

# Evaluation of the DVB-H data link layer

G. Gardikis, H. Kokkinis and G. Kormentzas

University of the Aegean, Department of Information and Communication Systems Engineering  
GR-83200, Karlovassi, Samos, Greece.

**Abstract** - The DVB-H (Digital Video Broadcasting for Handheld devices) specification was standardized by ETSI in 2004 to achieve IP data broadcasting (“datacasting”) to handheld terminals. DVB-H emerged as an evolution of DVB-T, introducing new features –mainly at the data link layer- allowing for power saving at the receiver and for better tolerance to a mobile fading channel. This paper presents a laboratory-based software implementation of the DVB-H data link layer, combined with the appropriate physical-layer hardware components to form a complete DVB-H chain. Measurements are carried out to evaluate the efficiency of the new features of DVB-H.

**Index terms** – DVB-H, MPE-FEC, time slicing

## I. INTRODUCTION

THE DVB-H specification [1] belongs to the ETSI DVB family of standards, which define the transmission of broadcast streams over various environments (satellite, cable or terrestrial). It is defined as a “broadcast transmission system for datagrams”, and it specifies the physical and data link layer of a broadcast chain designed to wirelessly deliver unidirectional IP streams, focusing on mobile TV, to handheld terminals within an extended coverage area.

DVB-H was introduced in 2004, following the success of DVB-T, which was designed for stationary terrestrial transmission. The new specification exploits the exceptional performance of DVB-T in urban environments and inherits its physical-layer procedures, including coding and modulation. Additionally, two main features are added at link-layer, namely MPE-FEC and Time Slicing for better interleaved error protection, and burst-mode transmission respectively. These features achieve better support for mobility and power saving at the receiver, thus making handheld reception easier. DVB-H is world-widely gaining ground as a system, not only for handheld television, but for a broad spectrum of broadcast-based IP services [2] Very promising is the synergy of DVB-H with interactive cellular platforms like GPRS/UMTS [3][4][5], allowing for IP-based interactive broadcasting “on the move”. This paper attempts an in-depth analysis of the innovative features of DVB-H. For this purpose, a fully functional DVB-H data link layer is implemented (Encapsulator/Decapsulator), and combined with the appropriate hardware physical-layer modules to realise an end-to-end DVB-H chain. This laboratory platform is subject to a series of measurements in order to validate the efficiency of the innovative features of DVB-H.

Section II briefly presents an overview of DVB-H as a broadcast technology. Section III describes the realisation and the structure of the implemented Encapsulator and Decapsulator. Section IV presents the set-up which was implemented and discusses the methodology of the measurements and the results derived. Finally, Section V concludes the paper.

## II. OVERVIEW OF DVB-H

The DVB-T specification was adopted by ETSI in 1997 to enable terrestrial transmission of digital television streams. It adopted OFDM (Orthogonal Frequency Division Multiplexing) transmission with three options for carrier modulation: QPSK, 16QAM or 64QAM. Channel coding is performed in two stages, employing a convolutional and a block Reed-Solomon coder, while a two-layer interleaving is also used. The baseband format is the MPEG-2 Transport Stream (TS), consisting of constant-sized 188-byte packets. The whole system operates in a 6-, 7-, or 8-MHz channel within the UHF band, matching the bandwidth of an analogue TV program.

Although DVB-T was initially designed for stationary use, during the field trials it showed an exceptional performance in mobile reception also [6] However, when it comes to handheld use, there is a series of requirements that have to be satisfied:

- *Power consumption.* Limited battery life is a crucial issue for mobile DVB receivers since the demodulation/demultiplexing/ decoding chain consumes about 1W.
- *Mobility support.* A handheld terminal should operate in a network which allows and assists handovers, i.e. switching from one DVB macrocell to the other.
- *Tolerance to mobile receiving conditions.* For proper mobile reception, the impairments introduced by the mobile channel, including frequency and time selective fading, interference and Doppler, must be compensated.
- *Increased immunity to interference and impulse noise.* The handheld receiver can easily experience decreased SNR due to a strong fading or a nearby noise source.
- *Operation in multiple bands.* Given the saturation of the UHF band, the system should be able to operate in other frequency zones also.

