From Analog to Digital Television – the Common Way How to Digitize European Broadcasting

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Abstract—**This paper deals with the origin, history, present and future of the DTV (Digital Television) in the Europe. It introduces DVB (Digital Video Broadcasting) Project that creates global standards for digital television since 1991. Fundamental European standards for DVB provides transmission of DTV (digital television) via three transmission media – DVB-S (Satellite), DVB-C (Cable) and DVB-T (Terrestrial) channels. These standards are in the paper described with the according depth. With the development of HDTV (High Definition TV), IPTV (Internet Protocol TV), Mobile TV using DVB-H (Handheld) and interactive data broadcasting using DVB-MHP (Multimedia Home Platform) the new approaches to DTV broadcasting are outlined. This paper contains compiled information from the DVB Project webpage, DVB fact sheets, standards ETSI (European Telecommunications Standards Institute) and EBU (European Broadcasting Union) and internet resources to present the DVB as a real "Milestone in Digital Communications". All used resources are properly quoted in references list.**

Index Terms—**digital television, cable, satellite and terrestrial broadcasting, Digital Video Broadcasting, DVB project**

I. Introduction

THE DVB (Digital Video Broadcasting) [1] [2] [3] Project is the consortium of over 280 broadcasters, manufacturers, network operators, software developers, regulatory bodies and others in over 35 countries committed to designing open interoperable standards for the global delivery of digital media services. As DVB's name suggests, these include mainly broadcasting. Services using DVB standards are available on every continent (not only European area) with more than 200 million DVB receivers deployed.

Towards the end of 1991, broadcasters, equipment manufacturers and regulatory bodies in Europe came together to discuss the formation of a group that would oversee the introduction of DTV (Digital TV). The group, which became known as the European Launching Group (ELG), realized that a consensus-based framework, through which all of the key stakeholders could agree on the appropriate technologies to be used. A Memorandum of Understanding (MoU) was signed in September 1993 by all ELG participants, and the DVB Project was born [4] [5]. A key report from the Working Group on Digital Television was also central to setting out important concepts that would go on to shape the introduction of DTV not only in Europe [6].

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II. DVB Core Principles

The DVB Project began the first phase of its work in 1993. The project's philosophy was as follows [7]. The initial task was to develop a complete suite of digital satellite, cable and terrestrial broadcasting technologies in one pre-standardization body. Rather than having a one-to-one correspondence between a delivery channel and a program channel, the systems would be containers which carry any combination of image, audio or multimedia. They would thus be open and ready for SDTV (Standard), EDTV (Extended), HDTV (High Definition) or any kind of new media which roll out over time. The work should result in ETSI (European Telecommunications Standards Institute) [8] standards for the physical layers, error correction, and transport for each delivery medium. It should also result in an ETSI report which outlines the baseband systems which are options for carriage. Wherever possible there should be commonality across the different delivery. Only when there was no other choice would there be differences between different delivery media.

III. DVB Project and European Standards

The first phase of DVB's work involved establishing standards to enable the delivery of DTV to the consumer via the traditional broadcast networks. Thus, the three key standards during this phase were DVB-S [9] for satellite networks, DVB-C [10] for cable networks and DVB-T [11] for terrestrial networks. In addition to these the whole range of supporting standards were required covering areas such as service information DVB-SI [12], subtitling DVB-SUB [13], interfacing DVB-ASI [14], etc. Interactive TV, required the creation of a set of return channel standards and the Multimedia Home Platform (MHP), DVB's open middleware specification [15] [16].

DVB then moved to embrace network convergence through the development of standards using innovative technologies that allow the delivery of DVB services over fixed and wireless telecommunications networks (e.g. DVB-H [17] for mobile TV, DVB-IPTV [18] [19]). The latest phase of DVB's work is a natural progression into areas such as a system for content protection and copy management DVB-CPCM [20], and looking at how DVB devices operate in the environment of the home network. Thus we have already seen the scope of DVB-H expanded into the S-band through DVB-SH [21] and publication of DVB-S2 [22]. In 2008 is in progress the developments of next generation terrestrial DVB-T2 [23] and cable DVB-C2 [24] standards. Future work items may cover areas such open Internet TV and middleware for interactive services on IPTV and mobile TV.

