Laboratory Tests for testing DVB-T2 mobile performance


Abstract—This paper presents DVB-T2 laboratory tests carried out for testing mobile reception.

The aim of this study is to analyze DVB-T2 technology in order to obtain system assessment on pedestrian and low speed mobile reception. Results provide first approximation about the influence of the new options included in the standard. Furthermore, they can provide noteworthy information for next trials planned to validate the best parameter set for handheld reception.

Index Terms—DVB-T2, Laboratory Tests, Mobile Reception, Terrestrial Digital Broadcasting.

I. INTRODUCTION

Increasingly, an important part of consumer multimedia services are based in reception on mobile portable or handheld terminals. Terrestrial handheld reception has been developed by European DVB project in DVB-H standard [1], taking a considerable weight in the world of digital broadcasting standards. DVB-H derived from the successful DVB-T standard improving DVB-T limitations for mobile signal reception [2].

In 2008, DVB project finalized the development of the second generation terrestrial transmission system DVB-T2 [3]. The two main drivers for development of the DVB-T2 standard have been HDTV (High Definition TV) and the switch off of analogue terrestrial broadcasting networks [4].

Moving from analogue to digital transmission enables better picture quality, more TV programs but also new types of services that could be transmitted using the DVB-T2 standard and new type of reception scenarios for these digital terrestrial signals, like mobile and handheld pedestrian reception scenarios. In fact, this new standard has been fundamentally designed for fixed reception (receiver devices with rooftop and set-top antennas). However, the DVB-T2 reception is also feasible in portable and mobile devices (PCs, laptops or in-car receivers).

The new standard includes improved techniques, such as rotated constellations, new modulation schemes, FFT sizes and guard intervals (GI). More configuration modes were also included in DVB-T2 comparing to its predecessor, some of them improving mobile/pedestrian reception of the signal.

Currently semiconductor manufacturers are implementing chips for the new specification, and some receivers have been recently presented in the UK according to the beginning of the first DVB-T2 transmissions at the end of 2009 in this country [5]. However, due to the recent approval of the standard, the technology available is still very immature, limiting the possibilities to make deeper studies at the moment.

This paper presents laboratory tests with DVB-T2 real signals and configuration modes to check system performance, and to narrow DVB-T2 configuration options for mobile and pedestrian reception.

II. DVB-T2 SYSTEM OVERVIEW

DVB-T2 adopted technical functionalities mainly from two legacy systems, DVB-T [2] and DVB-S2 [6]. OFDM modulation with guard interval was chosen as in DVB-T.

Compared to its predecessor DVB-T, the new system offers significantly improved performance in mobile channels. DVB-T2 system involves new physical layer for terrestrial broadcasting, providing lower C/N requirements and higher capacity [7], due to many new features that provide important configuration flexibility for mobile reception.

Improved performance is reached by several means such as a more powerful Forward Error Correction (FEC). Whereas inner and outer error-control coding in DVB-T was based on convolutional and Reed-Solomon codes, DVB-T2 uses concatenated LDPC/BCH coding, as for DVB-S2. These codes assure a better protection, allowing more data to be transported in a given channel.

Since this coding scheme greatly outperforms the performances of the FEC used in DVB-T, DVB-T2 also introduces a higher order constellation, 256-QAM, which increases the spectral efficiency and bit rate, although this new feature is not compatible with any mobile/pedestrian reception scenario. However, the flexibility of DVB-T2 offers other configurable parameters that could be usable for this purpose, like rotated constellations, the introduction of a flexible time interleaver, other new modulation schemes and larger range options in FFT sizes, bandwidths, guard intervals or pilot patterns. A correct choice of some of these parameters enables DVB-T2 mobile/pedestrian reception.

All these parameters allow many configuration modes,
providing different levels of protection and data rate for DVB-T2 signal. Some of them increase the robustness of the signal; others optimize data transmission capacity, and some combinations can be chosen to balance between robustness and transmission capacity. The DVB-T2 services and higher layer signalling data are transmitted in physical layer pipes (PLP) [3]. The new standard allows the transmission of multiple PLP at the same time, with different levels of coding, modulation, and time interleaving. So, separate streams with different protection levels can be transmitted simultaneously, for example, one service for mobile/pedestrian reception and other service for fixed HDTV reception.

