ABSTRACT

The VALIDATE project has verified the performance of the DVB-T specification in the laboratory and in field trials. Its successful collaboration has advanced DVB-T technology to the point where services are ready to start. Recent achievements include a multidimensional interworking demonstration, a transmitter specification, single-frequency network synchronisation and gap-filler transmitters (on-channel repeaters). Trials have shown that mobile reception of DVB-T is possible with bitrates up to 15 Mbit/s, offering a range of attractive new services. A new project, MOTIVATE, will develop mobile reception of DVB-T.

INTRODUCTION

The VALIDATE project started work in November 1995 with the aim of verifying the DVB-T specification and laying the foundations for the launch of digital terrestrial TV services. These aims have been achieved and VALIDATE completed its work in June 1998.

Mobile reception was not a main aim of the DVB-T specification. However, measurements by Deutsche Telekom AG within the VALIDATE project showed that mobile television and multimedia services are possible using some of the more rugged modes of the Specification.

Most of the VALIDATE participants were keen to extend their collaboration to investigate this new possibility. Deutsche Telekom AG took the lead in forming this new project, MOTIVATE, which started work in May 1998, just before the end of VALIDATE.

This paper reviews the work of VALIDATE, highlighting progress in the final year, and describes some of the work that will be done by MOTIVATE – starting by suggesting some possible applications of mobile DVB-T.

VALIDATE: PREPARING FOR LAUNCH OF SERVICES

Introduction

The VALIDATE project (TABLE 1) formed a Europe-wide ‘virtual laboratory’ to test the DVB-T system and speed up its acceptance. Members agreed the testing needed and the procedures to be followed; this allowed the work to be shared out and ensured

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V - VALIDATE partner  * - Coordinator  M - MOTIVATE partner  * - Coordinator
that results of tests by different Partners could be compared within the Project and presented together to the standards authorities.

The first task of the VALIDATE project was to verify the DVB-T specification. This verification required three elements:

- checking that the specification was clear and unambiguous by demonstrating interworking between simulations and then between real hardware produced by separate laboratories,
- checking that the system performed as expected in the repeatable conditions of the laboratory,
- checking that it met broadcasters’ expectations in field trials.

This vital task was completed by the end of 1996, with the result that the DVB-T specification was rapidly approved as an ETSI standard. The work was described by Nokes et al. (1). Since then further field trials of different network configurations have been carried out in many European countries: a compendium of the results has been given by Weck (2). These field trials have shown not only that the DVB-T specification meets broadcasters’ current expectations, but have opened the possibility of mobile reception.

The laboratory tests and field trials reported by VALIDATE formed the basis of international agreements on coordination of digital TV transmitters agreed by 32 countries at Chester (UK) in July 1997(3).

VALIDATE has also carried out a wide range of other work on distribution networks, transmitters, service planning parameters, single frequency networks (SFNs), and gap-fillers both for professional and domestic use. Much of this work has been documented in Implementation Guidelines, prepared for the DVB Project and now published as an ETSI Technical Report (4).

These Guidelines draw attention to the technical questions that need to be answered in setting up a DVB-T network and offer some guidance in finding answers to them. They give an explanation of the DVB-T specification and the basic characteristics of transmission networks; they then cover transmitters and issues of sharing with existing services, distribution networks, SFN operation, and network planning.

**Some recent successes**

**Interworking tests**

In June 1998 VALIDATE organised a final interworking demonstration, bringing together a wide range of DVB-T equipment from different manufacturers within and outside the Project. There were seven different modulators, including first generation prototypes and industrial products, and nine different receivers including first generation prototypes, commercial professional receivers and consumer chip-sets.

Sixty-one different DVB-T modes were tested; these included examples of all the possibilities and options offered by DVB-T specification. Interoperation of hierarchical modes was successfully demonstrated for the first time. Remotely synchronised SFN operation (see below) was successfully demonstrated using modulators from different manufacturers.

The successful results of all of these tests prove the interoperability of DVB-T equipment from different manufacturers. Network operators can safely mix equipment from different manufacturers in their networks. These results provide a sound basis for the launch of commercial services.

