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Performance of DVB-T2 improvements over low Doppler mobile channels

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Abstract— This paper addresses the simulation and the detailed analysis of some performance indicators and graphics of the changes in channel coding and modulation envisaged for DVB-T2. Results are given not only for ideal (Gaussian) or static (F1/P1) channels, but also for classical mobile channels (TU6) for low Doppler frequency (around 10 Hz). Finally the effects of implementing a channel (pilot) estimator (and interpolator) in both time and frequency domains have been analyzed and compared with one domain estimators (and interpolators).

I. INTRODUCTION

We had already described in a previous paper [1] the envisaged changes in DVB-T2 with respect the previous DVB-T standard, the most remarkable being: the applicability to fixed, portable and mobile communications, a capacity increase (to endure with HD-TV) and a higher coverage area. These facilities will be mainly achieved through changes in modulations, codes, pilot structure, OFDM number of sub-carriers and probably with the introduction of MISO/MIMO schemes.

In this previous paper we also described in detail the simulator scheme [2] and analyzed the improvements of increasing the modulation order, as well as reducing the number of pilot sub-carriers, but the results were only given for Gaussian an F1(Rician)/P1(Rayleigh) channels, because this are the models suggested in DVB-T ETSI document [2].

Now we have completed the simulations with the inclusion of:

- Typical Urban (TU6) channel performance, able to support any Doppler frequency. Anyway in the simulations we have considered only low speed terminals (15 km/h maximum).
- The replacement of Red Solomon and Convolutional codes by BCH and LDPC.

Also the improvement using a two domain channel estimator (for both frequency and time) is given, when compared with the simplest estimator only in one domain.

We will not describe again the simulation platform, nor the different blocks implemented. We are interested in focusing this presentation just in showing and comment the main results of our work.

II. RESULTS

a. 1D/2D channel interpolation

In DVB-T the pilots are distributed in a 2D-grid at different time and frequency locations and in a diagonal ways as can be appreciated in Figure 1. Pilot sub-carriers are transmitted at a higher power (normalized 1.3(pilot)/1(signal)). Probably new pilot structure will be proposed for new DVB-T2 standard, but at the moment there is no public information about propossals, so we have decided to maintain the actual structure, but improving the way we perform the data sub-carriers estimation.

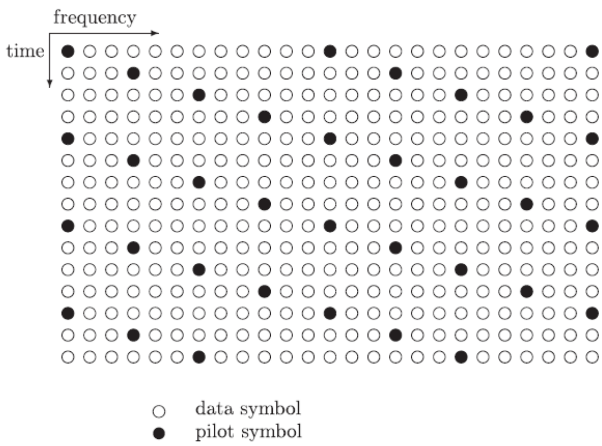

Figure 1 Pilot structure

The channel fading is extracted at the receiver at the pilot symbol locations. The channel behaviour at the data symbols can be estimated by interpolation. This interpolation can be done in two ways [3]

- Only in the frequency domain: for each OFDM symbol we will have several estimated sub-carriers (pilots) and the other sub-carriers are estimated through interpolation.

- Perform a 2-D interpolation, first in time direction (through several OFDM symbols, being the considered interpolation depth equal to 6 in our simulations), and tacking the interpolated values as if they were new pilot symbols, so we could in the limit say that we have “estimated the channel each three sub-carriers”

Figures 2 and 3 show the differences obtained when using different schemes for channel estimation and interpolation for 64QAM and 16QAM respectively.

- ideal pilot estimation and 1D or 2D interpolation for data sub-carriers.
- real pilot estimation (noise is considered) and then 1D or 2D interpolation for data sub-carriers.

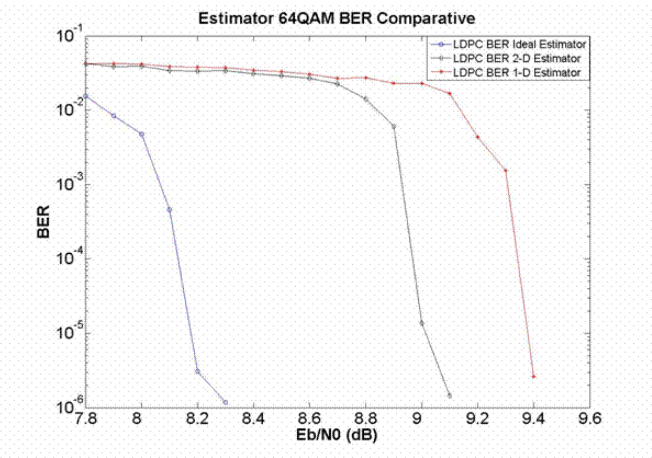

Figure 2: Comparative of channel estimation schemes for F1 channel model

It can be appreciated that the difference between ideal estimation and real ones is around 1.2 dB in Eb/No (an increase of around 1.2 dB is required to maintain BER) for one dimension pilot estimation, while it is reduced to 0.8 dB for two dimension pilot estimators.