To satisfy this requirements, DVB-H adopts the DVB-T physical layer, and introduces certain innovations, both at the physical and (mainly) at the data link layer.

In the physical layer three main new features are introduced:

- *Additional TPS (Transmission Parameters Signalling)* are added to extend physical-layer signalling
- *4K transmission mode*, in addition to 2K and 8K of DVB-T, is used for a better trade-off between Doppler tolerance and SFN (Single Frequency Networks) operation. With the 4K mode, satisfactory Doppler performance at high speeds is achieved, allowing at the same time for operation within medium-sized SFNs
- *In-depth symbol interleaving*, adding an extra time-

interleaving layer for better protection against short fades of impulse noise.

The target operating frequency band is not restricted to the IV-UHF band, but also other options are given, the most promising being the L-band around 1.5 GHz.

In the data-link layer, the support of native MPEG-2 DTG streams is abandoned, and DVB-H focuses exclusively at the transmission of IP datagrams. DVB-H is IP-oriented, and mobile TV services are also assumed to be carried over IP. The IPDC (IP Datacast) group of specifications [7][8] have been recently adopted to provide a thorough upper-layer framework for the provision of broadcast IP services to handheld terminals, mainly via DVB-H.

The IP datagrams are transmitted encapsulated in an MPEG-2 Transport Stream using the MPE (Multi Protocol Encapsulation) defined in [9]. Prior to MPE IP-over-TS encapsulation, DVB-H introduces a new layer of FEC (Forward Error Correction), namely the MPE-FEC. Its purpose is to increase the immunity to impulse noise and degraded SNR in general. The Reed-Solomon block coder is used to add extra parity bytes to a group of IP datagrams, organised in an MPE-FEC frame. Within this frame, the IP datagrams are organised in columns, and parity is calculated across each row according to a Reed-Solomon (255,191,64) code. The IP datagrams are consecutively transmitted, and the R-S overhead follows. At the receiver, the MPE-FEC frame is reconstructed, and possible bit errors / erasures are recovered.

Fig. 1 shows the structure of the MPE-FEC table. The “mother” code rate is 3/4, which means that 33% overhead is normally added to the useful payload. Via puncturing or padding, other stronger or weaker rates can also be achieved.

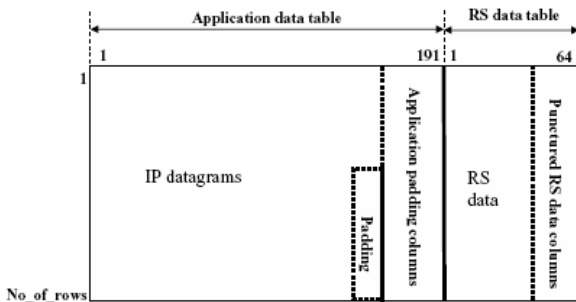


Fig. 1. Structure of a MPE-FEC frame

In order to optimise the power saving at the receiver, an additional mechanism, namely Time Slicing, is introduced, taking advantage of the fact that a DVB-H stream normally contains more than one service. Instead of randomly multiplexing all services in a statistical TDM scheme prior to transmission, as happens in traditional DVB multiplexers, the DVB-H Time Slicer organises each service in bursts, each one having the size of a single MPE-FEC frame. Each burst is continuously transmitted at a short duration and an instantaneous bit rate much higher than the average rate of the service. The time interval until the next burst of the same service (“delta-t”) is signalled within the burst (see Fig.2). After each burst, the bursts conveying the other services follow.

It may be possible that a burst contains more than one services, which is the case in low bit-rate streams.