**Transmitter Parameters**

Transmitter manufacturers and transmission network operators must agree on the specifications for the performance of transmitters, as must the network operators and the service providers. As this is a new technology, there is no existing basis for such specifications. VALIDATE has therefore drawn up a transmitter performance specification. It suggests the parameters that need to be measured and some realistic values for them as well as defining minimum interface specifications (not all of which are mandatory).

A useful method of specifying the overall performance of a transmitter is the Equivalent Noise Floor (ENF). To measure ENF the transmitter is connected to a demodulator and noise is added to achieve quasi-error-free reception (QEF – a bit error ratio of $2 \times 10^{-4}$ before Reed-Solomon correction, corresponding to about one error an hour after correction). The transmitter under test is then replaced by an undistorted laboratory test modulator and noise is added from a second noise generator in parallel with the first to obtain QEF reception again. The level of noise from the second generator then represents the ENF of the transmitter.
**SFN Synchronisation**

Two approaches are possible to the planning of DVB-T networks: multi-frequency networks (MFNs) and single frequency networks (SFNs).

All transmitters in an SFN must be synchronised so that their broadcasts are frequency identical and bit identical. VALIDATE partners have led the standardisation of a method of synchronising an SFN by defining a megaframe in the MPEG-2 transport stream using a megaframe identification packet (MIP) (5). The megaframe length has been chosen to contain an integral number of OFDM frames, of Reed-Solomon packets, and of the energy dispersal sequences. The MIP contains a timestamp indicating the time at which the megaframe should be broadcast, related to a universal time and frequency reference such as that available from the GPS satellite system. By comparing the timestamp with the reference at the transmitter, all signals can be time synchronised.

To test this synchronisation technique, VALIDATE partners RTE and ITIS set up, with the assistance of TDF, a DVB-T SFN using two transmitters in the Dublin area on UHF channel 30 (see Fig. 1). The transmission mode used for this experiment was 8K, 64-QAM, R=2/3, guard interval=1/4. An MPEG-2 Transport Stream (TS) generator, an SFN adapter, a DVB-T modulator, and a 1kW TV transmitter operating at 50 W were set up at Three Rock. A second DVB-T modulator and a 25 W transmitter were set up at Donnybrook. A 34 Mb/s PDH link was established from Three Rock to Donnybrook which fed the second DVB-T modulator with the MPEG-2 TS output from the SFN adapter. This complete SFN arrangement was synchronised by using an SFN adapter (MIP inserter) and GPS receivers.

At a site near Donnybrook where the signals from the two transmitters were at similar levels, the programme was received successfully with a small omni-directional antenna and a professional DVB-T receiver. This field arrangement represents the world's first SFN operation based on a real primary distribution network according to the ETSI specification (5).

**Gap-Filler Transmitters**

SFN techniques can be used on a smaller scale to improve coverage. VALIDATE partners have been studying both professional gap-fillers, installed by the network operator to fill gaps in the coverage of a main transmitter caused by shadowing from terrain or large buildings, and domestic gap-fillers installed within a house to improve portable reception. Obviously, the main technical problem of such gap-fillers is oscillation caused by feedback of the transmitted signal to the receiving antenna.

A professional gap-filler was demonstrated by Mier and DT Berkom in Berlin to provide coverage to the Potsdam area that is shadowed by hills from the main transmitter at Alexanderplatz in the centre of Berlin (see Fig. 2). With both receiving and transmitting antennas mounted on the same concrete tower an isolation of 105 dB was obtained. The ripple on the output DVB-T signal spectrum was less than 3 dB with an output ERP of 100 W. Field trials in Potsdam showed that portable reception was possible at all locations with a reasonable field strength.
For the domestic gap-filler, VALIDATE partner Televés carried out a feasibility study that gave encouraging conclusions, then built a prototype. As a domestic device, the safety of such a device and its cost were important considerations.

In a first test conducted by the BBC in the London area, the domestic gap-filler gave sufficient field strength to provide portable reception in all rooms of a house with an output power less than 200 μW. There were no problems of stability when it was fed from a rooftop antenna, but some care was needed in setting up when a receiving antenna within the roof space of the house was used.

Five more houses and flats of different sizes and different methods of construction have been measured since, some of them in areas of poor reception where indoor portable reception would otherwise have been impossible; in all cases use of the gap-filler allowed portable reception in all rooms of the dwellings. Reception has been proved possible even with very poor input signals (20 dB tilt across the channel and 5 dB ripple).

