Performance Enhancement of FEC Code For DVB-T2 System by Using Rotated Constellations

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***Abstract*—This paper deals with the rotated constellations technique's performance, which results in additional diversity to enhance Bit Interleaved Coding and Modulation (BICM) in various fading channel environments that improve the overall Digital Video Broadcasting Terrestrial Second Generation (DVB-T2) gain. The rotated constellation's performance gain has been analyzed by comparing each case of using a non-rotated constellation. In this comparison, three constellation types have been used: QPSK, 16-QAM, and 64-QAM, with all available six code rates supported by the DVB-T2 system. The simulation has been performed in MATLAB version R2020b under various fading channels such as Gaussian, Ricean, Rayleigh, and 0 dB Echo to illustrate the effectiveness of the described technique. Finally, obtained results show an outstanding improvement in DVB-T2 performance when employing rotated constellation in terrible fading environments by choosing a particular parameters configuration.**

Keywords*—*DVB-T2, Rotated Constellations, Cyclic Q Delay, OFDM, Fading Channels

I. INTRODUCTION

The alternative to decommissioning analog broadcasts in Europe was the first-generation European standard for providing Digital Terrestrial Television (DTT); this standard is called Digital Video Broadcasting Terrestrial (DVB-T) [1]. DVB-T introduces a new range of frequencies located in the band of Ultra-High Frequency (UHF). It provides unique services like High-Definition broadcast (HD), on-demand video, and handheld Television (TV) [2]. DVB-T was the most widely DTT that supplies terrestrial air services for different countries worldwide [3]. The increasing demand for broadcasting services is continual, and these services required a more efficient broadcasting system. DVB-T was limited by frequency capacity, so a new standard was needed to accomplish market demands by boosting the spectral efficiency to carry additional services [4]. DVB project introduces the development of DVB-T known as DVB-T2 [3]. DVB-T2 technology has the features of being the world's most developed DTT system, where it presents a terrestrial transmission system with high performance and good broadcasting robustness. DVB-T2 can increase channel capacity over different terrestrial environments, which considers another good point for the DVB-T2 standard [5]. DVB-T is used as base technology in building the DVB-T2 system, where it's passed through specific developing steps. DVB-T2 uses all available concepts for the DVB-T standard to minimize overhead to produce a new transmission technology with an output approach to theoretical channel capacity. The most prominent advantage of DVB-T2 is the ability to boost DTT capacity [6]. Compared with DVB-T, DVB-T2 can obtain a more net data rate with 30% to 67% higher and achieve preferable suitability with handheld usage. Many different applications need high data throughput and require a system to be rugged with variable mobile circumstances. DVB-T2 standard benefits when dealing with impulsive and multipath interference than the old DVB-T mode [5]. The fixed reception mode is the basic layout of the DVB-T2 standard. It can also deal with mobile and portable applications if a compatible specification is utilized [6]. This work aims to test the behavior of the DVB-T2 standard when applying the rotated constellation technique. To do this, the performance gain from employing rotation is obtained and compared with the non-rotation case. Several fading channels have been presented in the simulation, such as Additive White Gaussian Noise (AWGN), Ricean, Rayleigh, and 0 dB Echo channels. Furthermore, this research evaluates the parameters configuration that produces optimal performance suitable for each channel's conditions. After presenting the introduction in section I, the paper is organized as follows: Section II demonstrates a description of the DVB-T2 standard and its specifications and a review of the attached techniques and their developments over the DVB-T system. In section III, the concepts of the constellation rotation and cyclic Q delay techniques are explained. Section IV represents a description of the fading channels models that are employed in this simulation. Section V indicates the discussion and simulation results. Finally, in section VI, the conclusions are summarized.

II. DVB-T2 SYSTEM SPECIFICATIONS

There are several essential differences between DVB-T2 and the base standard DVB-T. These differences make the standard flexible regarding transmission robustness in many terrestrial circumstances and allow the new standard to operate with a high capacity [1],[7]. The several improvements introduce by DVB-T2 are recent Forward Error Correction (FEC) coding to fulfill an achievement close to the AWGN channel capacity, modulation techniques, guard intervals, Fast Fourier Transform (FFT) sizes, new pilot patterns, multiple antenna technologies, constellations rotation, and cyclic delay schemes [8]. DVB-T2 presents many other parameters and optional features like interframe and subslicing interleaving. Fig. 1 below shows the high-level DVB-T2 system block diagram [2]. DVB-T2 system employs Low-density parity-check (LDPC) concatenated with Bose Chaudhuri Hocquengham (BCH) codes. This concatenation scheme gives the system enough protection ability versus noise and interference. They present superior achievement producing a signal that has a robust reception scheme in different broadcasting environments. A significant capacity increasing considered as another main advantage obtained from using the developed FEC [9].