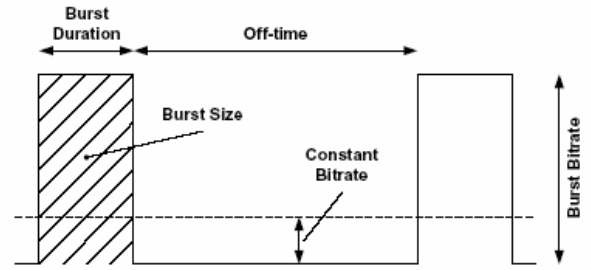


Fig.2. Time Slicing: the organisation of each stream in bursts

Normally, each handheld terminal is “listening” to one service only, e.g. viewing a single TV programme. After receiving a burst containing this specific service, it can store it in a buffer, and switch off the entire receiving/decoding/decapsulating chain until the next burst is expected. Then, the receiver front-end is switched on again. Meanwhile, during the off-period, the terminal “consumes” the data of the last burst, which are stored in the buffer. By switching off the DVB-H subsystem when not needed, the terminal achieves a high energy saving, which can reach 90% or even more, depending on the burst size and the inter-burst (“delta-t”) interval [10].

This technique has an additional benefit: during the off-time, the terminal has the opportunity to use its RF front-end to scan for other frequencies, trying to lock to the same service transmitted from neighbouring cells. The process of terminal-initiated handover is thus greatly assisted [11]

### III. DESIGN AND DEVELOPMENT OF THE DVB-H DATA LINK LAYER

In order to attempt an in-depth analysis of the Time Slicing and MPE-FEC features, a complete DVB-H Encapsulator and Decapsulator module was designed and implemented, equipped with both mechanisms. The software implementation is fully customisable, and measurements can be derived at each step of the whole process. Real operating modules were developed, rather than simulation blocks, so that they can be integrated in an operable DVB network.

#### A. The Encapsulator

The Encapsulator process receives the IP useful data to be transmitted and produces the MPEG-2 Transport Stream to be sent to the DVB-H Modulator. It organises the IP packets into an Application Data Table (See Fig.2), computes the Reed-Solomon parity, forms the MPE encapsulated sections, and splits them into the payload of consecutive MPEG-2 Transport Packets. The whole module was developed in C++ on a Win32 platform, and its functional diagram is depicted in Fig.3.

The Encapsulator accepts as input either IP datagrams sent over a network, or a local stored data file to be transmitted. In the second case, the file is split into IP packets adding a 20-byte header.

At first, the IP datagrams are counted, grouped, and vertically organised in an Application Data Table (see Fig.2). The latter corresponds to a single burst and consists of 1024 rows. As the standard specifies, the use of the FEC mechanism is user selectable and, in this case, is declared by the boolean variable useMPE. Without FEC parity overhead, the table has 191 columns (only useful data) and is sized 195584 bytes, and if R-S parity is added, the table expands to 255 columns (261120 bytes) to accommodate the extra overhead. In this second