VALIDATE – summing up

In just under three years VALIDATE has verified the DVB-T specification and has provided test results for reliable service planning and international coordination. Its work has ensured that a range of conformant equipment is available and has helped IC designers to design chips for domestic receivers with confidence. DVB-T services are now ready to start in the UK and Sweden, with long-term trials on air in several more European countries. This success has been achieved thanks to the excellent teamwork of the Partners in exchanging and comparing results from tests and trials carried out all over Europe.

MOTIVATE: DEVELOPING MOBILE SERVICES

Introduction

In some countries – such as the UK – terrestrial television is still dominant. In these countries the initial application of DVB-T will be to provide more channels to increase choice. In other countries – such as Germany – there is a much higher penetration of cable and satellite: only 6.8 M of the 36 M German households rely on terrestrial broadcasting. DVB-T could overcome some of the limitations of analogue terrestrial TV but this alone would not guarantee a successful introduction of DVB-T services in such countries: added value services are needed to attract more users and increase revenues for broadcasters and network providers.

Mobile reception of video, Internet and multimedia data could be an attractive feature to help the launch of DVB-T in countries such as Germany. Only terrestrial broadcasting could bring mobility to the end user. A data rate up to 15 Mbit/s using one 8 MHz UHF channel seems to be possible with the 64-QAM mode. Mobility is one of the advantages of the European DVB-T solution against competing standards.

Mobile Services

Mobile reception of DVB-T could bring new features to broadcast networks, making applications and services accessible and usable by anyone, anywhere, anytime, for business or individual use. A narrowband return channel could be integrated using GSM. Here are some examples of mobile services, some of which will be tested in the MOTIVATE project.

Digital television for cars, buses and trains

Digital television in cars, buses and trains could become the first service for mobile users. It would use some of the existing programmes with additional traffic and navigation information. An audio description service would be needed to make programmes safely accessible to drivers and front-seat passengers.

Mobile contribution links

RTÉ and Deutsche Telekom Berkom have tested mobile transmission of DVB-T signals for contribution links. A low power transmitter can be
installed in a vehicle to transmit MPEG-2 signals from a vehicle – even while in motion – to a studio. Tests have been made at UHF and in the L-Band. This service might be used at sports events, such as the Tour de France or the London Marathon, for interviews with busy politicians, or for the reporter in the field.

**Mobile Webcasting**

Today, solutions for Webcasting have been developed for stationary reception, mainly using satellite and cable based services. Webcasting is based on an Integrated Receiver Decoder (IRD) which could combine broadcast and telephony. The return channel and interactivity is limited to the bandwidth of the telephony network. Mobile DVB-T together with GSM would allow users to receive Internet in cars, buses, on ‘watchmen’, laptops, on-the-move. GSM as a return channel for DVB-T was standardised by the DVB project.

**Mobile reception of DVB-T**

The analysis of mobile reception using DVB-T started in early 1997. Since then, Deutsche Telekom has carried out an extensive series of measurements with a DVB-T compliant modem to investigate the performance of the DVB-T specifications in a mobile environment (6).

Doppler shift, deep fading, and shadowing are the dominant factors that decrease the system performance in mobile environments. The behaviour and limits of the DVB-T specifications were analysed through theoretical investigations, computer simulations, and laboratory tests. Field trials were performed in the area of Cologne in a variety of conditions, in the 2k mode only.

For the first time, measurements and field trials of mobile reception were carried out with higher orders of modulation, (16-QAM and 64-QAM) as well as QPSK. Results using channel 43 with an echo of 25μs showed that QPSK and 16-QAM need a carrier-to-noise ratio (C/N) about 6-7dB greater than in a Gaussian channel for a speed of 200 km/h; 64-QAM at 150 km/h needs C/N 10 dB greater. In all cases code rate 1/2 must be used.

It seems that the Doppler shift, especially for the QPSK or 16-QAM rate 1/2 modes, is not the fundamental limitation of the DVB-T specifications, although it does reduce the noise margin. Other limitations might be the lack of time interleaving (in the case of certain simulated channel profiles) and long echoes, particularly in the 2k mode; the 8k mode offers longer guard intervals to avoid inter-symbol interference effects. However, both laboratory measurements and field trials have shown that transmission of 15 Mbit/s is possible at 64-QAM. In this case the required C/N is about 27 dB up to a speed of 100 km/h.