IV. DVB Project Official Documents

DVB produces specifications which are subsequently standardized in one of the European statutory standardization bodies, usually the European Telecommunications Standards Institute (ETSI). ETSI, the Centre for Electrotechnical Standards (CENELEC) and the European Broadcasting Union (EBU) have formed a joint technical committee (JTC) to handle the DVB family of standards.

ETSI official publications are [25]:

--TR (Technical Report): typically a set of guidelines for the implementation of a more normative specification or standard.

--TS (Technical Specification): a document which can contain normative text, i.e. mandatory text such as "shall". A DVB TS is generally a stepping stone to a more stable document.

--ES (ETSI Specification): a document approved by the entire ETSI membership. It is a more stable document than either a TR or TS.

--EN (European Standard): the highest ranking ETSI publication approved by the national standards organizations of Europe.

--DVB BlueBooks: From time to time, DVB publishes documents following their approval by its Steering Board: the BlueBooks.

V. DVB for Satellite, Cable and Terrestrial

At the beginning of the 1990s, change was coming to the European satellite broadcasting industry, and it was becoming clear that the once state-of-the-art MAC (Multiplexed Analogue Components) systems would have to give way to all-digital technology. It became clear that satellite and cable would deliver the first broadcast digital television services. Fewer technical problems and a simpler regulatory climate meant that they could develop more rapidly than terrestrial systems. Market priorities meant that digital satellite and cable broadcasting systems would have to be developed rapidly. Terrestrial broadcasting would follow the previous standards but the terrestrial channel was more complicated [7].

A. Digital Video Broadcasting – Satellite (DVB-S)

The DVB-S system for digital satellite broadcasting was developed in 1993 [9]. It is a relatively straightforward system using QPSK (Quadrature Phase Shift Keying). The specification described different tools for channel coding and forward error protection which were later used for other delivery media systems.

B. Digital Video Broadcasting – Cable (DVB-C)

The DVB-C system for digital cable networks was developed in 1994 [10]. It provides a toolbox of QAM (Quadrature Amplitude Modulation) schemes from 16-QAM to 256-QAM for television and radio broadcasting services, as well as for data transmission. At the moment, this standard is deployed worldwide in cable systems ranging from the larger CATV (Community Antenna TV) networks down to smaller SMATV (Satellite Master Antenna TV) systems. It is centered on the use of 64-QAM (with coaxial cable). The European satellite and cable environment can, if needed, convey a complete satellite channel multiplex on a cable channel.

Responding to increased consumer demand for a broader range of DTV services, many cable operators have already upgraded their networks, deploying 256-QAM modulation (thus achieving 50 Mbit/s payload per cable channel) and increasing the frequency range used for downstream transmission up to its maximum of 862 MHz. Many cable operators currently offer a rich ATV (Analogue TV) package alongside several hundreds of DTV channels and an increasing amount of new, and more interactive and personalized services. The DVB-CS [26] specification described a version which can be used for SMATV installations.

C. Digital Video Broadcasting – Terrestrial (DVB-T)

The DVB-T [11] system for digital terrestrial television (DTT) was more complex because it was intended to cope with a different noise and bandwidth environment and multi-path [27]. The system has several dimensions of receiver agility, where the receiver is required to adapt its decoding according to signaling. The key element is the use of OFDM (Orthogonal Frequency Division Multiplex). There are two modes: 2k and 8k carriers plus QAM. The 8k mode can allow more multi-path protection, but the 2k mode can offer Doppler advantages where the receiver is moving.

DVB-T, in common with almost all modern terrestrial transmission systems, uses OFDM modulation. This type of modulation, which uses a large number of sub-carriers, delivers a robust signal that has the ability to deal with very severe channel conditions. DVB-T has technical characteristics that make it a very flexible system: 3 modulation options (QPSK, 16-QAM, 64-QAM), 5 different FEC (Forward Error Correction) rates, 4 Guard Interval options, a choice of 2k or 8k carriers and can operate in 6, 7 or 8 MHz channel bandwidths. Using different combinations of the above parameters a DVB-T network can be designed to match the requirements of the network operator, finding the right balance between robustness and capacity. Networks can be designed to deliver a whole range of services: SDTV, radio, interactive services, HDTV and, using multi-protocol encapsulation, even IP datacasting.