III. LABORATORY TESTS PLATFORM AND MEASUREMENT PROCEDURE

Laboratory tests system presented in this paper is based on two PCI cards that provide transmission and reception support for DVB-T2 signals.

The transmission platform consists on a multi-standard PCI modulator with support for OFDM based modulation standards. DVB-T2 signal generator software provides complete single-PLP and multi-PLP DVB-T2 test-signal generation with full user control over the DVB-T2 parameters configuration. It supports input from Transport-Stream files or built-in O.151 PRBS test-signal generator.

Test platform also includes a fully-featured channel simulator with AWGN generator (with adjustable SNR), multipath fading, Rayleigh channels and Doppler simulation to accurately simulate propagation channels in mobile reception.

The reception platform consists on a VHF/UHF PCI receiver with DVB-T2 demodulation software. This software is a real-time application for demodulating DVB-T2, displaying signalling information and outputting a demodulated Transport Stream on UDP port for decoding and viewing services. Signal measurements provided by this reception tool are too limited for a deep research of the DVB-T2 system, but some values give helpful and usable information to evaluate the performance of the different parameters of DVB-T2 under mobile/pedestrian reception conditions. The CRC error number of L1 signalling information and the LDPC iteration statistics have been chosen for this purpose.

Bit Error Rate (BER) measurements are not provided with this reception system, so other measured values have been considered to evaluate the performance of the different parameters of DVB-T2 under mobile/pedestrian reception conditions. The CRC error number of L1 signalling information and the LDPC iteration statistics have been chosen for this purpose.

DVB-T2 frame consists of two types of preamble symbols, called P1 and P2, and data symbols [3]. The P2 symbols carry the L1 signalling. The L1-pre signalling, carrying information about how to decode the L1-post signalling, is mapped evenly onto the first sub-carriers of all P2 symbols. The L1-post signalling, carrying the information about the frame structure and PLPs, is mapped evenly onto the next sub-carriers of all P2 symbols. Therefore, number of CRC errors detected in this signalling information is significant to evaluate the performance of the DVB-T2 signal reception under mobile/pedestrian conditions.

The measurement procedure starts computing the frame length based on the number of data symbols, the FFT size, and the guard interval fraction. Then, the total number of possible CRC errors in 15 seconds is calculated for each different configuration.

CRC errors have been measured in 15 seconds time interval for a given SNR value. In each test, with number of possible total errors known and with the measured error number, the percentage of erroneous CRC is determined.

SNR can be chosen in the channel modelling application and matches with the measures given by the spectrum analyser in order to validate the results obtained by software. Each test starts with a value that does not cause errors, and reduces SNR ratio until receiver synchronization fails with the incoming signal.

This test methodology has been repeated for each parameter under evaluation to test the influence of the different configuration choices available on T2 physical layer to improve handheld reception. Table I summarizes the parameter set chosen for these laboratory tests.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>DVB-T2 PARAMETERS UNDER EVALUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFT size</td>
<td>1K, 2K, 4K and 8K</td>
</tr>
<tr>
<td>Guard Interval</td>
<td>1/128, 1/32, 1/16, 19/256, 1/8, 19/128 and 1/4</td>
</tr>
<tr>
<td>Pilot structures optimization</td>
<td>YES</td>
</tr>
<tr>
<td>Rotated constellations</td>
<td>YES</td>
</tr>
<tr>
<td>Reception scenarios</td>
<td>Typical Urban; Pedestrian Indoor; Pedestrian Outdoor</td>
</tr>
</tbody>
</table>

Data transmitted has been the O.151 PRBS test-signal. Transmission frequency has been 666 MHz in all cases.

IV. CHANNEL MODEL SELECTION

Traditionally, the channel models used for planning digital television broadcasting systems are intended to describe the rooftop antenna reception, portable indoor reception and mobile reception. For rooftop antenna reception a multipath static Ricean channel has been widely used and for portable reception a rather similar static multipath Rayleigh channel has been used. Both of these models are described in detail for example in the DVB-T specification [2].