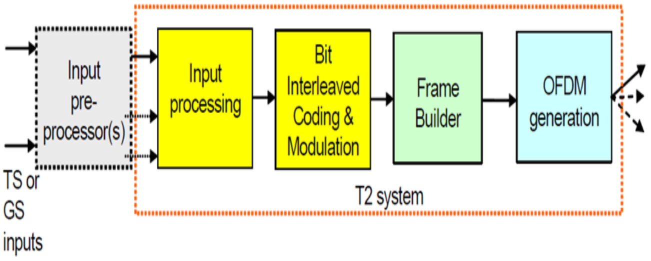


Fig.1. High-level DVB-T2 block diagram

The second-generation standard uses four types of interleavers arranged in cascaded orders. These four types are called a bit, cell, and frequency interleavers. The essential purpose of cascaded stages is to minimize and reject burst errors that directly affect each FEC frame as random error patterns [5],[10]. The high data rate presented by any communication system is highly limited by multipath interference in various channel environments. An attractive technique should be applied to overcome this issue, such as Coded Orthogonal Frequency Division Multiplexing (COFDM). Terrestrial DVB systems use OFDM technology to minimize multipath interference [11]. COFDM supplies a low complex and efficient scheme to decrease intersymbol interference during broadcasting over the fading of frequency selective channels. The system supports a new 256 Quadrature Amplitude Modulation (QAM) modulation mode, which permits the data cells to carry more bits, enhancing system rate and spectral efficiency [8].

In DVB-T2, COFDM employs 16K, 32K carriers mode with long symbols to increase transmission capability without affecting the system spectral efficiency [3],[12]. DVB-T2 system supports two kinds of carriers' scheme, regular and extended modes. The COFDM symbols can employ more carriers using extended carriers mode, which gives a significant capacity increasing [8],[9]. In addition to the OFDM scheme, DVB-T2 is characterized by several advanced specifications that made it suitable to improve the system performance in the fading environment. Constellation rotation and cyclic Q delay are considered the most developed specifications [1],[13]. System robustness can be enhanced because when a particular effect happens to the data within one channel component, the second component can quickly regain the damaged data. According to this specification, the information is mapped using QAM and then rotated in an I-Q plane. The parts of the I-Q plane are transmitted with several time slots and cells [14].

DVB-T2 model employs scatter pilot patterns to recover channel variation as an effect of frequency and time. There are eight possible patterns for scattered pilots, the selection among them based on guard interval and FFT to increase the payload of data [10]. Physical Layer Pipes (PLPs) allows the individual service to have a particular modulation with various protection and robustness levels. The DVB-T2 modes support multiple PLPs transmission. One or several data streams to be carried in a single PLP with different parameter selection such as mapping order and code rate [15].

III. ROTATED CONSTELLATIONS AND Q DELAY

In base or typical constellation schemes, the constellation point is represented by both quadrature Q and in phase I components, where these two components are used to recognize the transmitted data. The receiver side requires discovering the two parts because the Q component's estimate has no idea about the I component and vers-versa. In a typical constellation, the two pieces are exposed to the same fading effect as the signal travels through the channels [12][16].

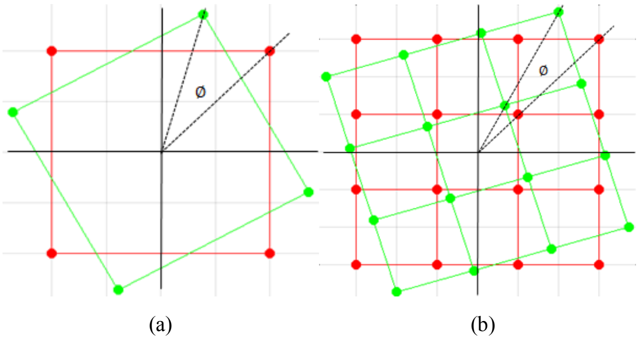


Fig.2. Non-rotated and rotated constellations (a) QPSK (b) 16-QAM

In the new constellation rotation technique, the complex plane is rotated by applying a specific rotation angle to the classical one. Each I or Q component has the individual right information to estimate the transmitted symbol [2],[17]. The base and rotated constellations are illustrated in Fig. 2 (a) with QPSK and (b) for 16-QAM constellation examples. The rotation angle values used according to each modulation type are (29^{o} for QPSK, 16.8^{o} for 16-QAM, 8.6^{o} for 64-QAM, and 3.6^{o} for 256-QAM) [5],[18].

