS bits (OFDM part), or a header Signalling Field (TDM part). They allow the various parameters of both components to be controlled and can be made complementary – in particular when common operation of both different components is required in SH-B. In terms of PSI/SI, DVB-SH is fully compatible with [3] and [4]. And in some modes (inter-burst physical FEC, local content insertion), straightforward synchronization between the service and radio layers is achieved via the use of an SH Initialization Packet, defined in [5].

Market deployment

In February 2007, the European Commission confirmed that a slice of S-Band spectrum could be used for mobile satellite services and that complementary ground components of a hybrid satellite/ terrestrial system are also permitted. This clears the way for those companies with access to suitably-equipped satellites to launch services in the coming years. A number of manufacturers have already announced their intention to support the market, both with head-end equipment and with terminals by the end of 2007.

Figure 6
Eutelsat’s W2A satellite

As early as October 2006, Eutelsat had announced the decision to embark an S-Band payload on the W2A satellite (see *Fig. 6*) to deliver mobile multimedia broadcast services (Mobile TV, digital radio etc.) directly onto user terminals across France, Germany, Italy, Poland, Spain and the UK. And at the beginning of May 2007, ICO Global Communications Limited announced the selection of DVB-SH for the mobile video component of its Mobile Interactive Multimedia services. ICO is planning an alpha trial in North America for spring 2008, based on the ICO G1 geostationary satellite and the deployment of an Ancillary Terrestrial Component.

As mentioned above, DVB-H systems have already been widely deployed, mostly on a trial basis so far. DVB-SH will be a complement to DVB-H and could potentially be used as such in a number of ways. Nationwide coverage could be achieved with the satellite footprint. Terminals that are in development will be dual mode, receiving DVB-SH in S-Band and DVB-H at UHF, and the over-lapping use of the DVB-IPDC specifications ensures that the two systems will be complementary.

Next steps

The technical work on the specification is on-going within the DVB Technical Module. Now that the system and waveform specifications have been approved by the Steering Board and forwarded to

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ETSI, the next key work items are the MPE-FEC extension, the development of a set of implementation guidelines and the validation of the interfaces with DVB-IPDC. All these work items are scheduled for completion in 2007.

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References

[1] ETSI EN 301192: **Digital Video Broadcasting (DVB); DVB specification for data broadcasting (DVB-DATA)**.

[2] ETSI TS 102005: **Digital Video Broadcasting (DVB); Specification for the use of video and audio coding in DVB services delivered directly over IP**.

[3] ETSI EN 300468: **Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems (DVB-SI)**.

[4] DVB BlueBook A079 Rev. 1: **IP Datacast over DVB-H: PSI/SI**.

[5] DVB BlueBook A111: **Framing structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3GHz**.

[6] DVB-Scene edition No. 21: **A New Star in the Sky**, by Prof. Dr-Ing. Ulrich Reimers.