# DVB-H

## — the emerging standard for mobile data communication

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**DVB-H (Digital Video Broadcasting – Handheld) is the new digital broadcast standard for the transmission of broadcast content to handheld terminal devices, developed by the international DVB (Digital Video Broadcasting) Project and recently published by ETSI (European Telecommunications Standards Institute).**

**DVB-H is based on the DVB-T standard for digital terrestrial television but tailored to the special requirements of the pocket-size class of receivers. This article presents an overview of the emerging DVB-H technology and an analysis of the performance characteristics of the DVB-H transmission system.**

The digitization of traditional broadcast systems has made significant progress in recent years. This development could be observed recently with respect to the standard for digital terrestrial television, **DVB-T (Digital Video Broadcasting – Terrestrial)**, which is already in operation in many countries throughout the world. Currently, the system is being rolled out in Germany and the UK (the Freeview DTT platform). DVB-T has also started in the Netherlands and Italy and was announced to start in France in early 2005; further countries have plans to start services in the near future. In many countries, the decision to select DVB-T as the terrestrial television system was based on the exceptional features of the DVB-T standard, among them the possibility to receive broadcast services also with portable devices and even in cars.

Meanwhile the benefits of a powerful terrestrial broadcast system like DVB-T have attracted the interest of the mobile communication industry. In particular, the ability to reach mobile terminals via a wireless point-to-multipoint link, in connection with wide geographical coverage and high transmission capacity that DVB-T can offer, are features which have sparked the interest of this industry.

The international DVB Project has responded to the industry interest by specifying a new transmission standard: **DVB-H** (Digital Video Broadcasting - Transmission System for Handheld Terminals). DVB-H is the latest development within the set of DVB transmission standards. Work on the technical specification started in autumn 2002 and was finalised in February 2004; the DVB-H standard was finally published by ETSI (European Telecommunications Standards Institute) as a European Norm in November 2004 [1].

The DVB-H technology is a spin-off of the DVB-T standard. It is to a large extent compatible with DVB-T but takes into account the specific properties of typical terminals which are expected to be small, lightweight, portable and – very importantly – battery-powered. DVB-H can offer a downstream channel at a high data-rate which will be an enhancement to the mobile telecommunications network, accessible by most of the typical terminals. Therefore, DVB-H creates a bridge between the classical broadcast systems and the world of cellular radio networks. The broadband, high-capacity downstream channel provided by DVB-H will feature a total data-rate of several Mbit/s and may be used for audio and video streaming applications, file downloads and for many other kinds of services. The system thereby introduces new ways of distributing services to handheld terminals, offering greatly-extended possibilities for content providers and network operators.

## System requirements

The commercial requirements of the system were determined by the DVB Project in 2002:

- DVB-H shall offer broadcast services for portable and mobile usage, including audio and video streaming with acceptable quality. The data-rates feasible in practice have to be sufficient for this purpose. For the DVB-H system, a useful data-rate of up to 10 Mbit/s per channel is envisaged. Transmission channels will mostly be allocated in the regular UHF broadcasting band. VHF Band III may be used alternatively. Non-broadcast frequencies should be useable also.
- The typical user environment of a DVB-H handheld terminal is very much comparable to the mobile radio environment. Therefore DVB-H needs to have the potential for similar geographic coverage. The term ***handheld terminal*** includes multimedia mobile phones with colour displays as well as personal digital assistants (PDAs) and pocket PC types of equipment. All these kinds of devices have a number of features in common: small dimensions, light weight, and battery operation. These properties are a precondition for mobile usage but also imply several severe restrictions on the transmission system. The terminal devices lack an external power supply in most cases and have to be operated with a limited power budget. Low power consumption is necessary to obtain reasonable usage and standby cycles.
- Mobility is an additional requirement, meaning that access to services shall be possible not only at almost all indoor and outdoor locations but also while moving in a vehicle at high speed. Also, the handover between adjacent DVB-H radio cells shall happen imperceptibly when moving over larger distances. However, fast varying channels are very error-prone. The situation is worsened by the fact that antennas built into handheld devices have limited dimensions and cannot be pointed at the transmitter if the terminal is in motion. A multi-antenna diversity approach is mostly impossible because of space limitations. Moreover, interference can result from GSM mobile radio signals transmitted and received within the same device. As a result, accessing a downstream of several Mbit/s with handheld terminals is a very demanding task.
- Finally, the new system needs to be similar to the existing DVB-T system for digital terrestrial television. The DVB-H and the DVB-T network structures shall be as compatible to each other as possible in order to enable the re-use of the same transmission equipment.