Nevertheless further investigations, especially field trials, have to be made to get a clear impression of this problem and the necessary transmitted power to overcome the problem of signal blocking.

**The MOTIVATE project**

The MOTIVATE project started work in May 1998 as a successor to VALIDATE. It will investigate the mobile reception of digital terrestrial TV in single-frequency and multi-frequency networks with data rates up to 15 Mbit/s. It is led by Deutsche Telekom Berkom GmbH and builds on the strong consortium shown in TABLE 1. The project has the backing of a number of sponsoring partners (Tele Danmark, RTÉ, DVB promotional module) which could make MOTIVATE the spearhead for the implementation of mobile DVB-T services. MOTIVATE is open for cooperation with broadcasters and network operators interested in DVB-T services.

The main objective of MOTIVATE is to provide practically-based implementation guidelines for mobile DVB-T reception. To ensure that these guidelines are soundly based, MOTIVATE will carry out theoretical and practical work on network structures, service planning and receivers.

**Network structures**

The MOTIVATE project will investigate coverage aspects of different network configurations (MFN, SFN, gap fillers) for portable and mobile reception to evaluate SFN network gain. Laboratory measurements and field trials will be carried out to optimise the network topology by selection of the antenna polarisation, the combination of MFNs and SFNs, the use of gap-fillers, and the choice of suitable DVB-T modes (modulation, code rate, and guard interval).

**Service planning**

The planning of different configurations of DVB-T networks needs parameters describing the receiver performance for mobile reception. MOTIVATE will specify a reference receiver and a minimal set of performance parameters needed to obtain a certain service quality with a certain type of receiver.

**Receivers**

MOTIVATE will study, implement, test and optimise efficient receiver algorithms for synchronisation, channel estimation and channel correction appropriate to the mobile environment. Prototypes of mobile
receivers will be tested in MFNs and SFNs, in order to evaluate the real gain of the network. MOTIVATE will also contribute to the development of new and intuitive user interfaces.

**Importance of MOTIVATE**

MOTIVATE could have an impact on political decisions on a national and European level. The successful implementation of DVB-T for stationary reception in the UK and Sweden will help to make political decisions in other European countries; the successful verification of mobile DVB-T will help to overcome political constraints in other countries.

**THE IMPORTANCE OF COLLABORATIVE R&D**

Collaborative R&D is needed in selected areas where no one player can act alone, and where common European specifications and standards are necessary. This objective of the ACTS programme is true for the introduction of DVB-T. No single player – network operator, broadcaster, programme provider or manufacturer – could start DVB-T in Europe in the narrow window of time available: new technologies are overtaken or will wither away if they are not quickly implemented.

One of the outstanding results of the ACTS programme was the verification by VALIDATE of the DVB-T specification and the implementation guidelines derived from it. A collaborative project of this kind involving broadcasters, network operators, and manufacturers is an excellent vehicle for verifying standards and ensuring a common basis for the early start of services.

**CONCLUSIONS**

The work of the VALIDATE project has verified the very flexible DVB-T specification, technically proving the excellent behaviour of DVB-T in critical broadcasting situations. VALIDATE has studied all technical aspects of the implementation of DVB-T networks and services. It has made its experience available to other broadcasters in the form of Implementation Guidelines. In particular it has developed the concept of the ‘gap-filler’ transmitter for DVB-T and has pioneered the mobile reception of DVB-T signals.

Though DVB-T was not specified for mobile reception, it appears to work also in mobile environments. Mobile reception could open up new possibilities for digital terrestrial broadcasting, offering value-added services that could make terrestrial broadcasting an attractive proposition even in countries where there is substantial penetration of cable and satellite.

The new project MOTIVATE will carry on the work of VALIDATE with a special emphasis on mobile reception. It will study the network topologies, service planning constraints, and receiver features needed for mobile reception.

Collaborative research and technological development is needed to bring together the resources needed to launch a new technology and to ensure interoperability on a European scale.

**REFERENCES**


**ACKNOWLEDGEMENTS**

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