Digital Video Broadcasting T2 Lite Performance Evaluation Based on Rotated Constellation Rates

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Abstract

DVB-T2 offers the best levels of efficiency, reliability, and flexibility of any digital terrestrial broadcast technology now available. It provides the most up-to-date coding and modulation techniques to make the valuable terrestrial spectrum extremely effectively usable for many types of transmission. The mobile configuration of DVBT2 also known as T2-Lite, employs a constrained set of possible modes that are suited for movable transmission and reduce the demands placed on the receiver. This study compares the T2-Lite system's performance before and after using constellation rotation and cyclic Quadrature (Q) delay methods among different types of constellations, coding rates, and fading channels. Results show a significant improvement in T2-Lite system performance while using a rotating constellation in a bad fading environment. Moreover, the utilization of this technique enhances DVB-T2 Lite gain. All simulation of system components and channels were carried out in MATLAB R2021a software.

Keywords: RQD, Fading Channel, DVBT2 Lite.

1 Introduction

The DVB-T standard was released in 1997 as European Telecommunications Standards Institute standard EN 300 744. It is a DVB European-based consortium standard for the broadcast and transmission of DTT (E. ETSI, 2009). The document assigns modulation, channel coding, and framing structure for the DTT are described in this document. Due to the high degree of flexibility offered by DVB-T, networks may be created to supply a variety of services, from SDTV to High DTV (E. ETSI, 2009), (E. ETSI, 2011), (Kratochvíl & Štukavec, 2008). Due to its absence of power-saving features and, more significantly, temporal interleaving, DVB-T was initially intended for fixed and portable receiving (Gozálvez, et al., 2010). It is currently the most widely utilized digital television system in the world, with services available in many nations around Europe. OFDM (E. ETSI, 2009), (T. ETSI, 2004), (Kratochvíl & Štukavec, 2008) modulation with efficient FEC is used in DVB-T. This kind of modulation employs a significant number of subcarriers and generates a strong signal that can handle a range of transmission channel conditions. This method makes it considerably simpler to receive

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broadcast TV signals in environments with poor channel characteristics (echoes, signal delays, etc.). The DVB group came to the conclusion that there are appropriate technologies that could boost capacity and robustness in the terrestrial environment, particularly for HDTV transmission, according to previous research findings and a set of commercial needs. As a result, a new standard known as DVB-T2 was created with the same spectral characteristics as those in the DVB-T standard (E. ETSI, 2011), (T. ETSI, 2004), (Mendicute, Sobrón, Martínez, & Ochandiano, 2010). The most recent DVB-T2 standard, which offers greater efficiency, resilience, and flexibility than DVB-T, appears to be the most proceeding DTT system in the world. DVB-T2 is at least 50% more effective than DVB-T thanks to advancements and fresh signal processing methods (T. ETSI, 2004). HD (High Definition) TV channels require a minimum capacity increase of 30% over DVB-T, hence DVB-T2 was created to handle this. To strengthen the reliability of the broadcast information, DVB-T2 uses the most recent modulation and coding techniques. In order to achieve a per-service particularization of the transmission characteristics, DVB-T2 also adds physical layer pipes (PLPs). This trait enables the supply of various use cases-fixed, mobile, and portable-in the same frequency channel (Schmidbauer, T., 2022). Although DVB-T2 primarily focuses on fixed and portable receiving, it is ideally suited to mobile situations because to its increased durability and high degree of flexibility. The DVBT2's highly flexible time interleaving enables a variety of trade-offs between latency, temporal diversity, and power efficiency. While fixed services in DVB-T2 can give up time diversity in order to reduce latency, mobile services in DVB-T2 can benefit from increased time diversity or power savings at the risk of longer delays. Due to its excellent performance and high flexibility, the physical layer of DVB-T2 is currently recognized as a reference in the standardization process of the next generation mobile TV standard DVB-NGH (Gozálvez et al., 2010). There are substantial variations between the current (DVB-T) and planned (DVB-T2) terrestrial broadcasting standards. DVB-T2 offers a very resilient signal due to the use of an advanced and FEC (E. ETSI, 2011). In contrast to DVB-T, the DVB-T2 standard offers a variety of new option parameters, including the number of transmission modes (1K, 4K, 16K, and 32K) and the GI (Guard Interval) sizes (19/256, 18/128, and 1/128) (T. ETSI, 2004). Two updated versions of the DVB-T2 standard have been released: V1.2.1 in February 2011 and V1.3.1 in April 2012. The addition of a new profile called T2-Lite in this most recent version makes it particularly pertinent (Eizmendi et al., 2014). With the aim of reducing receiver complexity, cost, and power consumption of mobile services, this profile is designed for mobile receiving. One of the most significant improvements in the DVB-T2 configuration is the unique constellation technique known as rotating constellation. To increase performance even for very frequency selective channels, it is an optional feature (Vangelista et al., 2009). The idea of utilizing the constellation rotation in communication systems is not a new one. This method has been studied ever since Giraud et al. initially announced the scheme of constellations for Rayleigh fading channel in 1997. (Giraud, Boutillon, & Belfiore, 1997). Evaluation of the Bit Error Rate BER for the rotational constellation approach has been done in (Perez-Calderón et al., 2009) and (Nour & Douillard, 2008). This paper examines how the rotating constellation performs in fading channels under the DVB-T2 Lite standard. Four types of channels have been used; fixed (Ricean), 0 dB Echo, portable (Rayleigh), and Additive White Gaussian Noise (AWGN) channels. Additionally, the parameter configuration that yields the best performance appropriate for each channel's conditions is assessed in this study. The following sections make up the remainder of the paper after the introduction in section 1: An overview of the DVBT2 standard and its contemporary profile T2 light is provided in section 2. Section 3 represents the signal to noise ratio and bit error rate effect on system performance. The constellation rotation and cyclic Q delay concepts is presented in the following part. The proposed model for this investigation is characterized in section 5. Finally, the last two sections, which are the results and conclusions are presented.