## System overview

DVB-H, as a transmission standard, specifies the physical layer as well as the elements of the lowest protocol layers. It uses a power-saving algorithm based on the time-multiplexed transmission of different services. The technique, called ***time slicing***, results in a large battery power-saving effect. Additionally, time slicing allows soft handover if the receiver moves from network cell to network cell with only one receiver unit. For reliable transmission in poor signal reception conditions, an enhanced error-protection scheme on the link layer is introduced. This scheme is called ***MPE-FEC*** *(Multi-Protocol Encapsulation – Forward Error Correction)*. MPE-FEC employs powerful channel coding on top of the channel coding included in the DVB-T specification and offers a degree of time interleaving. Furthermore, the DVB-H standard features an additional network mode, the ***4K mode***, offering additional flexibility in designing single-frequency networks (SFNs) which still are well suited for mobile reception, and also provides an enhanced signalling channel for improving access to the various services.

## *The physical layer*

The physical radio transmission is performed by means of the DVB-T standard employing OFDM multi-carrier modulation [2]. There is only one obligatory new feature on the physical layer which makes the DVB-H signal distinguishable from a DVB-T signal – namely an extended parameter signalling for the DVB-H elementary streams in the multiplex. Several further optional new elements exist which will be described in the paragraph *Physical layer extensions*. The signalling is realised in a way which is downwards compatible with the DVB-T system. Furthermore, the DVB-H data stream is fully compatible with DVB transport streams carrying “classical” DVB-T offerings. These properties guarantee that the DVB-H data stream can be broadcast (i) via DVB-T transmitter networks totally dedicated to DVB-H services as well as (ii) via DVB-T networks carrying these classical services in addition to DVB-H services. For this reason, essential technologies specific to DVB-H – such as time slicing and the enhanced forward error correction – are deliberately put onto the protocol layer above the DVB Transport Stream.

## *Time slicing*

A special problem for DVB-H terminals is the limited battery capacity. In a way, being compatible with DVB-T would place a burden on the DVB-H terminal because demodulating and decoding a broadband, high data-rate stream like the DVB-T stream involves a certain power dissipation in the tuner and the demodulator part. An investigation at the beginning of the development of DVB-H showed that the total power consumption of a DVB-T front end was more than 1 Watt at the time of the examination and was expected not to decrease below 600 mW until 2006; meanwhile a somewhat lower value seems possible but the envisaged target of 100 mW as a maximum threshold for the entire front end incorporated in a DVB-H terminal is still unobtainable for a DVB-T receiver.

A considerable drawback for battery-operated terminals is the fact that with DVB-T, the whole data stream has to be decoded before any one of the services (TV programmes) of the multiplex can be accessed. The power saving made possible by DVB-H is derived from the fact that essentially only those parts of the stream which carry the data of the service currently selected have to be processed. However, the data stream needs to be reorganized in a suitable way for that purpose. With DVB-H, service multiplexing is performed in a pure time-division multiplex. The data of one particular service are therefore not transmitted continuously but in compact periodical bursts with interruptions in between. Multiplexing of several services leads again to a continuous, uninterrupted transmitted stream of constant data-rate.

This kind of signal can be received time-selectively: the terminal synchronizes to the bursts of the wanted service but switches to a power-save mode during the intermediate time when other serv-

### Abbreviations

| | |
|---|---|
| **AWGN** | Additive White Gaussian Noise |
| **BER** | Bit-Error Rate |
| **COST** | European Cooperation in the field Of Scientific and Technical research |
| **DVB** | Digital Video Broadcasting |
| **DVB-H** | DVB - Handheld |
| **DVB-T** | DVB - Terrestrial |
| **ETSI** | European Telecommunication Standards Institute |
| **FEC** | Forward Error Correction |
| **FFT** | Fast Fourier Transform |
| **GSM** | Global System for Mobile communications |
| **IP** | Internet Protocol |
| **MPE** | Multi-Protocol Encapsulation |
| **MUX** | Multiplex / multiplexer |
| **OFDM** | Orthogonal Frequency Division Multiplex |
| **PDA** | Personal Digital Assistant |
| **QAM** | Quadrature Amplitude Modulation |
| **QEF** | Quasi-Error-Free |
| **RS** | Reed-Solomon (code) |
| **SFN** | Single-Frequency Network |
| **SI** | Service Information |
| **S/I** | Signal-to-Interferene ratio |
| **S/N** | Signal-to-Noise ratio |
| **TPS** | Transmission-Parameter Signalling |
| **TU** | Typical Urban channel profile |
| **UHF** | Ultra High Frequency |
| **VHF** | Very High Frequency |