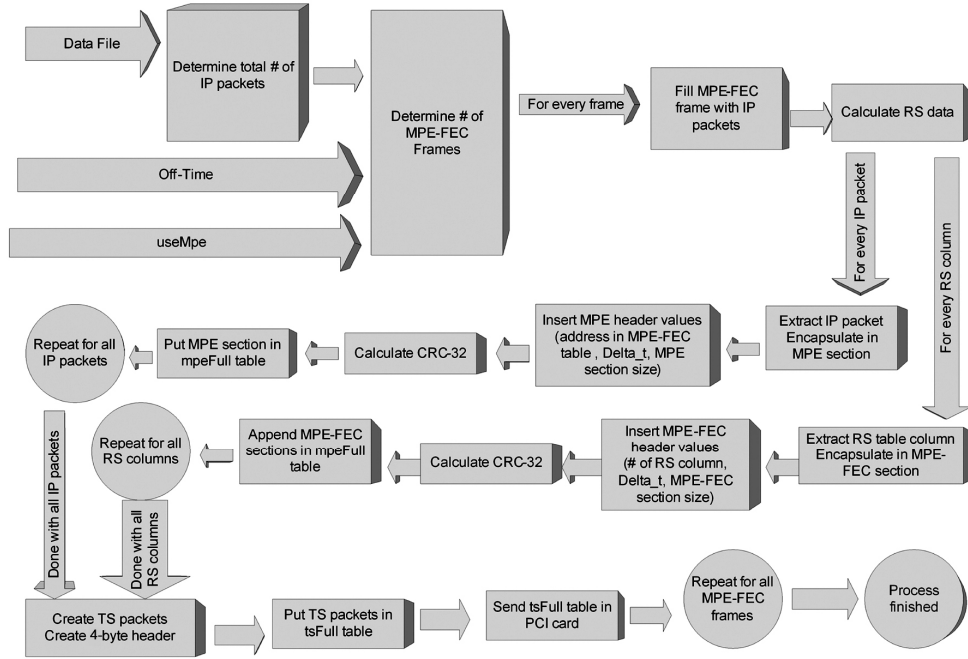


Fig. 3. Functional diagram of the Encapsulator module

option, the 191 useful bytes of each row are sent to the R-S encoder which produces the 64 parity bytes. The polynomial which is used for the generation of the Galois field, is:

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

Only the “mother” code rate of 3/4 is used in this implementation.

After encoding, the data are extracted from the table, column-by-column and each IP datagram is encapsulated in an MPE section according to [9]. A header of 12 bytes precedes, the IP payload follows, and a 4-byte CRC-32 is computed over the entire MPE section and appended at its end. If MPE-FEC is activated, the R-S parity bytes are also encapsulated in MPE-FEC sections and transmitted after the useful data.

The off-time variable is user selectable and defines the inter-burst interval i.e. the time duration between two consecutive bursts. This is used to calculate the “delta-t” field which is placed in the header of each MPE section. The burst of sections is buffered in a reserved memory area (mpeFull).

The last step is the fragmentation of the MPE and MPE-FEC sections into MPEG-2 Transport Packets. The latter have a constant length of 188 bytes of which the first 4 are reserved as a header and the rest 184 carry a fragment of the corresponding section. The TS burst is thus created, consisting of Transport Packets and buffered in a reserved memory area (tsFull). It is then output over a UDP stream via an Ethernet network interface.

### B. The Decapsulator

The decapsulating process is taking place at the receiver. It can be considered as a peer-to-peer process to the Encapsulator, operating at the data link layer, and involves the processing of the demodulated and decoded Transport Stream and the extraction of the original IP datagrams. The inverse process of MPE-FEC, as described in the previous section is carried out

for error recovery. A separate control module reads the Time Slicing signalling and, in an integrated implementation, should normally switch off the receiver front-end when necessary, i.e. when no useful data are expected.

The Decapsulator software module is also developed in C++ running in a Win32 environment. Its functional diagram is depicted in Fig. 4.

The Decapsulator receives the Transport Packet bursts from the DVB-H Demodulator over a UDP socket via the Ethernet interface. The whole burst is stored in the tsFull buffer, the payload is extracted from the Transport Packets, and the sections burst is regenerated (mpeFull buffer).

The module accepts as a boolean input from the user (useMpe) which declares whether MPE-FEC has been used or not. Normally, this information is signalled directly at physical layer, so it does not have to be delivered manually.