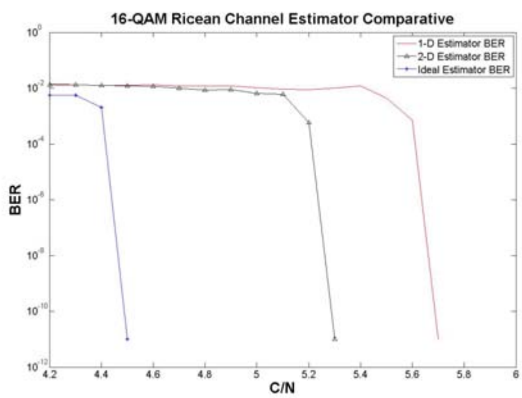

Figure 3: Comparative of channel estimation schemes for F1 channel.

There is again an improvement of around 0.3-0.4dB when using 2D interpolation.

Finally it will be interesting also to represent the effect of different Doppler frequencies, because probably there will be a hug difference between using 1D or 2D interpolators for large coherence time, but these differences will reduce as coherence time decreases.

b. LDPC

As for the LDPC codes we decided to implement the same structure as in DVB-S2 standard, this is a [32400,64800] LDPC code [4]. This is combined with a [752,762] BCH code which is the one given for the Chinese DVB standard [5]. In table 1 there is a comparison of required C/N between RS-convolutional codes and BCH-LDPC for F1 channel (QEF, code rate 1/2, guard period 1/4)

Modulation	RS-Viterbi	BCH-LDPC	Difference
QPSK	3.6 dB	1.7 dB	1.9 dB
16QAM	9.6 dB	4.7 dB	4.9 dB
64QAM	14.7 dB	8.2 dB	6.5 dB

Table 1: Comparison of required C/N for QEF, cyclic prefix 1/4 convolutional code rate 1/2 (F1 channel, ideal estimation)

We can appreciate that there is a considerable reduction in the required Eb/No value. As from now on, all the results of this paper will be given by the combination of LDPC and BCH codes, we feel it is not necessary to analyze in more detail their performance now.

c. TU6 channel

Mobile radio channel is considered as a time-varying multipath fading channel, modelled by a tapped delay structure where each path is and independent Rayleigh random process with a maximum Doppler frequency shift (GWSSUS). We have considered that the channel remains constant during a symbol, but fluctuates between consecutive symbols according to the chosen Doppler frequency. Number of taps as well as relative powers and delays can be changed, but for the simulations we have used the values suggested for the TU6 model. This is a pessimistic channel when compared with the models that have been traditionally used in DVB mainly for two reasons: mobility forces a time-varying system, and there is no LOS path. In our programme the K factor is defined for each path, so the way to simulate a Rice component is trivial (just choosing a large K for the first path).

Tables 2.a, 2.b and 2.c show the required C/N over QEF condition when using BCH+LDPC codes, for different modulations and for different pilot estimation schemes; they summarize the results for Gaussian, Rice (F1) and TU6 Channels. In the case of TU6 we have considered a terminal speed of 15 km/h (around 10 Hz of Doppler). To have consistent results and eliminate fluctuations in BER, both 1000 errors should be counted and 30 coherence periods should be simulated. (for low Eb/No 1000 errors are produced immediately, so we should wait until 30 coherence periods have passed, while for large Eb/No is the opposite, we have to wait more than 30 coherence periods, because what is difficult is to obtain 1000 errors).

Several simulations in parallel are launched to the computers, but even in this case the large number of bits that have to be processed, causes that at the time of finishing this paper not all the simulations were finished. For this reason there are some holes in the tables that we expect could be filled soon.

C/N(dB)	Gaus(ideal)	Gaus(1D)	Gaus(2D)
QPSK	1.3	2.3	2
16QAM		5.3	5
64QAM		9.1	8.8
256QAM		12.6	12.2

2.a Gaussian channel

C/N(dB)	F1(ideal)	F1(1D)	F1(2D)
QPSK	1.7	2.8	2.5
16QAM	4.7	5.7	5.3
64QAM	8.2	9.4	9.1
256QAM		13	12.5

2.b Rician Channel

C/N(dB)	TU6(ideal)	TU6(1D)	TU6(2D)
QPSK	10.7		
16QAM			
64QAM	13.8		
256QAM	15.6		

2.c TU6 channel for 15 km/h

Table 2: QEF C/N for LDPC+BCH and different channel models.