ices are being transmitted. The power-save time between bursts, relative to the on-time required for the reception of an individual service, is a direct measure of the power saving provided by DVB-H. This technique is called ***time slicing***. Bursts entering the receiver have to be buffered and read out of the buffer at the service data-rate. The amount of data contained in one burst needs to be sufficient for bridging the power-save period of the front end. The position of the bursts is signalled in terms of the relative time difference between two consecutive bursts of the same service. Practically, the duration of one burst is in the range of several hundred milliseconds whereas the power-save time may amount to several seconds. A lead time for powering up the front end, for resynchronization etc. has to be taken into account; this time period is assumed to be less than 250 ms. Depending on the ratio of on-time / power-save time, the resulting power saving may be more than 90 %.

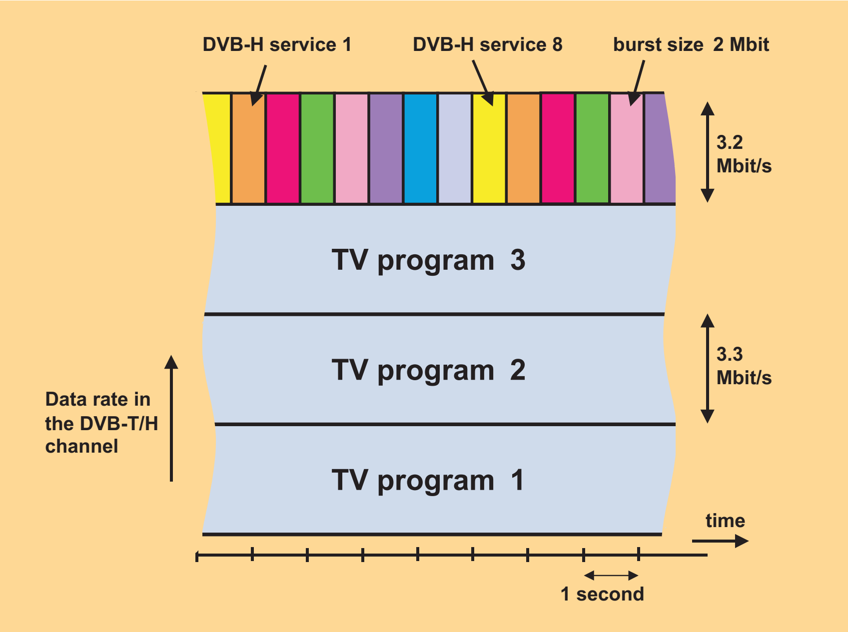


**Figure 1**
**The time slicing principle: example of a service multiplex in a common DVB-T/H channel, including time-sliced DVB-H services**

As an example, *Fig. 1* shows a cut-out of a data stream containing time-sliced services. One quarter of the assumed total capacity of the DVB-T channel of 13.27 Mbit/s is assigned to DVB-H services whereas the remaining capacity is shared between ordinary DVB-T services. This example shows that it is feasible to transmit both DVB-T and DVB-H within the same network.

Time slicing requires a sufficiently high number of multiplexed services and a certain minimum burst data-rate to guarantee effective power saving. Basically, the power consumption of the front end correlates with the service data-rate of the service currently selected.

Time slicing offers another benefit for the terminal architecture. The rather long power-save periods may be used to search for channels in neighbouring radio cells offering the selected service. This way a channel handover can be performed at the border between two cells which remains imperceptible for the user. Both the monitoring of the services in adjacent cells and the reception of the selected service data can be realized with the same front end [3].

## *IP interfacing and enhanced forward error correction*

In contrast to other DVB transmission systems which are based on the DVB Transport Stream [4] adopted from the MPEG-2 standard, the DVB-H system is based on ***IP (Internet Protocol)***. In consequence, the DVB-H base-band interface is an IP interface. This interface allows the DVB-H system to be combined with other IP-based networks. This combination is one feature of the *IP Datacast system* which is expected to be made available by DVB in the summer of 2005 [3]. Nevertheless, the MPEG-2 transport stream is still used by the base layer. The IP data are embedded into the transport stream by means of the *Multi-Protocol Encapsulation (MPE)*, an adaptation protocol defined in the DVB Data Broadcast Specification [5].