The intended performance cannot be achieved using only the constellation rotation; however, an extra invention called Q cyclic delay is applied. The delay denotes that the Q component's status is shifted to the upcoming cell of COFDM [19]. This shift is done cyclically and achieved individually in the FEC levels. The interleavers separate the Q and I components into three stages, cell, time, and frequency. With this process, the parts are sent with various carriers, time slots, and frequencies [20]. Thus, if one component is lost during channel conditions, the second one is used to get back the Contents. Besides, the interleaving operations allow the I and Q components to be separately affected by fading. In very frequency selective channel profiles, the receiver robustness is boosted by applying the rotation and delay features [12],[21].

IV. CHANNELS MODELS

In this work, four types of channel fading models are used with the DVB-T2 system. Several conditions determine the fading channel models during the reception. Each fading model has a different signal path, delay, attenuation, Doppler frequency, and phase shift. The first channel model is AWGN, consisting of a single path with Gaussian noise only. The best signal quality can be received with this model, but the terrestrial system is not only affected by this model. The second channel model considered in the simulation is the Ricean channel. This channel, also known as the F1 channel, represents a fixed outdoor model's receiving conditions. This model does not contain Doppler frequency impact. The model has one component in the direct path, and 21 other paths have a different delay, attenuation, and phase shift. The third channel model is the Rayleigh channel, characterized by no direct path of the transmitted signal and heavy multipath. This model presents the portable outdoor or indoor channel conditions known as the P1 fading channel model. P1 channel has 20 taps of multipath components, and each scattered path comes with distinct time-delay and phase-shift. The last channel model considered in this work is the 0 dB Echo profile. It composes of two paths with identical amplitude. The directions are separated by a time equal to 0.9 from Guard Interval (GI), i.e., 90% GI. the second path comes with a 1 Hz frequency shift.

V. RESULTS AND DISCUSSION

The DVB-T2 standard defines several configurations. The right choice of a specific structure makes the system suitable for various uses. The main configuration settings applied for each test are one T2 frame, 8K FFT, 1/8 guard interval, PP2 Scattered pattern, 8 MHz bandwidth, one PLP, 64800 FEC Length, 48 FEC blocks, 50 LDPC decoding Iterations, And the changes are only defined for code rate, constellation type, rotation angle, and channel model for each test. The simulation of the DVB-T2 system is done using MATLAB software based on ETSI EN 302 755 v1.4.1. The simulation demonstrates the DVB-T2 system performance using the constellation rotation technique with various types of transmission profiles. The profiles consist of four-channel scenarios: AWGN, Ricean, Rayleigh, and 0 dB Echo channels. These results have been compared with system performance without using constellation rotation. The essential factor of this comparison is to obtain the achieved gain. In this paper, three types of constellation have been simulated in the rotated and non-rotated manner, and these types are QPSK, 16-QAM, and 64-QAM. All the available DVB-T2 code rates have been considered in the simulation.

This step aims to find the resulting diversity gain from employing the rotation technique. This gain depending on the minimum required SNR's numerical results based on Quasi Error Free reception (QEF) criteria. QEF is a minimal limit defined at Bit Error Rate (BER) less than or equal to $1*10^{-7}$ after inner decoder LDPC, as specified in the DVB-T2 implementation guidelines. The considered BER is obtained after applying the LDPC inner decoder. Results for all four channels are presented in Table I with the non-rotation case, and Table II represents the result of the rotation constellation case.

The performance gain achievable from rotated constellation with different constellation types and code rates are given in Table III. It should be noted that the maximum gain can be obtained from using rotated constellations with low constellation sizes like QPSK combined with higher code rates 4/5 and 5/6. This can be demonstrated simply because higher code rates have a lower ability to correct errors; therefore, the system's performance depends basically on the diversity presented by constellations rotation. On the other hand, the performance gain is significantly reduced due to high constellation and lower code rates. Rotated constellations display a more significant boost when the erasure percentage increases and give less profit when the erasures are low.