We can appreciate again the advantages of using 2D interpolator, as well as the degradation that mobility introduces to the system. Also the large increase in required C/N values when mobility is considered.

d. Other results

Figures 4 and 5 represent the detailed evolution of the BER as function of the C/N values for 256 QAM (which is considered only for the evolution of DVB-T, not for the running standard) and for two channel models Gaussian and F1 channel. In these figures it has been represented the BER evolution without considering the codes (OFDM BER), then the improvements given after the LDPC decoder (without considering BCH) and finally the BER after the BCH decoder.

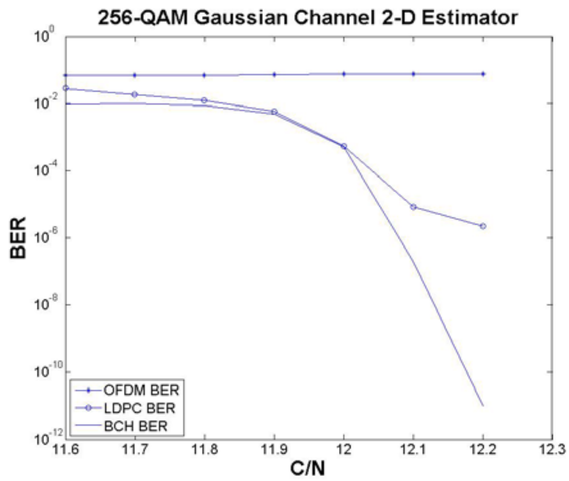

Figure 4: complete simulation of 256QAM performance over Gaussian channel

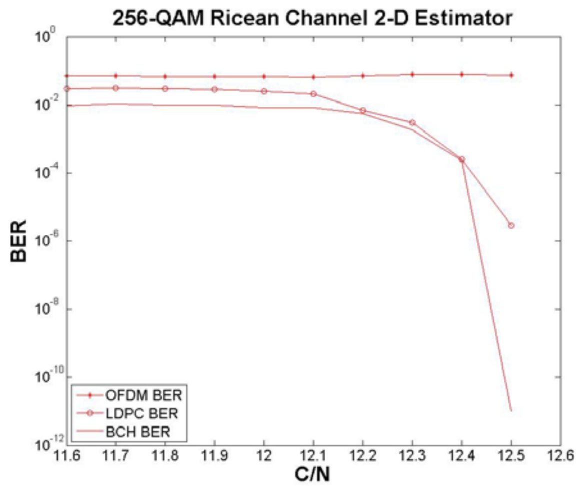

Figure 5: complete simulation of 256QAM performance over Gaussian channel

The last two figures are devoted to represent the comparative between Gaussian, F1(Rician) and TU6 in terms of BER. The values given in table 2 are extracted from this analysis; as we can see there is a hug increase in the required C/N to maintain the BER to 10^{-11} which is the quality requirement for DVB-T and DVB-T2 standard. Figure 6 is for QPSK modulation while Figure 7 is for 256QAM.

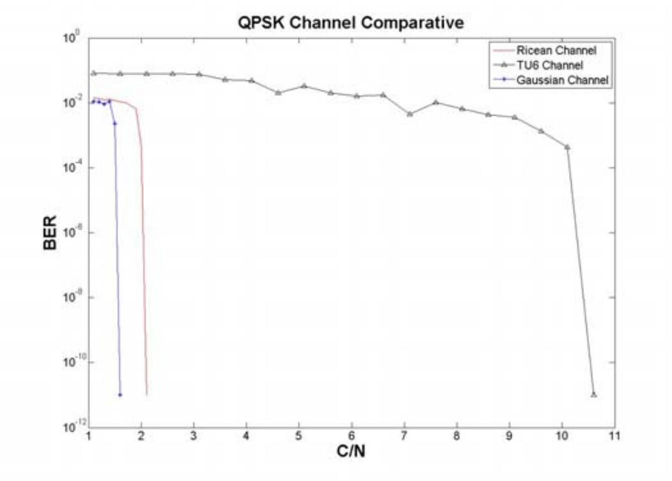

Figure 6: channel comparative for QPS modulation

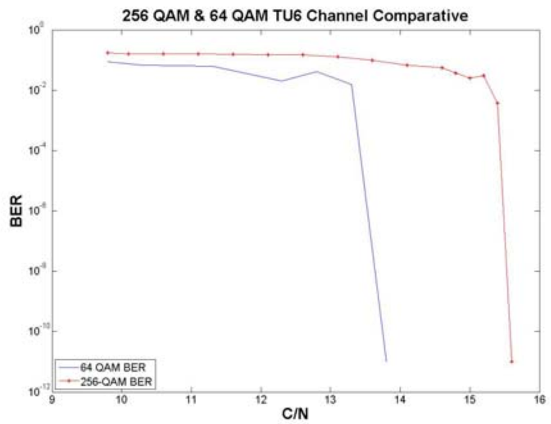

Figure 7: channel comparative for 256QAM

e. Future work

In the near future we expect to finish all the simulations to complete this study. We also expect that some information about the new standard is already made available so we can adapt our simulator to the new constraints. Meanwhile we have already started to introduce MISO/MIMO schemes (2x1 and 2x2).

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