On the level of the MPE, an additional stage of forward error correction (FEC) is added. This technique, called ***MPE-FEC***, is the second main innovation of DVB-H besides the time slicing. MPE-

FEC complements the physical layer FEC of the underlying DVB-T standard. It is intended to reduce the S/N requirements for reception by a hand-held device. Intensive testing of DVB-H, which was carried out by DVB member companies in the autumn of 2004, showed that the use of MPE-FEC results in a gain of some 7 dB over DVB-T.

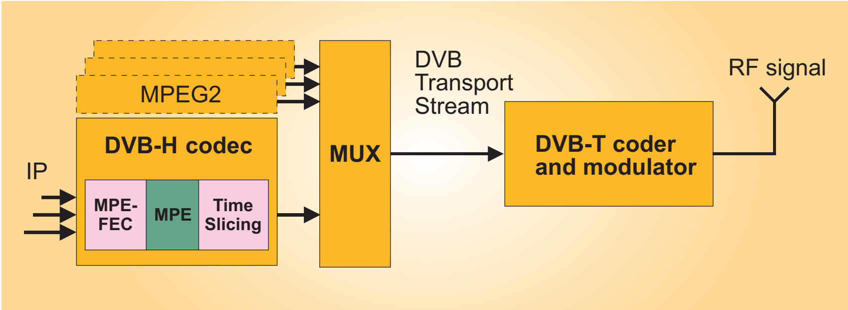


**Figure 2**
**Schematic of DVB-H codec and transmitter**

The MPE-FEC processing is located on the link layer at the level of the IP input streams before they are encapsulated by means of the MPE. The MPE-FEC, the MPE, and the time slicing technique were defined jointly and directly aligned with each other. All three elements together form the *DVB-H codec* which contains the essential DVB-H functionality *(Fig. 2)*. The IP input streams provided by different sources as individual elementary streams are multiplexed according to the time slicing method. The MPE-FEC error protection is calculated separately for each individual elementary stream. Afterwards encapsulation of IP packets and embedding into the transport stream follow. All relevant data processing is carried out before the transport stream interface in order to guarantee compatibility to a DVB-T transmission network.

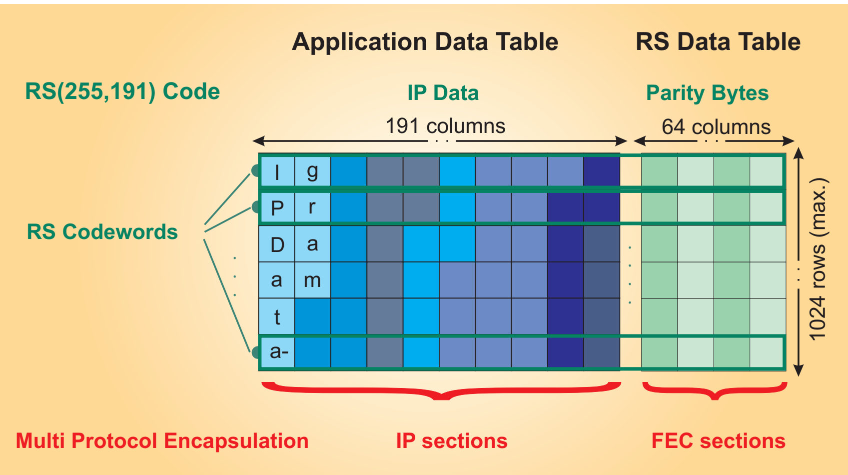


**Figure 3**
**MPE-FEC frame structure**

Looking at the details of the processing, one can see that the new MPE-FEC scheme consists of a Reed-Solomon (RS) Code in conjunction with a block interleaver. The MPE-FEC encoder creates a specific frame structure, the *FEC frame*, incorporating the incoming data of the DVB-H codec (*Fig. 3*). The FEC frame consists of a maximum of 1024 rows and a constant number of 255 columns; every frame cell corresponds to one byte, the maximum frame size is approx. 2 Mbit.

The frame is separated into two parts, the *application data table* on the left (191 columns) and the *RS data table* on the right (64 columns). The application data table is filled with the IP packets of the service to be protected. After applying the RS(255,191) code to the application data row-by-row, the RS data table contains the parity bytes of the RS code. After the coding, the IP packets are read out of the application data table and are encapsulated in *IP sections* in a way which is well known from the MPE method. These application data are followed by the parity data which are read out of the RS data table column-by-column and are encapsulated in separate *FEC sections*. The FEC frame structure also contains a "virtual" block interleaving effect in addition to the coding. Writing to and reading from the FEC frame is performed in column direction whereas coding is applied in row direction.