Almost there is no performance loss when using rotated constellations with Gaussian conditions. The maximum gain is about 3.6 dB can be achieved for the 0 dB Echo channel with QPSK constellation and 5/6 code rate. The second high gain is 3 dB obtained with the same system configuration but with a 4/5 code rate. The third high gain is 2.6 dB, supported by QPSK modulation and 5/6 code rate in Rayleigh channel conditions.

TABLE I. REQUIRED SNR FOR BER$< 1x10^{-7}$ WITH NON-ROTATION

Constellation	CR	AWGN	Ricean	Rayleigh	0 dB Echo
QPSK	1/2	0.90	1.30	2.60	2.30
QPSK	3/5	2.10	2.60	4.50	4.00
QPSK	2/3	3.10	3.60	5.90	5.60
QPSK	3/4	4.00	4.70	7.70	7.70
QPSK	4/5	4.60	5.40	9.20	9.50
QPSK	5/6	5.20	5.90	10.30	11.00
16-QAM	1/2	5.90	6.20	7.80	7.50
16-QAM	3/5	7.50	7.90	9.70	9.40
16-QAM	2/3	8.80	9.20	11.30	11.10
16-QAM	3/4	9.90	10.50	13.30	13.10
16-QAM	4/5	10.70	11.40	14.60	15.10
16-QAM	5/6	11.30	12.00	15.80	16.40
64-QAM	1/2	9.70	10.10	11.90	11.90
64-QAM	3/5	12.00	12.30	14.20	14.00
64-QAM	2/3	13.40	13.80	15.80	15.70
64-QAM	3/4	15.00	15.40	17.90	17.90
64-QAM	4/5	16.00	16.60	19.50	19.80
64-QAM	5/6	16.70	17.20	20.60	21.20

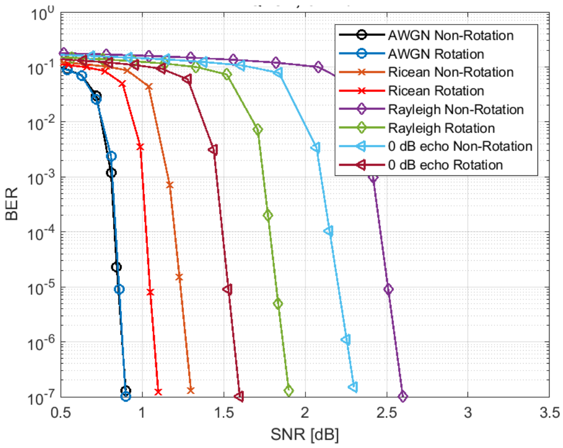
TABLE II. REQUIRED SNR FOR BER$< 1x10^{-7}$ WITH ROTATION

Constellation	CR	AWGN	Ricean	Rayleigh	0 dB Echo
QPSK	1/2	0.90	1.10	1.90	1.60
QPSK	3/5	2.20	2.40	3.40	3.10
QPSK	2/3	3.10	3.40	4.70	4.30
QPSK	3/4	4.10	4.50	5.90	5.60
QPSK	4/5	4.60	5.10	6.90	6.50
QPSK	5/6	5.10	5.60	7.70	7.40
16-QAM	1/2	5.90	6.10	7.40	7.10
16-QAM	3/5	7.50	7.80	9.10	8.90
16-QAM	2/3	8.80	9.10	10.60	10.30
16-QAM	3/4	9.90	10.40	12.30	11.90
16-QAM	4/5	10.70	11.30	13.50	13.20
16-QAM	5/6	11.30	11.9	14.40	14.30
64-QAM	1/2	9.80	10.10	11.70	11.60
64-QAM	3/5	12.00	12.30	14.00	13.80
64-QAM	2/3	13.40	13.70	15.50	15.40
64-QAM	3/4	15.00	15.50	17.60	17.40
64-QAM	4/5	16.00	16.60	19.10	19.00
64-QAM	5/6	16.70	17.20	20.10	20.10

