Performance of the Rotated Constellation in DVB-T2

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***Abstract*—This short paper deals with the performance of the rotated constellation, which is one of the main innovations in the DVB-T2 (Second Generation Digital Terrestrial Television Broadcasting) standard. Rotated constellation is an optional feature to improve performance in frequency selective channels. This paper contains the present and progress results of the rotated constellation performance. For the determination of differences between the non-rotated and rotated constellation, a 0 dB Echo channel model was used. Graphical dependences of the BER before and after LDPC coding are given. Finally, achieved results are evaluated and discussed with promising expectations of a very good performance of rotated constellation technique in DVB-T2.**

Keywords-DVB-T2; LDPC coding and decoding; rotated constellation; 0 dB Echo channel; BER

I. INTRODUCTION

Nowadays, DVB-T2 (2nd Generation Digital Terrestrial Television Broadcasting) standard is definitely the world's most advanced DTT (Digital Terrestrial Transmission) system, which offers robustness and high efficiency for terrestrial broadcasting [1]. It is built on the technologies used as part of the first-generation system (DVB-T), developed over a decade ago. DVB-T2 extends the possibilities of all parameters of DVB-T and significantly reduces overhead to build a system with a throughput close to theoretical channel capacity [2], [3].

DVB-T2 specification includes many innovations in system parameters. The combination of LDPC (Low Density Parity Check) and BCH (Bose-Chaudhuri-Hocquengham) codes give a very robust channel coding. Moreover, several options are available in areas such as the number of carriers, GI (Guard Interval) sizes and pilot signals. Therefore, the overheads can be optimized for any target transmission channel [1]- [3]. The advanced coding and interleaving techniques [2] offer good performance in so called non-selective channels. However, frequency selective channels (with deep fadings) need extra redundancy, previously given by a lower-rate code.

DVB-T2 also includes a novel technique of constellation, so called rotated constellation, which is one of the main innovations in DVB-T2 system configuration. It is an optional feature to improve performance even for very frequency selective channels [3]. The technique of the rotated constellation and the idea of its use in communication systems are not new. This method has been studied since 1997, when Giraud et al. presented the lattice constellations for the Rayleigh fading channel [4].

After then, in [5] an alternative diversity technique for Rayleigh fading channel was presented, which was achieved by the high diversity modulation schemes (rotation of constellation points). Now, the exploring of the possibilities of rotated constellation technique was used for the improving of the DVB-T2 system performance. In [6] and [7] the rotated constellation technique has been analyzed in terms of BER (Bit Error Ratio) evaluation. For the exploring of its performance a Rayliegh (P1 channel) and RME (Rayleigh Memoryless Erasures) [2] fading channel models were used. On the other hand, the appropriate design of the rotated demapper on the receiver side is very important [8]. When rotated constellation is not used, the LLRs (Log Likelihood-Ratios) soft decision metrics can be derived in the normal, one-dimensional way [2], well known from DVB-T. In case of rotated constellation the 2D LLR demapping is used. In [9] a very promising solution of this problem was presented, where a novel detection method (QAM detector) also reduces the demand of the computational resources.

In this work in progress paper, the investigation is focused on the performance of the rotated constellation in DVB-T2 standard from the perspective of transmission distortion in frequency selective channels. To demonstrate simply transmission distortions, a two path, 0 dB Echo channel was used [2]. Moreover, this article proposes and evaluates a configuration that has been optimized for the mentioned channel conditions.

The rest of the paper is organized as follows. After the introduction and related state-of-the-art works review in the area of rotated constellation, a brief description of the main differences between the non-rotated and rotated constellation techniques is presented in Section II. The parameters and short description of used channel model for the analysis and simulation are presented in Section III. Section IV contains the graphical dependences of the BER before and after LDPC decoding on C/N (Carrier-to-Noise Ratio) ratio for both, non-rotated and rotated constellation modes. Finally, the results are evaluated and discussed in Section V.

II. NON-ROTATED AND ROTATED CONSTELLATIONS

A. Non-Rotated Constellation

A constellation diagram is a representation of a signal modulated by a digital modulation scheme, such as QAM. In DVB-T2 standard, it is a selection from QPSK, 16QAM, 64QAM or 256QAM modulation. In a classical, non-rotated

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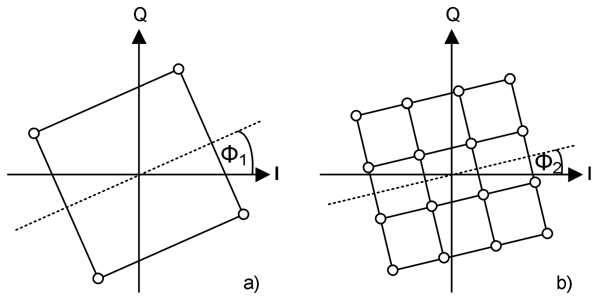

Figure 1. A theoretical rotated constellation diagram for a) QPSK with Φ_1 and b) 16QAM with Φ_2.