The MPE-FEC is directly related to the time slicing. Both techniques are applied on the elementary stream level, and one time-slicing burst includes the content of exactly one FEC frame. This enables the re-use of memory in the receiver chips. Separating the IP data and parity data of each burst makes the use of MPE-FEC decoding in the receiver optional, since the application data can be utilised while ignoring the parity information.

## *Physical layer extensions*

The signalling of parameters of the DVB-H elementary streams in the multiplex uses an extension of the *Transmission Parameter Signalling (TPS)* channel known from the DVB-T standard. TPS creates a reserved information channel which provides tuning parameters to the receiver. The new elements of the TPS channel provide the information that time-sliced DVB-H elementary streams are available in the multiplex and indicate whether MPE-FEC protection is used in at least one of the elementary streams. The additional physical transmission modes being described in this paragraph are also signalled in the TPS channel. Finally, broadcasting of the *cell identifier* known as an optional element of DVB-T is made mandatory for DVB-H. The availability of this identifier simplifies the discovery of neighbouring network cells in which the selected same service is available.

**Table 1**
**Parameters of the various possible DVB-H OFDM transmission modes**

| | Mode | | |
|---|---|---|---|
| **OFDM parameter** | **2K** | **4K** | **8K** |
| **Overall carriers (= FFT size)** | 2048 | 4096 | 8192 |
| **Modulated carriers** | 1705 | 3409 | 6817 |
| **Useful carriers** | 1512 | 3024 | 6048 |
| **OFDM symbol duration (μs)** | 224 | 448 | 896 |
| **Guard interval duration (μs)** | 7,14,28,56 | 14,28,56,112 | 28,56,112,224 |
| **Carrier spacing (kHz)** | 4.464 | 2.232 | 1.116 |
| **Maximum distance of transmitters (km)** | 17 | 33 | 67 |

DVB-H can be transmitted using an OFDM transmission mode which is not part of the DVB-T specification. DVB-T already provides a 2K and an 8K mode for the optimum support of different network topologies. DVB-H allows a 4K mode to be used in addition which is created via a 4096-point Inverse Discrete Fourier Transform (IDFT) in the OFDM modulator. *Table 1* shows some relevant parameters of the three different OFDM transmission modes. The 4K mode represents a compromise solution between the two other modes. It allows for a doubling of the transmitter distance in SFNs compared to the 2K mode and, when compared to the 8K mode, is less susceptible to the inverse effect of Doppler shifts in the case of mobile reception. The 4K mode will offer a new degree of network planning flexibility. Since DVB-T does not include this mode, it may only be used in dedicated DVB-H networks.

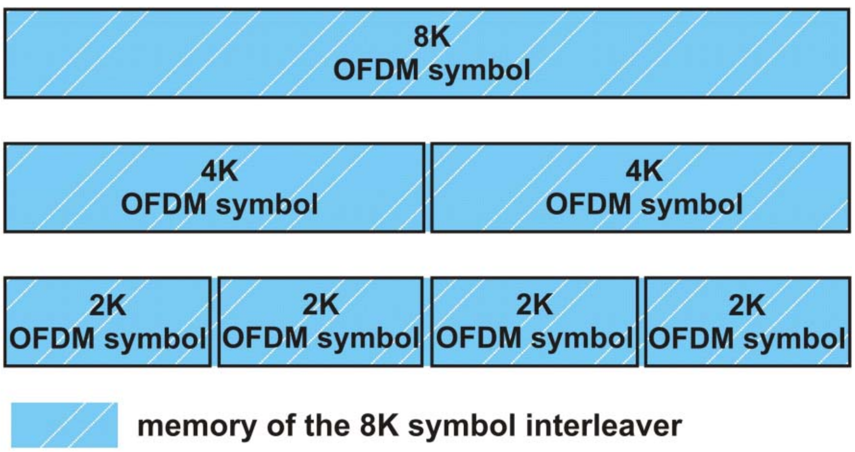


**Figure 4**
**In-depth symbol interleaving of OFDM symbols**

In connection with the three network modes, various symbol interleaving mode schemes are defined (see *Fig. 4*). A DVB-H terminal which is compliant with the specification supports the 8K mode and therefore incorporates an 8K symbol interleaver. It therefore is quite natural that one may wish to make use of the relatively big memory of the 8K symbol interleaver in all three network modes. The symbol interleaver in the terminal is able to process the data transmitted in one complete 8K OFDM symbol or alternatively the data transmitted in two 4K OFDM symbols or in four 2K OFDM symbols. The new scheme makes use of the available memory and results in an increased interleaving depth for the 2K and 4K modes and in improved performance. If the full amount of the available memory is used, the resulting method is called *in-depth interleaving* whereas the use of the symbol interleavers specific for the individual modes is called *native interleaving*.