2 DVBT-2 and T2 Lite Standards

The DVBT2 is a complicated standard. It's constructed of many different new building blocks, and each one needs to be precisely calibrated. These new, cutting-edge techniques for advanced signal processing, including Active Constellation Extension, rotated constellation, TR (Tone Reservation), PAPR reduction techniques, Multiple Inputs Single Output, FEF, Flexible time interleaver, and scalable frame structure, are excellent illustrations to improve broadcast technology (Eizmendi et al., 2014). Figure (1) shows the block schematic of this standard:

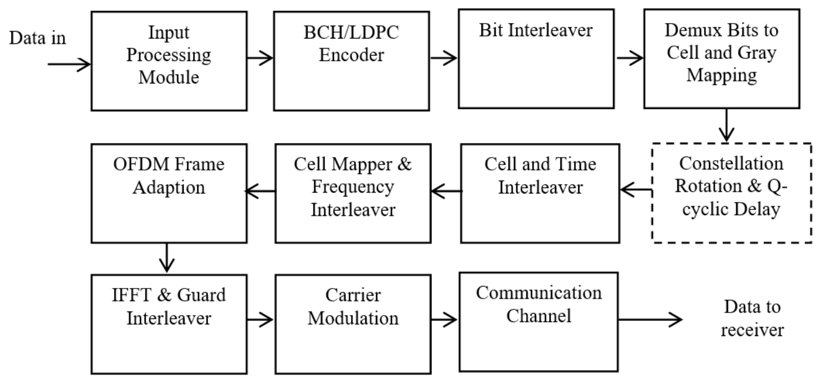


Figure 1: A Block Schematic for a DVB-T2 Transmitter (Polak & Kratochvil, 2012)

The Lite profile of DVBT2 is a modern profile introduced in the latest versions of the DVBT2 standard. The profile is designed for mobile and handheld reception. Therefore, it only includes modes that are possible to work in mobile environments. In addition, the profile was developed to reduce the expense and power consumption of mobile services by simplifying the complexity of DVBT2-Lite receivers (Cazalens et al., 2013). Table (1) compares the key features of these two standards:

Table 1: A Comparison Between DVB-T2 and T2 Lite Standards

	DVB-T2	**DVB-T2 Lite**
FEC	LDPC + BCH	LDPC + BCH
Code rate	1/2, 3/5, 2/3, 3/4, 4/5, 5/6	1/3, 2/5, 1/2, 3/5, 2/3, 3/4
Constellation	QPSK, 16QAM, 64QAM, 256QAM	QPSK, 16QAM, 64QAM, 256QAM
Guard Interval	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4
FFT size	1K, 2K, 4K, 8K, 8K ext., 16K, 16K ext., 32K, 32K ext.	2K, 4K, 8K, 8K ext., 16K, 16K ext.
Scattered pilots	1%, 2%, 4%, 8% of total	1%, 2%, 4%, 8% of total
Continual pilots	0,35% of total	0,35% of total
RF Bandwidth	1.7, 5, 6, 7, 8, 10 MHz	1.7, 5, 6, 7, 8, 10 MHz