By parsing an MPE-FEC section, the dimensions of the MPE-FEC table are derived. The sections are decapsulated one by one and the useful data are placed column-by-column in the Application Table. The MPE-FEC sections follow, carrying the parity bytes to be placed in the R-S data table (see Fig.2). Upon decapsulation, the CRC-32 algorithm is applied on each section. If the value derived coincides with the declared value at the end of the section, then the section has been received without errors. Otherwise, it is considered corrupt, and the whole IP datagram is marked as erroneous. This is achieved by the use of a separate structure, the erasureTable, which has the same size as the MPE-FEC table. When an erroneous packet is placed in the MPE-FEC table, the corresponding bytes of the erasureTable are assigned a value of “1”.

When the MPE-FEC and erasure tables are filled, the whole burst has been processed and the Reed-Solomon decoding is about to begin. The count of “1” values within a row of the erasure table show the number of erasures (potential errors) inside a row of the MPE-FEC table. If this number is greater than 64, then, by nature, the R-S algorithm cannot correct them –since the number of parity bytes is also 64-, and the entire table (i.e. the entire burst) is discarded.

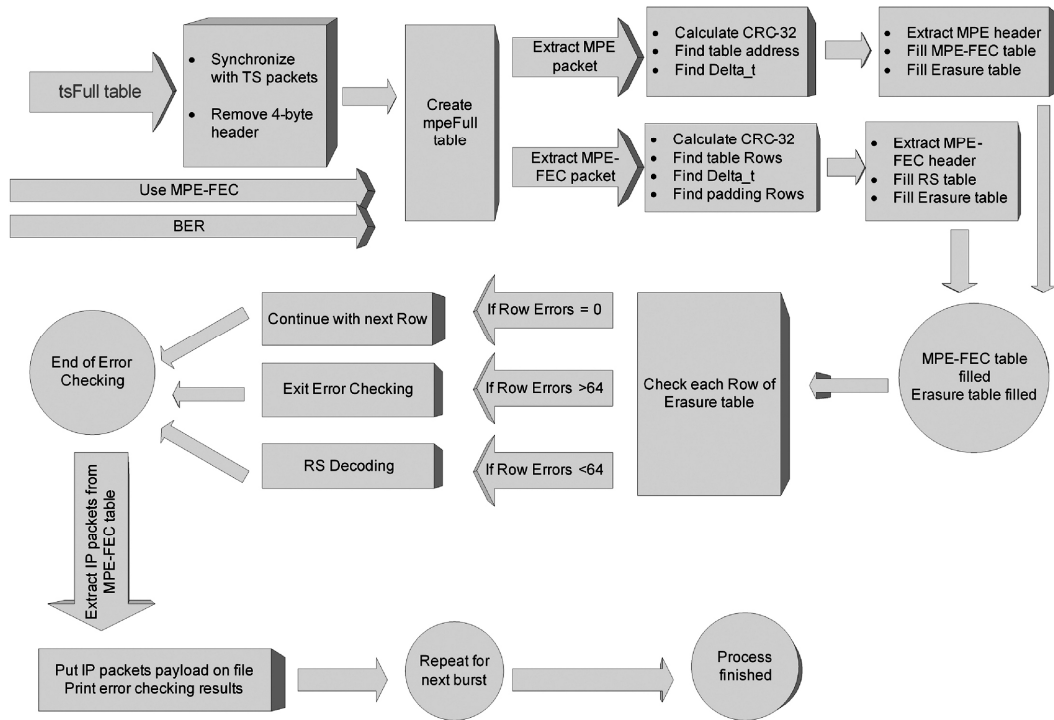


Fig.4. Functional diagram of the Decapsulator module

If the number of erasures in a table is less or equal than 64, then the R-S FEC procedure is carried out to correct them, deriving information from the erasure table to define the location of erasures. For this purpose, the Berlekamp-Massey algorithm is applied.

Upon the completion of the process, the row is replaced with the corrected one, and the program proceeds to the next.

Finally, the IP packets are read from the table, column by column, and sent out to the network. Optionally, their payload is extracted to form the original data file that was sent.

#### IV. TESTBED AND EVALUATION

In order to use the aforementioned modules to evaluate the DVB-H data link layer, a laboratory testbed was built, realising a complete end-to-end DVB-H chain. The set-up is shown in Fig.5.