DVB-H was specified not only for the channel bandwidths used in TV broadcasting but in addition for a channel bandwidth of 5 MHz. The DVB-T standard describes solutions for the three different VHF/UHF bandwidths used worldwide (6 MHz, 7 MHz, 8 MHz) which are therefore also supported in DVB-H. The 5 MHz bandwidth solution enables using this transmission standard outside of classical broadcast bands as well.

## Standardization of DVB-H

The DVB-H system is not specified in one single document. Instead, it is defined by a family of several specifications *(Fig. 5)* due to the prior existence of various DVB specifications which needed modifications:

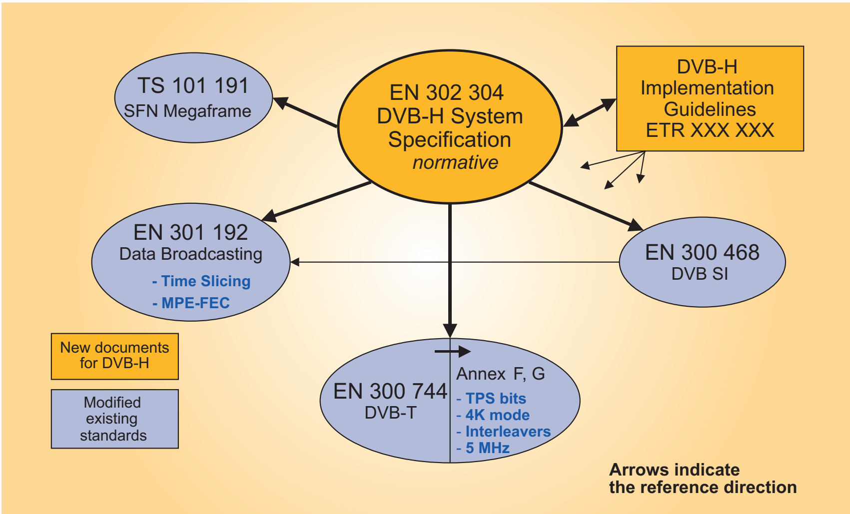


**Figure 5**
**The DVB-H standards family**

- The *DVB-H system specification* represents the central document, referencing all other necessary standards. It has been published as the new European norm EN 302 304 [1].
- The physical layer specification has been incorporated in the *DVB-T standard* [2]. It has been published as a new version of this standard which contains the DVB-H physical layer enhancements in an annex.
- Time slicing and MPE-FEC have been described in a new chapter of the *DVB Data Broadcast specification*. This document also defines the Multi-Protocol Encapsulation [5].
- DVB-H-specific signalling has been integrated into the *DVB Service Information (SI) specification* [6].
- Some modifications also affect the *DVB SFN Megaframe specification* which describes the synchronization of terrestrial single frequency networks [7].

The system specification determines mandatory and optional elements. Time slicing is mandatory for all DVB-H services and therefore has become a characteristic feature of them. The system specification is complemented by *DVB-H Implementation Guidelines* which contain hints for the use and practical implementation of the standard. These guidelines were released by the DVB Project in the autumn of 2004 and are expected to become a Technical Report (TR) published by ETSI.

## Implementation of the system and performance analysis

In order to validate the DVB-H standard, it has been completely implemented in software at the Institute for Communications Technology in parallel with the process of developing the system. The soft-