The use of OFDM modulation with the appropriate Guard Interval (GI) allows DVB-T to provide a tool for regulators and operators in the form of the Single Frequency Network (SFN). An SFN is a network where a number of transmitters operate on the same RF frequency. SFN can cover a country or be used to enhance in-door coverage using gap-filler.

One final technical aspect of DVB-T worth mentioning is its capacity for Hierarchical Modulation. Using this technique, two completely separate data streams are modulated onto a single DVB-T signal. A High Priority (HP) stream is embedded within a Low Priority (LP) stream. Broadcasters can thus target two different types of receiver with two completely different services. For example, DVB-H mobile TV services optimized for more difficult reception conditions could be placed in the HP stream, with HDTV services targeted to fixed antennas delivered in the LP stream.

Whilst not originally designed to target mobile receivers, DVB-T performance is such that mobile reception is not only possible, but forms the basis of some commercial services. The use of a diversity receiver with two antennas gives a typical improvement of 5 dB in the home and a 50% reduction in errors is expected in a car [27].

D. Digital Video Broadcasting – Multipoint Distribution System (DVB-MDS)

There are two systems for MMDS (Multi-channel Microwave Distribution Systems), one for systems which operate at radio frequencies below 10 GHz (DVB-MC [28], which is like the DVB-C system), and one for systems which operate at radio frequencies above 10 GHz (DVB-MS [29], which is like the DVB-S system). An MMDS system like DVB-T, DVB-MT [30], is also available.

VI. Innovation in DVB

A. Digital Video Broadcasting – Satellite 2nd (DVB-S2)

A higher efficiency digital satellite broadcasting system DVB-S2 [22] has recently been developed. It has both DVB-S backwards compatible and non-backwards compatible versions. The non-compatible version allows about 30% more data capacity for the same receiving dish size compared to DVB-S. It uses 8-PSK (Phase Shift Keying) and LDPC (Low Density Parity Check) code to achieve the efficiency increase. DVB-S2 is likely to be used for all future new European digital satellite multiplexes, and satellite receivers will be equipped to decode both DVB-S and DVB-S2 [31].

The original DVB-S system, on which DVB-S2 is based, specifies the use of QPSK modulation along with various tools for channel coding and error correction. Further additions were made with the emergence of DVB-DSNG (Digital Satellite News Gathering), for example allowing the use of 8-PSK and 16-QAM modulation.

DVB-S2 benefits from more recent developments and has the following key technical characteristics:

There are four modulation modes available, with QPSK and 8-PSK intended for broadcast applications in non-linear satellite transponders driven close to saturation. 16-APSK (Amplitude and Phase Shift Keying) and 32-APSK, requiring a higher level of C/N, are mainly targeted at professional applications such as news gathering and interactive services.

DVB-S2 uses a very powerful forward error correction scheme (FEC), a key factor in allowing the achievement of excellent performance in the presence of high levels of noise and interference. The FEC system is based on concatenation of BCH (Bose-Chaudhuri-Hocquengham) coding with LDPC inner coding.

Adaptive Coding and Modulation (ACM) allows the transmission parameters to be changed on a frame by frame basis depending on the particular conditions of the delivery path for each individual user. It is mainly targeted to unicasting interactive services and to point-to-point professional applications.

DVB-S2 offers optional backwards compatible modes that use hierarchical modulation to allow legacy DVB-S receivers to continue to operate, whilst providing additional capacity and services to newer, more advanced receivers.

DVB-S2 delivers excellent performance, coming close to the Shannon limit, the theoretical maximum information transfer rate in a channel for a given noise level. It can operate at C/N ratio from -2dB (i.e. below the noise floor) with QPSK, through to +16dB using 32-APSK. The performance test shows the improvements in efficiency that DVB-S2 delivers when compared to DVB-S with typical TV broadcast parameters, with gains in the useful bitrate of more than 30% in each case [31].