Nowadays, there is one commonly used mobile radio channel model for DVB systems, namely the 6-tap Typical Urban channel (TU6). The channel model was designed for GSM in the COST 207 project [8]. In DVB-T/H developments the TU6 model was used for modelling mobility of the receiver. TU6 gave reasonable results even though bandwidths of GSM and DVB-T/H are very different. One apparent reason for using TU6 also in DVB systems development is that the frequency range is below 1 GHz in both systems.
In addition to TU6, CELTIC Wing TV project [9] proposed new channel models for handheld reception according to some measurement campaigns for DVB-T/H signals. These models were added to recommendation ITU-R BT.1368-6 [10]. These new channel models are the Pedestrian Indoor (PI), for slowly moving indoor reception, and the Pedestrian Outdoor (PO), for slowly moving outdoor reception. The models describe the radio channel behaviour in a dense Single Frequency Network (SFN) and receiver speed is expected to be below 3 km/h, which corresponds about 1.5 Hz Doppler at the middle of the UHF-band.

The Pedestrian Indoor and Pedestrian Outdoor models are Tapped Delay Line (TDL) models, with Doppler spectrum, amplitude distribution, and power delayed values specified for each tap.

In this paper, DVB-T2 mobile performance has been tested considering four different channel models. TU6 channel has been defined for mobile (50 km/h) and pedestrian conditions (3 km/h), called TU6_50 and TU6_3, respectively. PI and PO channels have been used considering 12 tap models, as proposed in [10].

V. EVALUATION OF THE INFLUENCE OF DIFFERENT DVB-T2 PARAMETERS IN MOBILE/PEDESTRIAN CHANNELS

This section presents the analysis of the influence of different parameters and configuration modes of DVB-T2 over mobile/pedestrian channels. This study supposes the first approximation to evaluate the performance of DVB-T2 transmissions in mobile/pedestrian reception conditions with real DVB-T2 signals. The following parameters have been tested:

A. FFT size

The possible FFT modes for DVB-T2 are 1K, 2K, 4K, 8K, 16K and 32K. 1K was included for flexibility in bandwidths and frequency, as the 1K FFT size is primarily intended to be used in the VHF band using a bandwidth of 1.7 MHz [7]. The 16K and the 32K modes were included to enable improved SFN performance and less overhead from the guard interval, enabled by the longer symbol period. These big FFT sizes do not match with the requirements for a correct mobile/pedestrian reception due to their vulnerability with the fast time varying channels and the Doppler effects expected in these scenarios. Therefore, the 16K and the 32K models are not considered.

In these laboratory tests 1K, 2K, 4K and 8K modes had been tested. In each case, to avoid the influence of the guard interval that ensures only the testing of the FFT size, the guard interval fraction (GIF) chosen for each FFT size is the one that maintains the same guard interval duration \( T_{GI} \) for selected FFT sizes. The GIF is the ratio between guard interval duration and total duration of the active symbol period \( T_{active} \). The duration of the guard interval ratio, chosen in terms of the elementary period \( T \), has been 256\( T \), because is the only one permitted for the FFT sizes selected. For 8MHz channel this duration is 28\( \mu \)s.

In the case of 1K FFT size it implies the use of GI=1/4; GI=1/8 for 2K; GI=1/16 for 4K and GI=1/32 for 8K. Measurements have been performed for TU6_3 channel with 16-QAM modulation for L1 signalling information over 8 MHz channel. The number of data symbols has been chosen to give payload bit rates of about 19 Mbps, close to typical 19.9 Mbps of Spanish DVB-T. In Fig.1 the performance of each FFT size is depicted in terms of CRC error rate of the L1 signalling, showing the evolution of the L1 CRC error rate for a given SNR value.

![Fig.1. FFT size influence evaluation for TU6_3 channel.](image)

B. Guard Interval

DVB-T2 offers seven possible guard intervals in order to support a range of needs of broadcasters. The possible values are 1/128, 1/32, 1/16, 19/256, 1/8, 19/128 and 1/4 [7]. However, as stated in former section, it is reasonable to distinguish two concepts, the guard-interval duration \( T_{GI} \), and the guard-interval fraction GIF. The former has the dimensions of time and the latter is dimensionless.

The guard interval duration concept has been used for FFT size analysis in previous section, and the guard interval fraction is studied in this section for testing its influence over received signals in the TU6_3 channel. The FFT sizes that allow the inclusion of all possible GIF values are 8K, 16K and 32K, so the chosen size has been 8K for its better performance over pedestrian channel compared to 16K and 32K. The chosen modulation scheme of the L1 signalling has been 16-QAM for all cases.