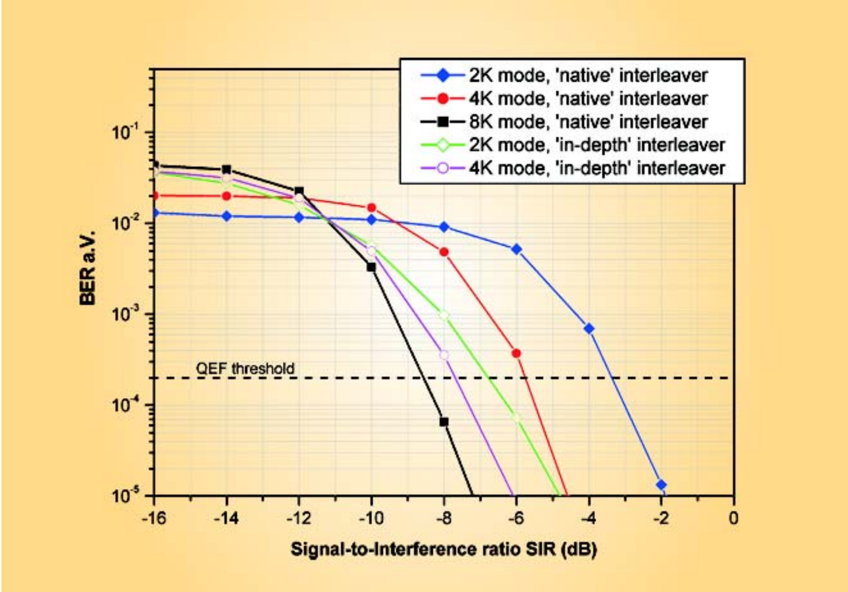


**Figure 6**
**Comparison of the OFDM modes and interleaving schemes as a function of the level of impulse interference**

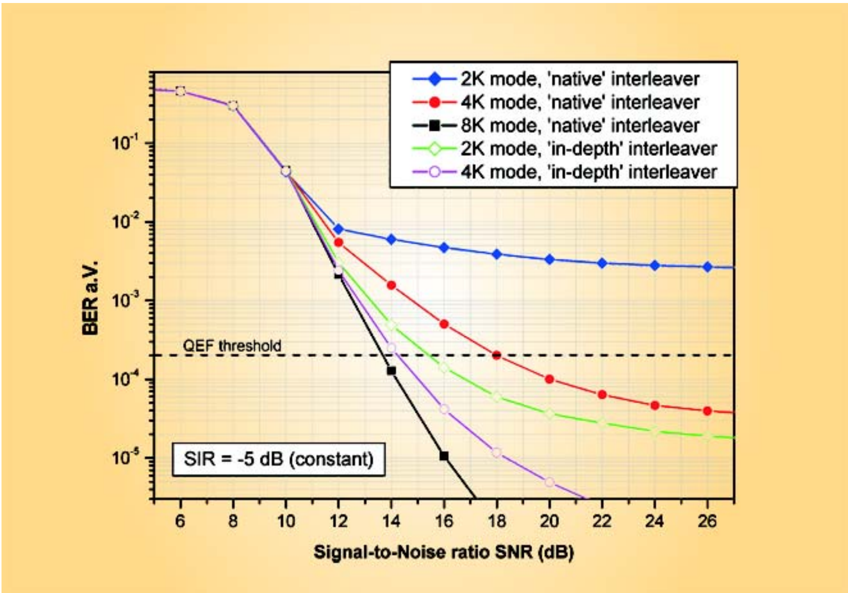


**Figure 7**
**Comparison of the OFDM modes and interleaving schemes at a constant impulse interference level as a function of SNR**

ware implementation allows comprehensive system simulations to be made using all kinds of possible transmission channels affected by all kinds of impairments. The existing simulation chain is able to accept arbitrary standard-conformant DVB-H transport streams, to simulate the physical layer and the radio channel transmission, and to perform the whole processing necessary for decoding the data in the receiver terminal.

The simulation results reported here as an example of the analysis done, relate to the performance of the 4K network mode and to the effect of the use of "in-depth" symbol interleaving. The simulation results reported describe the impact of signal interference by an impulse noise source (in practice a radiating electrical device or the ignition system of a car) and the effects of mobile reception in a multipath environment, respectively. The parameters used for the simulation were as follows:

- 16-QAM modulation;
- DVB-T convolutional code rate 2/3;
- guard interval length ¼.

These are the parameters which are used for DVB-T in Germany. All three network modes (2K, 4K and 8K) were compared with each other. In addition, the effect of the optional "in-depth" interleaver – which is defined only for the 2K and the 4K cases – was examined. The bit error rate (BER) is shown as a function of the impairments in the various channels examined.

In the case of impulse interference, the transmitted signal was overlaid with periodical series of disturbing impulses following a defined pattern and having a fixed level. The definition of the impulse pattern and their parameters followed recommendations by the Digital Television Group (DTG) in the United Kingdom which are widely accepted in the DVB-T community [8]. At first, the instantaneous signal-to-interference ratio (SIR) of the pulses was varied with no other noise or signal distortion present (*Fig. 6*). Secondly, *Fig. 7* shows the performance comparison at a constant impulse noise level 5 dB above the signal level (SIR = –5 dB) as a function of the signal-to-noise ratio (SNR) when the noise present in addition to the impulses is AWGN. The results in *Fig. 6* and *Fig. 7* show that the "in-depth" interleaving scheme causes a real benefit in comparison to the "native" interleaving in both the 2K and 4K modes, but that the 8K mode outperforms 2K and 4K.