B. Digital Video Broadcasting – Terrestrial 2nd (DVB-T2)

DVB-T2 is a digital terrestrial transmission system designed for use in a post-Analogue Switch-Off (ASO) environment. It introduces the latest modulation and coding techniques to enable highly efficient use of valuable terrestrial spectrum for the delivery of audio, video and data services to fixed, portable and mobile devices. DVB-T2 is not designed to replace DVB-T. Rather the two standards will coexist in many markets for many years [23].

As with its predecessor, DVB-T2 uses OFDM modulation, with a large number of sub-carriers delivering a robust signal. Also in common with DVB-T, the new specification offers a range of different modes making it a very flexible standard. In the realm of error correction, DVB-T2 uses the same coding that was selected for DVB-S2. LDPC coding combined with BCH coding offers excellent performance in the presence of high noise levels and interference, resulting in a very robust signal.

Several options are available in areas such as the number of carriers (new 1k, 4k, 16k and 32k modes), guard interval sizes (3 new options) and pilot signals, so that the overheads can be minimized for any target transmission channel. A new technique, called Rotated Constellations, provides significant additional robustness in difficult channels. Also, a mechanism is provided to separately adjust the robustness of each delivered service within a channel to meet the required reception conditions (e.g. indoor antenna/roof-top antenna). This same mechanism allows transmissions to be tailored such that a receiver can save power by decoding only a single program rather than a whole multiplex of programs.

DVB-T2 also specifies a transmitter diversity method, known as Alamouti coding, which improves coverage in small scale SFN networks. Finally, DVB-T2 has defined a way that the standard can be compatibly enhanced in the future through the use of Future Extension Frames.

C. Digital Video Broadcasting – Handheld (DVB-H)

A more flexible and robust digital terrestrial system DVB-H has also recently been developed. The system is intended to be receivable on handheld receivers and thus includes features which will reduce battery consumption (Time Slicing function) and a 4k OFDM mode, together with other measures. DVB-H services will also use more efficient video compression systems such as MPEG-4 AVC (Advanced Video Coding).

DVB-H is an extension of DVB-T with some backwards compatibility, i.e. it can share the same DVB-T multiplex. It uses a mechanism called Multi-Protocol Encapsulation (MPE), making it possible to transport data network protocols on top of MPEG-2 TS (Transport Streams). A FEC scheme is used in conjunction with this to improve the robustness and thus mobility of the signal. In addition to the 2k and 8k modes available in DVB-T, a 4k mode is added to DVB-H giving increased flexibility for network design. A short in-depth interleaver was introduced for 2k and 4k modes that lead to better tolerance against impulsive noise (helping to achieve a similar level of robustness to the 8k mode). The system was built on the proven mobile performance of DVB-T.

Another essential element of DVB-H is Time Slicing, the main technique used to achieve the required power savings. Each individual TV service in a DVB-H signal is transmitted in bursts allowing the receiver to go into sleep mode, only waking up when the service to which it is tuned is transmitted. For handheld devices this can add up to very significant power savings in the front-end. For battery life and thermal balance this is a key functionality. Statistical multiplexing is also possible in DVB-H, ensuring optimum use of bandwidth to deliver services. DVB-H is designed for use in Bands III, IV and V as well as L-band [32].

D. Digital Video Broadcasting – Satellite Handheld (DVB-SH)

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 [21] standard, now the basis of a growing number of mobile TV services around the world. DVB-H is primarily targeted for use in the UHF (bands III, IV and V), currently occupied in most countries by ATV and DTT services. DVB-SH seeks to exploit opportunities in the higher frequency S-band, where there is less congestion than in UHF. DVB began work on the DVB-SH specifications in 2006.

DVB-SH is the name of a transmission system standard designed to deliver video, audio and data services to small handheld devices, such as mobile telephones and PDAs, using S-band frequencies. 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 not possible the terrestrial gap filler can be used to provide coverage. It is designed to use frequencies below 3GHz, typically around 2.2GHz. The system and waveform specifications have been published as ETSI standards.

OFDM 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 that uses OFDM both on the satellite and the terrestrial link and SH-B that uses TDM on the satellite link and OFDM for the terrestrial link [33].