3 Effect of Signal to Noise Ratio (SNR)and Bit Error Rate (BER) on System

Signal to noise ratio measures how much the signal intensity in a wireless channel overcomes the noise level. The bit error rate (BER), which is the proportion of bits that are corrupted or lost during transmission, decreases as the SNR increases, improving signal quality. A low SNR indicates a weak or noise-distorted signal, while a high BER might result in data loss, transmission delays, or retransmissions. SNR is usually measured in dB and can be calculated as follows:

$$\text{SNR (dB)} = 10 \log (S/N)$$

Where S is the signal power and N is the noise power. The performance and dependability of wireless networks depend on the SNR. Throughput is boosted when the SNR is high because it enables larger data rates and lower bit errors rates (BER). Furthermore, a low SNR results in a larger BER and more retransmissions, which adds to the latency. Additionally, SNR plays an important role for delivering a high level of service to consumers and applications with various demands on bandwidth, latency, jitter, and reliability. As a result, a high SNR allows for a network with improved quality of service (Linked in, 2023).

4 Constellation Rotation and Cyclic Q-delay (RQD)

A signal modulated by a digital modulation method, such as QAM, is represented as a constellation diagram. There are four modulation options available in the DVB-T2 standard: QPSK, 16QAM, 64QAM, and 256QAM. It takes both the I (In-Phase) and Q (Quadrature) components, the transmitted data can be recognized by these two components. As the signal passes across the channels in a typical constellation, the two components are exposed to the same fading effect. (Perez-Calderón et al., 2009). The usage of rotated constellations is one of DVB-novel T2's characteristics. This method, which was first proposed in (Boulle, 1992), is also known as signal space diversity (SSD), as its ultimate goal is to produce more variety that results in a redundancy in the information bits of the coded modulation. When channels are encountered that have been significantly fading, this method enhances receiver performance. As seen in figure 2, which shows a rotated 16-QAM constellation and its matching conventional constellation, cells are rotated by a specific angle when this feature is applied. The rotation angle varies according to the chosen constellation (Eizmendi et al., 2014).

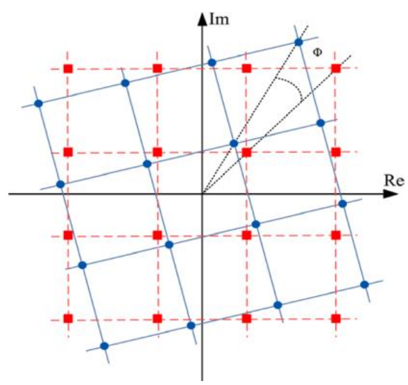


Figure 2: 16-QAM Classic and Rotated Constellation, where the Square Points and the Circle Points Denote to the Classic Constellation and Rotated Constellation Respectively (Eizmendi et al., 2014).

As seen in figure 2, this rotation results in each new component, whether it be in-phase (I) or quadrature (Q), having sufficient information on its own to identify the transmitted symbol. However, when I and Q experience the same loss in the fading channel, the use of rotated constellations does not by itself provide a notable improvement. After the rotation, an interleaving operation is carried out between the I and Q components to broadcast in various carriers and time slots in order to get over this restriction. This procedure, known as Q-delay, makes sure that the original constellation point's Q and I components are ultimately transmitted in various T2 cells. This method is referred to as (RQD), constellation rotation and cyclic Q delay (Eizmendi et al., 2014). Hence, the interleaving procedure ensures that the I and Q components of the symbol experience independent fading. As a result, the information can be recovered if one of the components is destroyed or impacted by a deep selective fading of the channel (Richardson, 2003). The information would be lost in a non-rotated constellation because both components experience the same fading during signal transmission over the channel. In summary, the rotational constellation technique adds a higher level of diversity to enhance DVB-T2 receiver performance, particularly in propagation scenarios with deep fading conditions or erasure events. As compared to traditional QAM constellations, simulations (Nour & Douillard, 2008) , (Perez-Calderón et al., 2009) demonstrate that the RQD approach offers a gain that can vary from 0.2 dB to several dBs depending on the order of the constellation, the code rat(CR), and the channel model. The use of this feature does not result in a capacity penalty, but it does make the receiver more complex, particularly for high order constellations. To make this work simpler, some demapper algorithms have been created (Perez-Calderon, Baena-Lecuyer, Oria, Lopez, & Doblado, 2013), (Kim, Basutkar, Bae, Xue, & Yang, 2013) and (Tomasin & Butussi, 2012). Rotation combined with 256-QAM constellation is not permitted in T2-Lite to prevent this complexity.