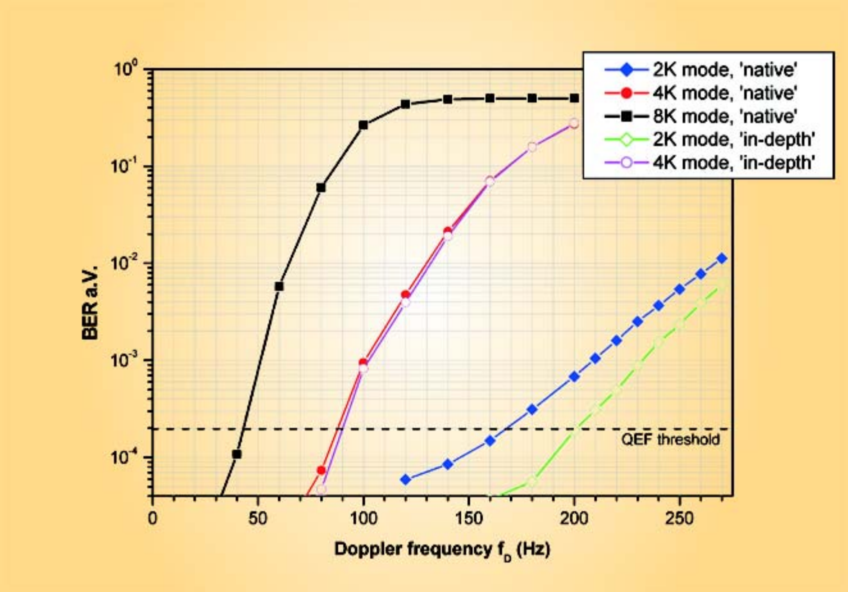


**Figure 8**
**Comparison of the OFDM modes and interleaving schemes in the case of mobile reception as a function of Doppler frequency (COST 207 channel, TU6 profile)**

In the case of mobile reception, a COST 207 radio channel model with 6-tap "typical urban" (TU6) profile and classical Doppler spectrum was used. The Doppler frequency in the received signal was varied which directly corresponds to the speed of motion of the receiver. Single antenna reception was simulated. No antenna diversity technique was employed and no optimized receiver signal processing algorithms were used in order to clearly see the impact of the choice of the various DVB-H modes.

The results in *Fig. 8* confirm that the Doppler tolerance of the 4K mode lies right between those of the 2K and 8K modes. The quantitative figures increase by a factor of two from one mode to the next which is completely in line with the relation between the parameters of the three modes. The "in-depth" interleaving scheme improves reception significantly only in the 2K case.

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After activities in the industry from 1982 until 1989 he became Technical Director of *Norddeutscher Rundfunk* (NDR). Since 1993, he has been a Professor at *Technische Universität Braunschweig* and Managing Director of the Institute for Communications Technology.

In his capacity as Chairman of the Technical Module of the DVB Project, Prof. Reimers is deeply involved in the development of digital television worldwide. His merits in this function have been honoured many times both internationally and nationally. His most recent awards were the IEEE Consumer Electronics Engineering Excellence Award 2002 which was presented to him by the Institute of Electrical and Electronics Engineers (IEEE) and the Richard Theile Medal of the German society of motion pictures and television engineers (FKTG).

Prof. Reimers is the author of more than 100 publications and a book on DVB, which has already been released in German and English in several editions.

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Mr Kornfeld is a member of the DVB Ad-Hoc Group which defined the technical specification for the DVB-H system, and a member of the technical board of the "DVB-T in Northern Germany" project which is dealing with the launch of DTT in Germany.

## Outlook

After having successfully concluded the work on the specification work, and in fact the standardization, the DVB Project has started the verification of the features of DVB-H. Trial networks are in operation in the cities of Helsinki, Berlin, Pittsburgh/USA, Barcelona, and Metz. First joint laboratory tests have been conducted in Berlin in October 2004 in order to prove functionality and interoperability of equipment and to gain knowledge about the practical performance. DVB-H field trials are planned immediately after the evaluation of the test data. Results can be expected to become available in January 2005. A European validation project will continue the work on the system evaluation and will broaden these activities starting at the beginning of 2005. As a result of these activities significant new know-how is expected to become available which will serve as an input to a new version of the Implementation Guidelines. Subsequently, the launch of commercial services is planned in several European countries as early as 2006. According to market prospects of relevant terminal and chip manufacturers, sales figures of DVB-H devices in the year 2008 are predicted to be in the order of 10s to 100s of millions.

## Acknowledgement

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