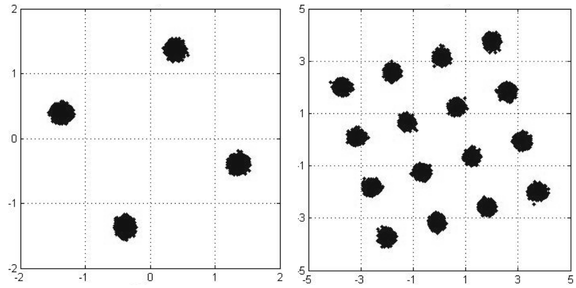

Figure 2. A simulated rotated constellation diagram for a) QPSK with Φ_1=29.0 and b) 16QAM with Φ_2=16.8 in AWGN channel with C/N = 20 dB.

constellation, the receiver needs both I (In-Phase) and Q (Quadrature) components of one constellation point to identify, which information was transmitted. The reason is that the estimation of I component does not give information about a Q component [6].

B. Rotated Constellation

As it was mentioned before, DVB-T2 standard introduces a novel technique to improve performance in selective fading channels. In case of the rotated constellation (see Fig. 1), a certain rotation angle is applied in the complex plane to a classical signal constellation. Then each component (I or Q), has enough information by its own to guess, which was the transmitted symbol [6]. Of course, the performances gain, in case of this technique, depends on the rotation angle. These angle values are different for each type of modulations in DVB-T2 and their exact value (see Fig. 2) can be found in [2].

Of course, only the rotation of constellation points is not enough for achieving a good performance. The additional innovation, and also the trick, is that the rotated constellation comes with Q-delay (after the constellation mapping). Delay means in this context that the Q components are shifted to the next COFDM (Coded Orthogonal Frequency Division Multiplexing) cell. This cyclical delay is realized on the level of individual FEC (Forward Error Correction) blocks [7], [10]. Thank to the combination of rotated constellation and Q-delays, I and Q components are now separated by the interleaving process (in cell, time and frequency) so that in general they are transmitted on different frequencies, different carriers and at different time. Therefore, if the channel destroys one of the components (I or Q) the other component (Q or I) can be used to recover the information [2].

III. SIMULATION PARAMETERS

A brief description of two constellation techniques for DVB-T2 broadcasting standard was presented in the previous section. Due to the innovations in constellation mapping, DVB-T2 standard enables to improve the performance of data reconstruction on the receiver side, when the transmission conditions contains a lot of fadings. For the comparison of differences between the mentioned constellation techniques, we used a special type of fading channel, 0 dB Echo, well known from DVB-T.

The 0 dB Echo channel profile has been defined by Motivate partners [2]. Its composition has been largely influenced by the nature of the DVB-T/T2 signal. Concretely, it is defined by the following parameters:

- Spread spectrum technique - introducing ICI (Inter Carrier Interference) sensitivity to Doppler spread,
- Guard Interval - introducing IS (Inter Symbol) sensitivity to the echo delays.

This profile is made of two paths, having the same power (0 dB). These echoes are delayed by half of the GI value and they are presenting a pure Doppler characteristic [2]. The general graphical representation of the impulse and frequency response of 0 dB echo channel is shown in Fig. 3 and Fig. 4. The *Tg* is representing the value of the GI.

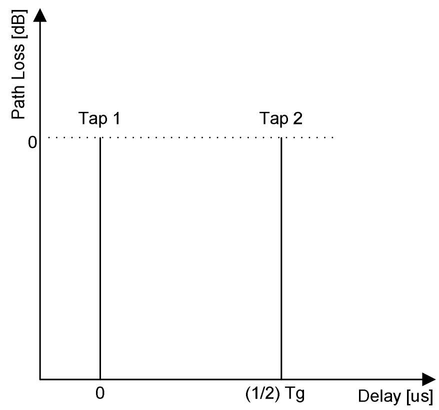

Figure 3. Impulse response of a 0 dB Echo channel.

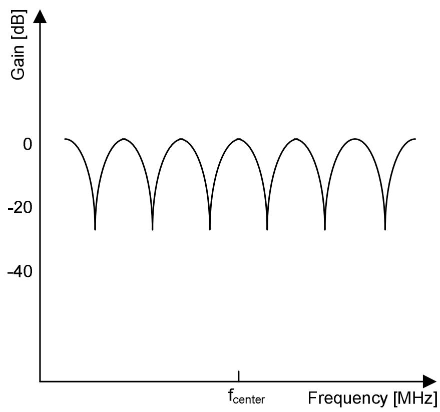

Figure 4. Frequency response of a 0 dB Echo channel.