5 Proposed Model

This proposed work's primary goal is to simulate the T2 Lite profile of DVBT2 as a whole, then to enhance the performance of the system by using RQD technique. The Common Simulation Platform (CSP) simulator of the DVBT2 (Haffenden, 2011), developed in MATLAB R2021a, was used for the simulation. Table (2) presents the primary configuration parameters used in this simulation.

Table 2: DVB-T2 System Parameters Configuration

Parameters	Configuration
OFDM FFT Mode	8K
Guard Interval	1/8
Constellation Type	QPSK, 16-QAM, 64-QAM
Scattered Pattern	PP8
PLP Numbers	one
Coding Rate	1/2, 3/5, 2/3, 3/4, 4/5, 5/6
FEC Length	16200 Bits
FEC Blocks	48 Block
Data Symbols	83 Symbol
Max. LDPC decoding Iterations	50 Iteration
Bandwidth	8 MHz

The proposed model is shown in figure (3):

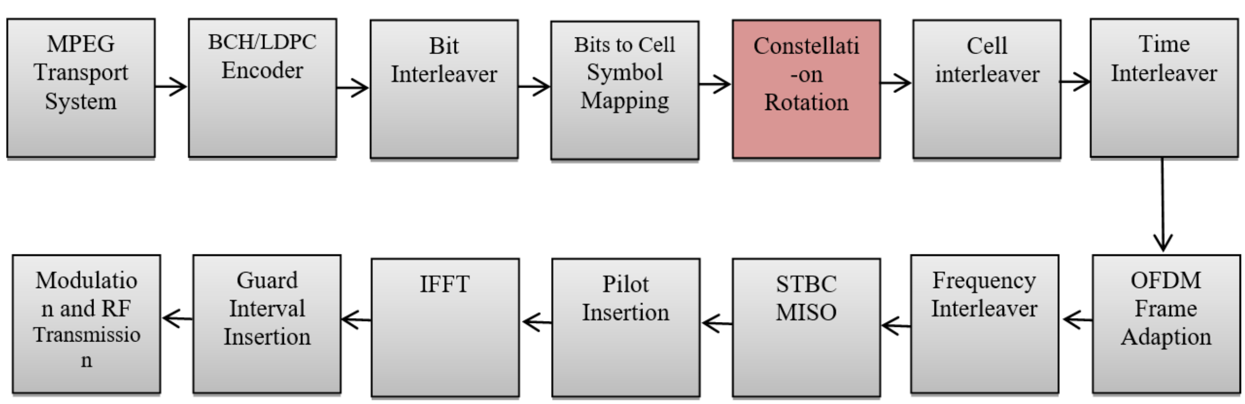


Figure 3: The DVB-T2 System's Transmitter Block Diagram

6 Results and Discussion

This part illustrates how simulated systems behave under various channel conditions. Tables and graphs will used to show the results of how well the simulated systems performed by using MATLAB R2021a program. The outcomes of modelling the T2-Lite profile are included in this part. T2-Lite profile simulation uses both rotated and non-rotated constellation approaches, The models include four different scenarios: Ricean F1 AWGN, 0 dB Echo, and Rayleigh P1. The SNRs needed for all four types of channels, when employing RQD techniques, to obtain BER of less than or equal to (1*10-6). Before implementing RQD technique, the SNRs produced by the system performance are compared. Getting the obtained gain is crucial for this comparison. As a result, the performance improvements made possible by rotated constellations for various modulation modes, code rates, and channel models are shown in table (3), (4) and (5).