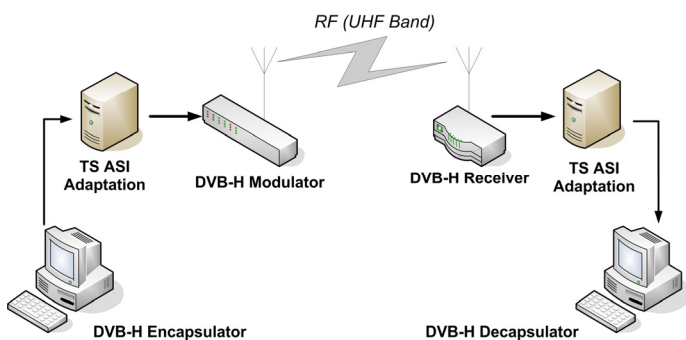


Fig.5. Laboratory set-up based on the developed modules

The Encapsulator and Decapsulator modules are hosted in two separate PCs running WinXP Pro on an Athlon64 2800+ processor. With MPE-FEC disabled, the two modules can operate in real-time for low useful (IP) data rates (in the order of a few Mbps). With MPE-FEC enabled, mainly due to the high requirements of the software Reed-Solomon decoding

algorithm at the Decapsulator, only off-line, non-real-time processing is possible.

The output of the Encapsulator is MPEG-2 TS, conveyed over a network socket. To be adapted to the physical ASI (Asynchronous Serial Interface) input which most DVB modulators accommodate, a separate Linux gateway is inserted, equipped with an ASI PCI interface, which receives the network stream from the Encapsulator and feeds the Modulator via the ASI output. The inverse process is carried out at the receiver side, where the TS fed by the ASI output of the DVB-H receiver is sent over a network stream to be processed by the Decapsulator.

The DVB-H Modulator is a SODIELEC SMX 600 COFDM Transmitter whose output (tuned to UHF channel 29) feeds the transmission antenna via a low-power amplifier. The Receiver is a PTV PT5765 COFDM Monitor – Demodulator.

##### A. Evaluation of the Time Slicing mechanism

This section presents the assessment of the power saving achieved by the Time Slicing mechanism. As useful data, the Encapsulator uses a stored file of 1.3 Mbytes. The file is split by the Encapsulator in 1500-byte IP packets, organised in 7 equal bursts of 196 KB each, as described in Section IIIA, with MPE-FEC disabled. The TS rate is set to 1.5 Mbps, so the duration of each burst is 1 second. The inter-burst time is user configurable. The Decapsulator, as it was implemented, features an internal module which calculates the off-time according to the “delta-t” parameter signalled in the MPE sections. Normally, this module commands the RF front-end to shut off when no useful data are expected, and wakes it up just before the next burst. The data derived by this module can be used to calculate the power saving at the receiver, defined as the fraction of the time during which the front-end is inactive. Inter-burst time is adjusted at the Modulator, from 2 to 20 seconds. With a fixed burst size, increasing the inter-burst time leads to the decrease in the average bit rate of the service. Fig.

6 shows the power saving percentage, as measured at the receiver based on the outcome of the Time Slicing control module.

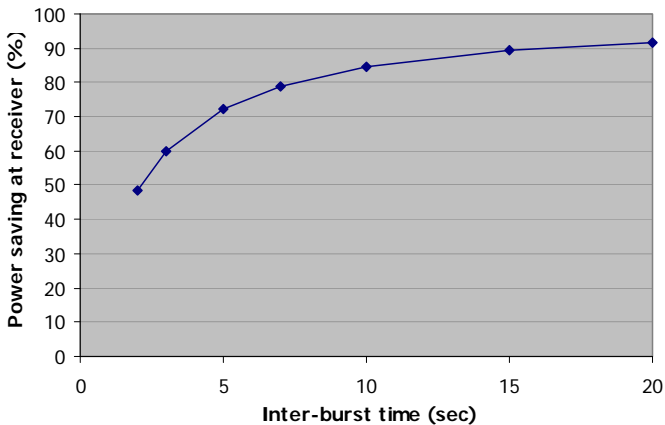


Fig. 6. Measured power saving at the receiver vs. inter-burst time

The results show that when the service is of a relatively low bit rate, the bursts can occur at intervals of several seconds, resulting in power savings up to 90% or even more.