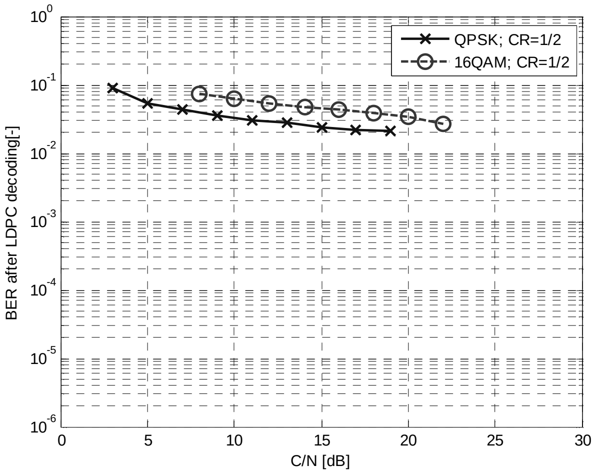

Figure 5. BER before LDPC decoding as a function of C/N ratio in the "0 dB Echo" channel (QPSK and 16QAM – non-rotated constellation, 2k mode, CR 1/2 and GI 1/16).

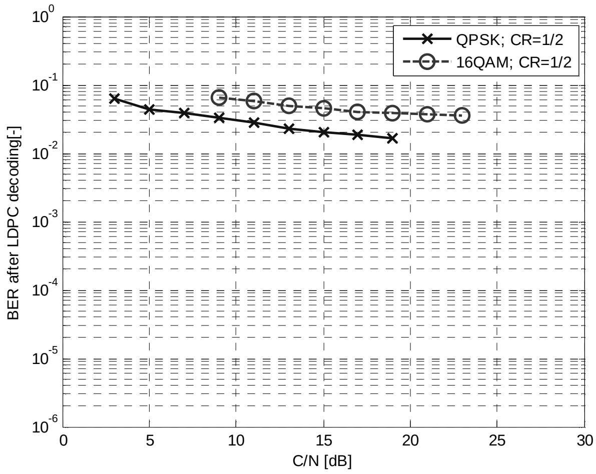

Figure 7. BER before LDPC decoding as a function of C/N ratio in the "0 dB Echo" channel (QPSK and 16QAM – rotated constellation, 2k mode, CR 1/2 and GI 1/16).

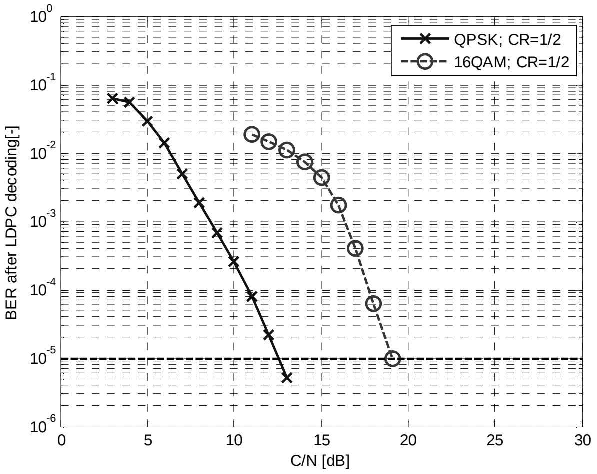

Figure 6. BER after LDPC decoding as a function of C/N ratio in the "0 dB Echo" channel (QPSK and 16QAM – non-rotated constellation, 2k mode, CR 1/2 and GI 1/16).

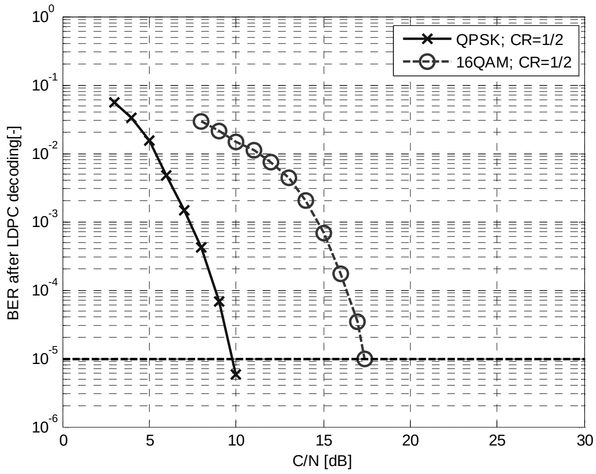

Figure 8. BER after LDPC decoding as a function of C/N ratio in the "0 dB Echo" channel (QPSK and 16QAM – rotated constellation, 2k mode, CR 1/2 and GI 1/16).