Table 3: Required SNR for BER < 1E-6 Before RQD

The Constellation	Code Rate	AWGN	Fixed	portable	0dB Echo
QPSK	1/2	7	8.5	15.5	16.6
QPSK	3/5	7.2	9	16.6	19.7
QPSK	2/3	7.6	9.2	17.2	22.5
QPSK	3/4	8	9.3	18.5	23.5
QPSK	4/5	8.2	9.6	19.6	25
QPSK	5/6	8.4	9.7	20.1	27
16 QAM	1/2	13.2	14.2	20.2	23
16 QAM	3/5	13.7	14.6	21.2	25.5
16 QAM	2/3	14.1	15.4	23.2	26.5
16 QAM	3/4	14.5	15.8	23.6	29.5
16 QAM	4/5	14.7	16.1	25	31.2
16 QAM	5/6	14.8	16.2	26	31.4
64 QAM	1/2	19	19.6	26	28
64 QAM	3/5	19.8	20.7	26.5	30.8
64 QAM	2/3	20	20.8	28	31
64 QAM	3/4	20.4	21.5	29.3	34
64 QAM	4/5	20.7	21.8	30	35
64 QAM	5/6	20.9	22	31	36.5

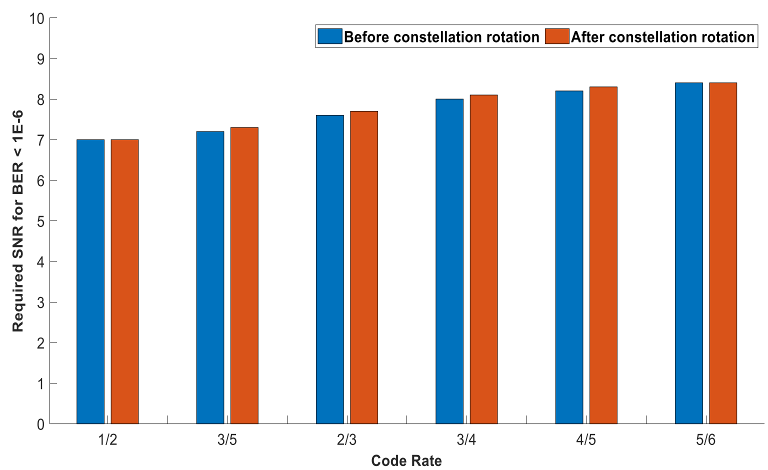
Table 4: Required SNR for BER < 1E-6 After RQD

The Constellation	Code Rate	AWGN	Fixed	Portable	0dB Echo
QPSK	1/2	7	8.7	15.6	16.6
QPSK	3/5	7.3	9.2	16.6	19.8
QPSK	2/3	7.7	9.2	17.3	22.6
QPSK	3/4	8.1	9.5	18.6	23.6
QPSK	4/5	8.3	9.6	19.6	25.1
QPSK	5/6	8.4	9.7	20.2	27.1
16 QAM	1/2	13.5	14.3	20.3	23.1
16 QAM	3/5	13.8	14.9	21.3	25.6
16 QAM	2/3	14.2	15.4	23.4	26.6
16 QAM	3/4	14.6	15.8	23.7	29.5
16 QAM	4/5	14.7	16.1	25.1	31.5
16 QAM	5/6	15	16.2	26.3	31.5
64 QAM	1/2	19.2	19.8	26	28.1
64 QAM	3/5	19.9	20.7	26.6	30.9
64 QAM	2/3	20	21.1	28	31
64 QAM	3/4	20.5	21.7	29.4	34.1
64 QAM	4/5	20.9	21.8	30.1	35.1
64 QAM	5/6	21	22	31.1	36.6

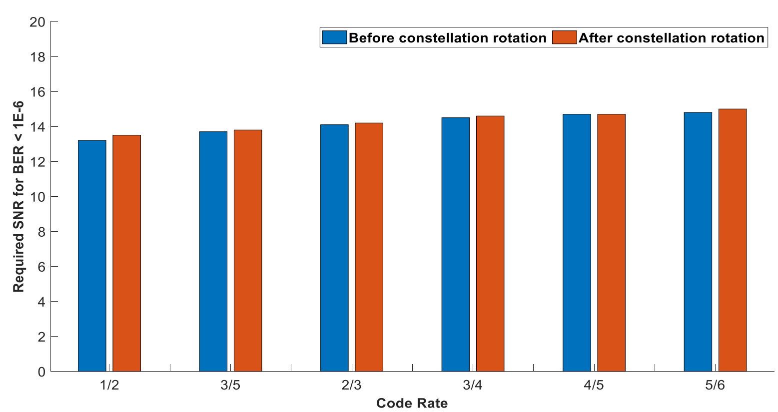
Table 5: Gain in dB for Channels After Rotation