Considering a realistic scenario, it can be assumed that the overall TS rate can be 10 Mbits/s, and a typical video service for handhelds can demand 500kbts/s. Assuming bursts of 2 Mbits, each burst has a duration of 200 msec and the inter-burst time is 4 seconds. The theoretical power saving is 96%, while the real value should be expected a bit lower, due to other parameters, like the time duration requested for the power-on and the re-tuning and synchronisation of the front-end.

It must be noted that, in the case of real-time streaming applications, the inter-burst time must be kept in a relatively low value, so that the service access time remains within acceptable limits.

### B. Evaluation of MPE-FEC mechanism

For the evaluation of the MPE-FEC mechanism, and the protection it offers against channel errors, the same 1.3 MB data file is used, as in the previous section. The Encapsulator splits it into 7 bursts, which now have a size of 266 KB, due to the use of MPE-FEC. 33% overhead is inserted due to the presence of the parity bytes.

The Demodulator is customised to simulate channel bit errors. Errors, in the DVB-H case which is oriented to mobile use, will most probably occur due to fluctuations in the mobile channel. A user-specified parameter (BER, see Fig.4) is used to define the bit-error-ratio of the demodulated Transport Stream. This ratio includes the errors that have not been corrected by the hardware FEC modules at physical layer and are randomly present within the TS. Uniform error distribution is assumed, corresponding mostly to an AWGN channel. Using this value, the Demodulator processes the received TS burst, stored in the tsFull buffer, and inserts random errors with uniform distribution using the given error probability. The result is an erroneous TS burst, which the MPE-FEC mechanism will attempt to correct.

The CRC-32 algorithm in each MPE section detects the presence of the errors and marks the corresponding datagrams as invalid in the erasureTable. The R-S decoding procedure, carried in each row of the MPE-FEC table, corrects the errors,

provided that there are less than 64 erasures in each row. A counter at the output of the Decapsulator counts the IP packets that are delivered uncorrected, and calculates the Packet Error Rate as the ratio of the uncorrected IP datagrams to the total ones.

The procedure is carried out with and without the use of MPE-FEC with various BER values, and the results are shown in Fig. 7.

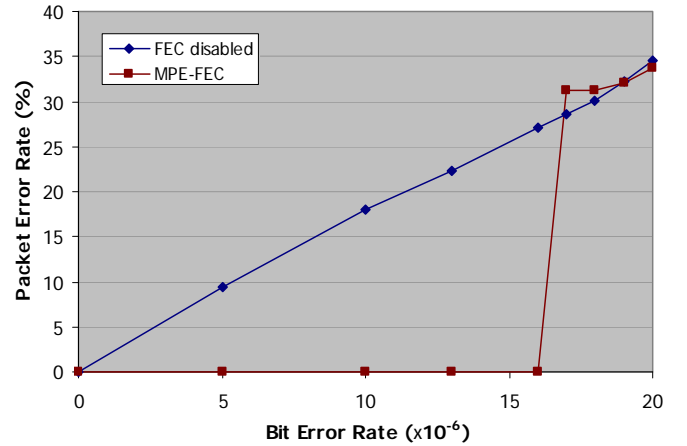


Fig.7. PER at the Decapsulator output vs. BER at the input, with and without MPE-FEC

With the FEC mechanism disabled (which means that no redundancy bytes are inserted in the Encapsulator), the PER at the output normally increases linearly with BER. The activation of the MPE-FEC adds an overhead of almost 33% to the bit stream, as aforementioned, but increases the immunity of the receiver to channel noise. Up to a certain threshold of TS-level bit error rate ( $17 \cdot 10^{-6}$ ), the R-S decoding algorithm corrects all impairments, and the data stream is delivered without errors. Above this threshold, the R-S process fails at least in one row of the MPE-FEC table, and no errors are corrected. In this case, the PER is equal to this derived without the use of FEC.