The combination of a satellite footprint and a terrestrial complement in S-band can deliver nationwide coverage to terminals which could implement the TDM and OFDM modes of SH, a combination of SH and DVB-H, or simply the OFDM mode of DVB-SH operating in SFN. Key to deployment is DVB-SH's interface with DVB-IPDC layer.

E. Digital Video Broadcasting – Cable 2nd (DVB-C2)

In 2007 a study mission of the DVB Technical Module produced a report identifying some possible technologies which could be considered as alternatives succeeding the existing DVB-C specification [24]. Following this process, the DVB Commercial Module was requested to capture commercial requirements for a second generation DVB transport layer specification applicable to cable networks.

The DVB-TM-C2 ad-hoc group was requesting the submission of proposals for technologies which could be considered as candidates for a second generation DVB cable transmission system DVB-C2. The Call for Technologies follows the work done by the earlier Technical Module Study Mission and is issued in response to DVB-C2 Commercial Requirements. Responses were requested by June, 2008.

Respondents should note that the group has made the working assumption that exactly the LDPC forward error correction code from DVB-S2 will be used, hence proposals are sought which implement this channel coding scheme into the cable physical layer. Whilst responses may be submitted based around other channel coding techniques, these will only be considered if it is determined that the LDPC code implemented in the DVB-S2 specification will not be suitable for a cable channel, will provide significant performance drawbacks, or will impose unwanted restrictions on system design, selection of other technologies and system parameters (e.g. frame structure) appropriate for DVB-C2.

VII. Multimedia Broadcasting and Interactivity

Digital broadcasting has the capacity to deliver multimedia in addition to television programs. This can look like an electronic version of a magazine page or a web page. It is either independent of the television program or allied to it in some way. It can be one-way multimedia which displays pictures and information on screen - superimposed or separate - or it can be two-way multimedia which uses a return path system to the broadcaster, to allow the viewer to interact directly with the broadcaster.

The delivery of one way material is usually arranged in a carousel. This means that information is available in a repeating cycle. The receiver grabs the information the viewer has requested (via his controls) as it goes by. There can be a finite waiting time for broadcast multimedia whose length depends on luck and how much overall multimedia is being offered by the channel. The DVB Project agreed that it could not take any specific one of these as a DVB system, but needed an outside, new and open system. The system developed was MHP (Multimedia Home Platform) [34].

A. Digital Video Broadcasting - Multimedia Home Platform (DVB-MHP)

MHP is the collective name for a compatible set of middleware specifications developed by the DVB Project. MHP was designed to work across all DVB transmission technologies [15] [16]. The use of an open standard for interactive TV middleware means that receiver manufacturers can target multiple markets rather than developing products to the specification of a particular broadcaster. Equally applications based on MHP can be developed by multiple service providers, enabling a horizontal market in that area. Three versions of MHP have been published and each adding new features useful in a broadband world. In all versions, a broadcast-only profile can be supported, although most modern deployments include broadband connectivity.

At its simplest, MHP can be described as a set of instructions that tells the operating system on a DTV receiver how to deal with an interactive TV application it has received. MHP also defines the form in which the applications are delivered at the receiver, including the service information that signals that interactive applications are present in the transport stream [34].

MHP has a core based around a JVM (Java Virtual Machine). MHP does not compete with the different HTML or MHEG (Multimedia and Hypermedia Experts Group) flavors, since in MHP and each of these declarative content engines is just another MHP application. If new requirements emerge, updating and deploying an MHP application is much simpler and cheaper than re-defining and updating native HTML or MHEG engines.

B. Digital Video Broadcasting – Internet Protocol Television (DVB-IPTV)

DVB-IPTV [35] is the collective name for a set of open, interoperable technical specifications, developed by the DVB Project, that facilitate the delivery of digital TV using Internet Protocol over bi-directional fixed broadband networks. The work is taking place in two phases, with the first phase nearing completion. Key specifications already published include: Transport of MPEG-2 TS-Based DVB Services over IP Based Networks, Carriage of Broadband Content Guide (BCG) Information over Internet Protocol, Remote Management and Firmware Update System for DVB IP Services. DVB’s interactive middleware specifications, DVB-MHP and GEM (Globally Executable MHP), also include IPTV profiles. The initial phase of DVB’s work concentrates on the interface between the IPTV set-top-box (STB) and the IP-based home network [35].