The implementation of functional model for the simulation of DVB-T2 transmission in MATLAB was done as it is recommended in [2]. For the simulation of the DVB-T2 transmission the following settings were used:

- mode: 2k (mobile reception),
- LDPC code ratio: 1/2 (robust protection),
- modulation: QPSK and 16QAM,
- constellation: non-rotated and rotated,
- rotation angle [Φ]: 29.0 (QPSK) and 16.8 (16QAM),
- Guard Interval: 1/16 (mid SFN - Single Frequency Network),
- decoding method: LDPC + BCH (with 50 iteration, as recommended in [2]).

IV. SIMUALTION RESULTS

Simulation results of the DVB-T2 transmission for various C/N ratios in the 0 dB Echo fading channel were obtained. The simulation was done for two types of constellation technique: rotated and non-rotated.

DVB-T2 uses concatenated LDPC + BCH coding, the same as in DVB-S2 (2nd Generation Satellite DVB). These codes assure better protection, allowing more data to be transported in a given channel. It means that, for achieving a good signal quality (low BER); a lower C/N ratio is needed. In this paper, the limit of the error-free reception is considered as C/N for which BER is equal to 1.10^{-5} after LDPC decoding, as it is used in [6]. The number of iterations in LDPC decoding is depending on the hardware complexity of the receiver. In this paper, the number of iterations is equal to fifty (50) as recommended in [2].

TABLE I. COMPARISON OF THE SIMULATED RESULTS *C/N* FOR THE *BER* EQUAL TO10^{-5} IN 0 DB ECHO CHANNEL

Modulation	Configuration	Non-Rotated Constellation C/N [dB]	Rotated Constellation C/N [dB]
QPSK	2k mode CR_{LDPC} = 1/2 GI = 1/16	13.2	9.8
16QAM		19.3	16.5

As mentioned above, for the comparison of the performance of the non-rotated and rotated constellation 0 dB Echo channel was used. This type of channel is the worst case channel, which consists of two paths, with equal level and the second arriving later than the first as shown in Fig. 3. In this paper, we used configuration for the mobile scenario (2k mode) with mid size (GI = 1/16) of the SFN network. Therefore, the delay of the second path is equal to 7 us. Moreover, for the increase of the fadings in the channel, the speed of the receiver was set to 50 km/h.

Fig. 5 and Fig. 7 illustrate the BER before the LDPC decoding for QPSK and 16QAM modulations, when non-rotated and rotated constellation techniques were used. In these figures the effect of 0 dB echo fading channel can be observed. The BER decreases with the increased C/N ratio only slightly. The BER before the LDPC decoding (not corrected data) in both cases of non-rotated and rotated constellation are very similar. As can be seen, at this point, the performance of the non-rotated and rotated constellation is almost the same and any significant differences can not be found.

On the other hand, visible differences in achieved BER can be seen after the LDPC decoding, which are shown in Fig. 6 for non-rotated constellation, for rotated constellation in Fig. 8. In case, when we are using non-rotated constellation, for achieving a 1.10^{-5} BER it is needed high value of C/N ratio: 13.2 dB for QPSK and 19.3 dB for 16QAM modulation (see Tab. I). In case of rotated-constellation these values are 9.8 dB for QPSK and 16.5 dB for 16QAM modulation.

It should be noted that the maximum gain is obtained, when QPSK modulation with rotated constellation was used. This can be easily explained, since this modulation is the most robust to fadings. On the other hand, in comparison with classical constellation technique, the gain was better by 3 dB for both types of modulations, when the rotated-constellation technique was used.

V. CONCLUSIONS AND FUTURE WORKS

In this paper, the performance of the rotated constellation for DVB-T2, with comparison of non-rotated constellation, was explored. It has been shown that for fading channels with very bad conditions, a good performance can be obtained with rotated constellation. On the other hand, only the features of rotated constellation are not allowed for achieving a good signal quality. Unconditionally, the mentioned innovation of FEC coding/decoding, which is used in DVB-T2, has a significant role. Thank to the number of decoding processes (50 iterations in this simulation), which is used in this paper, the results in the special 0 dB Echo fading channel are much better. This advantage of DVB-T2 standard also improves the BER ratio in the fading channel [11]. The additional robustness can be used to increase the data rate by choosing a higher code rate while keeping the same minimum field strength.

This work will continue in the future by improving the rotated constellation technique for the analysis and simulation the transmission distortions in all possible scenarios, which can occur in DVB-T2 system configurations [12]. The work will be also focused on the investigation of the performance of rotated constellation in, so called, erasures channels. In case of DVB-T2 this is the RME channel [2]. Finally, the MER (Modulation Error Ratio) for both constellation techniques should be investigated deeper.

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