## V. CONCLUSIONS

As a system for data broadcasting to handheld terminals, DVB-H is currently gaining ground in the field of mobile TV and broadband multimedia [12] Based on DVB-T, DVB-H introduced two main innovations at data link layer, namely MPE-FEC and Time Slicing. To evaluate these features, a DVB-H Encapsulator and Decapsulator was implemented and integrated in a fully functional DVB-H end-to-end chain. The structure and operation of the two software modules was described in detail. Thanks to their customisation, in-depth performance measurements on the DVB-H data link layer were made possible. This evaluation process proved the importance of the Time Slicing mechanism, thanks to which power saving of over 90% can be achieved at the receiver, and MPE-FEC, which increases the tolerance of the system to channel impairments, even when bit errors are still present within the demodulated MPEG-2 Transport Stream after the physical-layer FEC decoding.

## ACKNOWLEDGEMENT

The DVB-H-related research effort from which this paper was

derived is carried out within the “PYTHAGORAS II” research framework, jointly funded by the European Union and the Hellenic Ministry of Education.

#### REFERENCES

- [1] ETSI EN 302 304, *Digital Video Broadcasting (DVB): Transmission System for Handheld terminals (DVB-H)*, European Standard, v.1.1.1
- [2] M. Kornfeld and U.Reimers, “DVB-H - the emerging standard for mobile data communication”, *EBU Tech. Rev.*, No.301, January 2005
- [3] C. Rauch and W. Kelleler, „Hybrid Mobile Interactive Services combining DVB-T and GPRS”, *Proc. European Personal Mobile Communications Conference (EPMCC) 2001*, Vienna, Austria, February 2001.
- [4] E. Stare, “Hybrid Broadcast-Telecom Systems for Spectrum Efficient Mobile Broadband Internet Access”, [Online] Available: [http://www.s3.kth.se/signal/edu/seminar/01/Mobile\\_Broadband\\_Internet\\_Access.pdf](http://www.s3.kth.se/signal/edu/seminar/01/Mobile_Broadband_Internet_Access.pdf)
- [5] G. Gardikis, G. Kormentzas, G. Xilouris, H. Koumaras, and A. Kourtis, "Broadband Data Access over Hybrid DVB-T Networks", in *Proc. 3rd Conf. on Heterogeneous Networks (HET-NETs) '05*, Ilkley, UK, July 18-20, 2005
- [6] E. Stare, “Mobile reception of 2K and 8K DVB-T signals”, *Proc. Intl. Broadcasting Convention (IBC '98)*, pp.473-478
- [7] *IP Datacast over DVB-H: Use Cases and Services*, DVB Document A097, November 2005
- [8] *IP Datacast over DVB-H: Architecture*, DVB Document A098, November 2005
- [9] ETSI EN 301 192, *Digital Video Broadcasting (DVB); DVB specification for data broadcasting*, November 2004
- [10] ETSI TR 102 401, *Digital Video Broadcasting (DVB); Transmission to Handheld Terminals (DVB-H)*, Validation Task Force Report, 2005
- [11] G. Faria, J. Henriksson, et al, “DVB-H: Digital Broadcast Services to Handheld Devices”, *Proc. IEEE*, 94 (1), pp.194-209
- [12] The DVB Project Office, *DVB-H, the global mobile TV*, [Online] Available at <http://www.dvb-h-online.org>