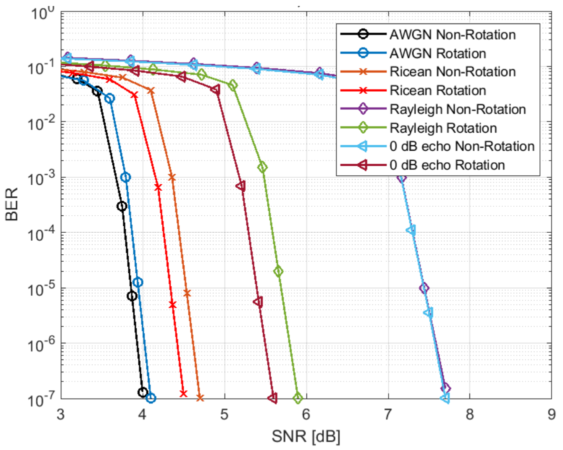
TABLE III. ROTATION GAIN IN DB WITH FOUR CHANNELS

Constellation	CR	AWGN	Ricean	Rayleigh	0 dB Echo
QPSK	1/2	0	0.20	0.70	0.70
QPSK	3/5	-0.10	0.20	1.10	0.90
QPSK	2/3	0	0.20	1.20	1.30
QPSK	3/4	-0.10	0.20	1.80	2.10
QPSK	4/5	0	0.30	2.30	3.00
QPSK	5/6	0.10	0.30	2.60	3.60
16-QAM	1/2	0	0.10	0.40	0.40
16-QAM	3/5	0	0.10	0.60	0.50
16-QAM	2/3	0	0.10	0.70	0.80

16-QAM	3/4	0	0.10	10	1.20
16-QAM	4/5	0	0.10	1.10	1.90
16-QAM	5/6	0	0.10	1.40	2.10
64-QAM	1/2	0.10	0	0.20	0.30
64-QAM	3/5	0	0	0.20	0.20
64-QAM	2/3	0	0.10	0.30	0.30
64-QAM	3/4	0	-0.10	0.30	0.50
64-QAM	4/5	0	0	0.40	0.80
64-QAM	5/6	0.10	0	0.50	1.10



(a)



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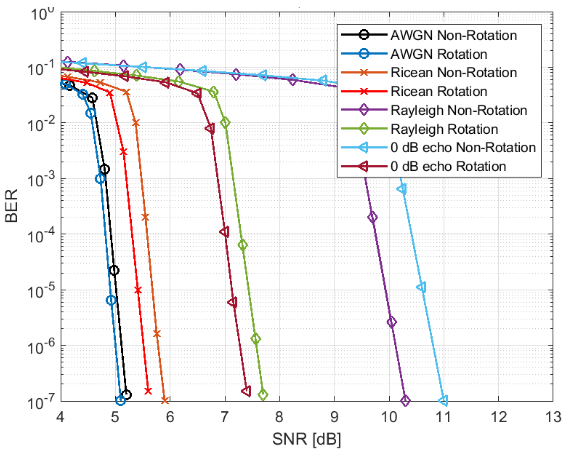

(c)

Fig. 3. BER of QPSK constellation with rotation and non-rotation for code rate of (a) 1/2 (b) 3/4 (c) 5/6

The BER curves are simulated for the QPSK constellation with three selected code rates which are 1/2, 3/4, 5/6, as a graphical sample to show the benefits of rotation over simulated channels. Tables I, II, and III offer the rotation's advantages for the remaining code rates and constellations size. BER curves for all mentioned cases are shown in Fig. 3. All BER results indicate a significant reduction in SNR when applying the rotated constellation technique. The maximum SNR reduction is achieved with a code rate of 5/6 and 0 dB echo conditions followed by the Rayleigh channel at the same code rate.

VI. CONCLUSION

In this paper, the performance gain for the rotated constellation technique in the DVB-T2 system was investigated. The gain has been compared with the case of employing a non-rotated constellation. Diversity gain is the primary parameter considered in the comparison to show the performance associated with the rotated constellation and BER curves are also taken into account. The simulation was done in four fading channels with all six available code rates and three constellation modes. It has been shown that the rotated constellation features can supply a good gain performance for conditions with very bad fading. The simulation results demonstrate that the performance gain is high for small constellation sizes such as QPSK. It has also been found that employing a high code rate (5/6) can achieve excellent gain rather than a low rate because the system depends on the diversity provided by the rotated constellation; therefore, the combination of high code rate with rotated constellation can offer additional robustness to improve the data rate while maintaining the same field strength.

REFERENCES

[1] D. Gomez-Barquero, Next Generation Mobile Broadcasting, CRC Press, Taylor & Francis Group, LLC, 2013.

[2] Digital Video Broadcasting (DVB), “Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2),” European Standard, ETSI EN 302 755, V 1.4.1, 07-2015.