Fig.2 represents the evolution of the L1 CRC errors measured in fifteen seconds with the SNR value for each GI duration value.
Constellation rotation shall only be used for the common PLPs and the data PLPs and never for the cells of the L1. Due to receiver measurements constraints, that are focussed on the L1 signalling information, the estimation of the rotated constellation influence cannot be performed analysing L1 CRC errors. For these laboratory tests, the performance of the rotated constellation has been studied considering the LDPC iteration number provided by the receiver software.

Fig.2. GI duration influence for TU6_3 channel with 8K FFT size.

C. Channel model

Section IV described the channel models used in this study, which are Typical Urban at 3 km/h and 50 km/h, called here as TU6_3 and TU6_50, and the new Pedestrian Indoor and Outdoor channels defined by the Wing TV project, called here as PI and PO.

In order to evaluate the influence of the DVB-T2 system in different mobile and pedestrian reception scenarios, the measurement methodology is the same as in former sections. DVB-T2 parameters have remained fixed and the L1 CRC error rate versus SNR has been analysed for each channel model under study. Signal is configured with 2K FFT size, 1/8 GI duration, pilot pattern PP2, L1 signalling with 16-QAM and 3/5 code rate. This configuration matches with similar used for DVB-H signals and will allow future comparisons between both systems.

Fig.3 shows DVB-T2 performance results in each channel model, analyzing L1 CRC errors with increasing SNR values.

D. Modulation and rotated constellations

The improved FEC performance compared to DVB-T allows higher modulation schemes. In addition to QPSK, 16-QAM and 64-QAM, already used in DVB-T, DVB-T2 allows 256-QAM. Moreover, a completely new technique called rotated constellations was introduced. When constellation rotation is used, the normalised cell values of each FEC block are rotated in the complex plane and the imaginary part is cyclically delayed by one cell within a FEC block. Rotated constellations enable good performance in erasure channels, even in combination with high FEC code rates. They provide significantly improved robustness against loss of data cells in difficult channels. This can also be utilized to increase bit rate, by selecting a higher FEC code rate with less overhead.

Constellation rotation shall only be used for the common PLPs and the data PLPs and never for the cells of the L1. Due to receiver measurements constraints, that are focussed on the L1 signalling information, the estimation of the rotated constellation influence cannot be performed analysing L1 CRC errors. For these laboratory tests, the performance of the rotated constellation has been studied considering the LDPC iteration number provided by the receiver software.

Fig.4 shows the relation of SNR value with the LDPC iteration number for TU6_3 channel at 3 km/h and for TU6_50 channel at 50 km/h.

VI. CONCLUSIONS

In terms of FFT size, as expected, results provides better performance with 1K and 2K FFT sizes for low SNR values below 15 dB, compared with 4K and 8K FFT sizes. For better conditions the behaviour is similar. The break point that supposes an exponential increase of errors is about 15 dB for all cases.

The different GI values studied have shown expected behaviour. New 1/128 GI duration included in DVB-T2 is clearly worse than others. Its use is recommended to improve data rates in fixed reception but not for low speed mobile reception. The protection offered by the higher values of GI is
most evident in this type of reception. The break point is also close to 15 dB value for SNR.

The different channel models tested show that the best performance is obtained for the TU6 mobile channel at a medium speed of 50 km/h (TU6_50). The comparison between the TU6 model at 3 km/h (TU6_3) and the pedestrian outdoor model (PO) shows better performance of TU6_3 under 13 dB and the opposite situation above 13 dB. These results could be related to the interleaving time, which is no too long and so the receiver works better over fast varying channels. Interleaver length should be analysed and optimized to improve reception over slower varying channels.

Finally, results from rotated constellations analysis show small benefit in the usage of this technique for mobile/pedestrian scenarios, as the number of LDPC iterations to correct the errors at the receiver is very similar using or not using this technique. Anyway, deeper research should be done in this way to validate results provided analysing LDPC iterations.

REFERENCES


[9] EUREKA/CELTIC WingTV Project web site [http://projects.celticinitiative.org/WING-TV/].