DVB’s work in IPTV can be divided into three broad areas: STBs on IP networks - the definition of appropriate standards to facilitate the automated connection and configuration of a STB connected to an IP network. This extends to how MPEG-2 TS based services are encapsulated onto an IP network. Home Networking - the definition of an appropriate sub-set of standards for a DVB home network (based on IP).

Additions to the DVB-MHP middleware specifications, to allow interactive TV applications running on MHP to use the resources available in a DVB-IPTV environment.

VIII. Next Steps for DVB Project

A. Next Steps for DVB-T

DVB-T is a complete solution for DTT, with the flexibility and capacity to deliver a whole range of services, in a range of channel bandwidths. It will continue to be the system of choice for the launch of new services for years to come, with consumers benefiting from the huge economies of scale that open standards bring to growing markets. For a number of countries, however, ASO is approaching in the next couple of years, and with it the release of valuable UHF spectrum. This transition will create a window of opportunity for the introduction of new technologies [27]. DVB Project is now actively working on DVB-T2.

B. Next Steps for DVB-T2

The specification setting work is largely completed. The draft specification will be before the DVB Steering Board for approval at the end of June 2008 [23]. On approval it will be released as a DVB BlueBook and sent to ETSI for publication as a formal standard. Vendors are already working on the design of DVB-T2 equipment, with the first prototypes expected by the end of 2008. In parallel, further work will be required within the DVB Project and elsewhere on the creation of implementation guidelines, validation testing, etc.

C. Next Steps for DVB-S2

The technical work on DVB-S2 has been completed and the work group within DVB is in sleep mode. The standard and related user guidelines can be downloaded from the ETSI website. DVB-S2 will not replace DVB-S in the short or even the medium term [31].

D. Next Steps for DVB-H

The DVB-H standard is fully specified and published. Some additional work is ongoing within the DVB Project revising the DVB-IPDC systems layers following extensive implementation experience. As with all elements of DVB-H, once finalized, the work is standardized as quickly as possible to facilitate implementers. DVB has also published a specification called DVB-SH (Satellite services to Handhelds) [32], introducing the option of using satellites operating in the S-band below 3GHz as part of the mobile TV chain. DVB-SH is also designed to utilize the DVB-IPDC systems layer specifications and thus complements the DVB-H specification.

E. Next Steps for DVB-SH

The DVB-SH system and waveform specifications have been published as formal ETSI standards. DVB-SH seeks to exploit opportunities in the higher frequency S-band, where there is less congestion than in UHF [33]. Work is continuing within the DVB Project's Technical Module on items such as the development of a set of implementation guidelines and the validation of the interfaces with DVB-IPDC.

IX. Conclusion

By any measure the DVB Project has been a success. More than 200 million devices around the world are receiving services that use DVB standards. Of these, about 100 million are satellite receivers and more than 60 million are receiving DVB-T signals. DVB-S/S2 forms the basis of digital satellite TV just about everywhere. DVB-C is the most commonly used system for digital cable TV. DVB-T has seen phenomenal growth in the last few years with services on air across Europe and in parts of Asia, with further launches to follow in Southeast Asia, Latin America and the EMEA (Europe, the Middle East and Africa) region. The economies of scale engendered by such success mean that the prices consumers have to pay for receivers are falling all the time.

References

[1] U. Reimers, *Digital Video Broadcasting, The family of international standards for digital television* (2nd edition) Springer-Verlag, 2004.

[2] W. Fisher, *Digital Television, A Practical Guide for Engineers* (1st edition). Springer-Verlag, 2004.