[3] H. Paz-Penagos, “OFDM comparison with FFT and DWT processing for DVB-T2 wireless channels,” INGE CUC, vol. 14, no. 2, pp. 97-105, 2018.

[4] N. Suwansukho and S. Promwong, “Evaluation of Rotated Constellation in DVB-T2 Based on Measurement Data,” 978-1-7281-0067-8/19/, IEEE, 2019.

[5] Digital Video Broadcasting (DVB), “Implementation Guidelines for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2),” Technical Specification, ETSI TS 102 831, V 1.2.1, 08-2012.

[6] L. Polak, O. Kaller, L. Klozar, J. Sebesta and T. Kratochvil, “Exploring and Measuring Possible Co-Existences between DVB-T2-Lite and LTE Systems in Ideal and Portable Fading Channels,” Journal of Applied Research and Technology, vol. 13,pp. 32-44, February 2015.

[7] Correia S., Velez M., Prieto G., Eizmendi I., Berjon-Eriz G., Fernandez C., and Ordiales J.L., “DVB-T2 modulator design supporting multiple PLP and auxiliary streams,” IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, Shanghai, China, 24-26 March 2010.

[8] DVB Fact Sheet, “DVB-T2-2nd Generation Terrestrial,” August, 2013.

[9] C. R. Senderos, “Reception Performance Studies for the Evaluation and Improvement of the New Generation Terrestrial Television Systems,” Ph.D. Thesis Higher Technical School of Engineering, Spain, May 2017.

[10] E. Dumic, S. Grgic, and D. Frank, “Simulating DVB-T to DVB-T2 Migration Opportunities in Croatian TV Broadcasting,” 22nd International Conference on Software Telecommunications and Computer Networks (SoftCOM), IEEE, Split, Croatia, 17-19 Sept. 2014.

[11] W. Fischer, Digital Video and Audio Broadcasting Technology a Practical Engineering Guide, 4rd ed., Springer Nature Switzerland, AG 2020.

[12] D. A. Samoa, M. Slimanib, G. Baruffaa, and L. Ruginiet , “A performance study of DVB-T2 and DVB-T2-Lite for mobile reception,” Digital Signal Processing, Elsevier Inc., 2014.

[13] I. G. Astawa and T. B. Santoso, “Analysis Of Performance DVB-T2 Using MIMO System Over MMSE Channel Estimation,” 978-1-5090-0931-2/16/, Region 10 Symposium (TENSYMP), Bali, Indonesia, IEEE, 2016.

[14] M. Liu, J. Helard, M. Helard, and M. Crussiere, “Towards the Next Generation Video Broadcasting Improved Performance Using Distributed MIMO,” Wireless Pers Commun, Springer Science+Business Media, New York, 31 May 2015.

[15] B. Akbarian and S. G. Maghrebi, “Better performace of new generation of digital video broadcasting- terrestrial (dvb-t2) using alamouti scheme with cyclic delay diversity,” Journal of Information Systems and Telecommunication, vol. 3, no. 2, pp. 108-114, April-June 2015.

[16] D. Gozalvez, D. Gomez-Barquero, D.Vargas, and N. Cardona, “Time Diversity in Mobile DVB-T2 Systems,” IEEE Transactions on Broadcasting, vol. 57, no. 3, September 2011.

[17] M. Mroue, A. Nafkha, J. Palicot, B. Gavalda, and N. Dagorne, “Performance and Implementation Evaluation of TR PAPR Reduction Methods for DVB-T2,” International Journal of Digital Multimedia Broadcasting, vol.10, August 2010.

[18] A. H. Eldieb, M. Z.Saleh, and S. Elramly, “A Comparative Study of Channel Estimation Techniques for OFDM in DVB-T2,” International Journal of Computer Applications,vol. 91, no.14, April 2014.

[19] R. Prasad, OFDM for Wireless Communications Systems, Artech House Inc.,London, 2004.

[20] M. Dąbrowski, “Investigation of Digital Terrestrial Television Receiver Architectures for DVB-T2 Standard,” *Ph. D. Thesis Warsaw University of Technology*, Faculty of Electronics and Information Technology, Warsaw, 2013.

[21] N. Tajbakhsh, M. A. Pourmina, and A. Khademzadeh, “Design And Simulation Of DVB-S2/T2 Baseband Digital Receivers With Using Processors & Software Defined Radio Techniques With Lowest Power,” Chemical and Process Engineering, Special Issue, 36 (2), pp. 627-642, 2014.