[3] DVB Homepage (2008, June). The main website of the DVB Project. [Online]. Available http://www.dvb.org

[4] DVB Fact Sheet (2008, June). Introduction to the DVB Project. Creating Global Standards for Digital Television. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[5] DVB Homepage (2008, June). Organisational structure. [Online]. Available http://www.dvb.org/about_dvb/structure/

[6] DVB Homepage (2008, June). DVB Worldwide. [Online]. Available http://www.dvb.org/about_dvb/dvb_worldwide/

[7] DVB Homepage (2008, June). History of the DVB Project. [Online]. Available http://www.dvb.org/about_dvb/history/

[8] ETSI standards. DVB standards free of charge for ETSI members. [Online]. Available http://www.etsi.org

[9] DVB-S. EN 300 421 V1.1.2 (08/97). Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services.

[10] DVB-C. EN 300 429 V1.2.1 (04/98). Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems.

[11] DVB-T. EN 300 744 V1.5.1 (11/04). Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television.

[12] DVB-SI. EN 300 468 V1.7.1 (05/06). Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems.

[13] DVB-SUB. EN 300 743 V1.3.1 (11/06). Digital Video Broadcasting (DVB); Subtitling systems.

[14] DVB-ASI. TR 101 891 V1.1.1 (01/01). Digital Video Broadcasting (DVB); Professional Interfaces: Guidelines for the implementation and usage of the DVB Asynchronous Serial Interface (ASI).

[15] MHP. ES 201 812 V1.1.2 (08/06). Multimedia Home Platform (MHP) Specification 1.0.3.

[16] MHP. TS 102 812 V1.2.2 (08/06). Multimedia Home Platform (MHP) Specification 1.1.

[17] DVB-H. EN 302 304 V1.1.1 (11/04). Digital Video Broadcasting (DVB); Transmission system for handheld terminals.

[18] DVB-IPTV. TR 102 033 V1.1.1 (04/02). Architectural Framework for the Delivery of DVB-Services over IP-based Networks.

[19] DVB-IPTV. TR 102 034 V1.3.1 (10/07). DVB-IPTV 1.3: Transport of MPEG-2 TS Based DVB Services over IP Based Networks (and associated XML).

[20] DVB-CPCM. DVB BlueBook A094r2 (07/07). DVB Content Protection and Copy Management.

[21] DVB-SH. EN 302 583 V1.1.1 (07/07). Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3 GHz.

[22] DVB-S2. EN 302 307 V1.1.2 (06/06). Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications.

[23] DVB Fact Sheet (2008, June). 2nd Generation Terrestrial. The world's most advanced Digital Terrestrial TV system. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[24] DVB-C2. Second Generation Transmission Technologies for Cable Networks. Call for Technologies. (2008, February). [Online]. Available http://www.dvb.org/technology/dvbc2/

[25] DVB Homepage (2008, June). Standards & BlueBooks. [Online]. Available http://www.dvb.org/technology/standards/

[26] DVB-CS. EN 300 473 V1.1.2 (08/97). Digital Video Broadcasting (DVB); DVB Satellite Master Antenna Television (SMATV) distribution systems.

[27] DVB Fact Sheet (2008, June). Digital Terrestrial Television. The world's most flexible and most successful DTT standard. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[28] DVB-MC. EN 300 749 V1.1.2 (08/97). Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for MMDS systems below 10 GHz.

[29] DVB-MS. EN 300 748 V1.1.2 (08/97). Digital Video Broadcasting (DVB); Multipoint Video Distribution Systems (MVDS) at 10 GHz and above.

[30] DVB-MT. EN 301 701 V1.1.1 (08/00). Digital Video Broadcasting (DVB); OFDM modulation for microwave digital terrestrial television.

[31] DVB Fact Sheet (2008, April). 2nd Generation Satellite. The most advanced Satellite Broadcasting system in the world. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[32] DVB Fact Sheet (2008, June). Broadcasting to Handhelds. The Global Technology Standard for Mobile Television. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[33] DVB Fact Sheet (2008, June). Satellite Services to Handhelds. The most advanced Satellite Broadcasting system in the world. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[34] DVB Fact Sheet (2008, June). Multimedia Home Platform. Complete set of Open Middleware Standards for Interactive TV. [Online]. Available http://www.dvb.org/technology/fact_sheets/

[35] DVB Fact Sheet (2008, April). Internet Protocol TV. Broadcast to Broadband - Open Standards for IPTV. [Online]. Available http://www.dvb.org/technology/fact_sheets/