The Constellation	Code Rate	AWGN	Fixed	Portable	0dB Echo
QPSK	1/2	0	-0.2	-0.1	0
QPSK	3/5	-0.1	-0.2	0	-0.1
QPSK	2/3	-0.1	0	-0.1	-0.1
QPSK	3/4	-0.1	-0.2	-0.1	-0.1
QPSK	4/5	-0.1	0	0	-0.1
QPSK	5/6	0	0	-0.1	-0.1
16 QAM	1/2	-0.3	-0.1	-0.1	-0.1
16 QAM	3/5	-0.1	-0.3	-0.1	-0.1
16 QAM	2/3	-0.1	0	-0.1	-0.1
16 QAM	3/4	-0.1	0	-0.1	0
16 QAM	4/5	0	0	-0.1	-0.3
16 QAM	5/6	-0.2	0	-0.3	-0.1
64 QAM	1/2	-0.2	-0.2	0	-0.1
64 QAM	3/5	-0.1	0	-0.1	-0.1
64 QAM	2/3	0	-0.3	0	0
64 QAM	3/4	-0.1	-0.2	-0.1	-0.1
64 QAM	4/5	-0.2	0	-0.1	-0.1
64 QAM	5/6	-0.1	0	-0.1	-0.1

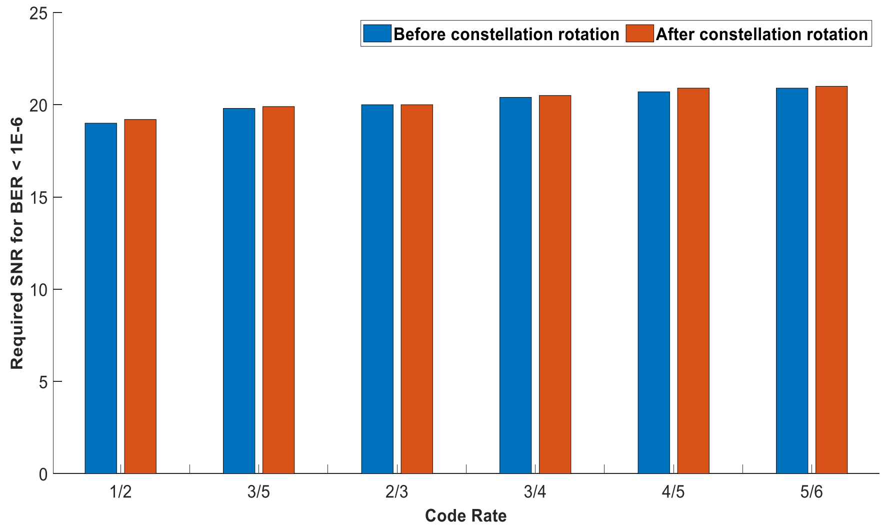
It is clear that in all cases, the rotation process has a significant impact on the required SNR to ensure an error rate of less than (1*10-6), and this effect is expected because the rotation process increases the probability of error, and therefore the system needs a higher SNR to overcome this challenge. The effect of noise on the system increases by increasing the constellation of the DVBT2-lite system because the samples will converge to each other, and this requires a higher SNR to overcome this noise and achieve the same required BER. This can be shown in figure (4) which contrasts the performance of a rotating and a non-rotating constellation. in AWGN channel for different constellations and code rates.



(a)



(b)



(c)

Figure 4: DVBT2-Lite SNR and Modulation for Different Code Rates in the AWGN Channel Before and After RQD for QPSK , 16 QAM and 64 QAM Respectively

The performance of the system is also impacted by the channel type. In the case of fixed channel, the system needed a higher SNR than in the AWGN channel to achieve the same BER about (1*10-6). The same thing was observed when comparing the rest of the types with each other. Figure (5), (6) and (7) show the relationship between SNR and BER for all channel types at different code rates with QPSK modulation.

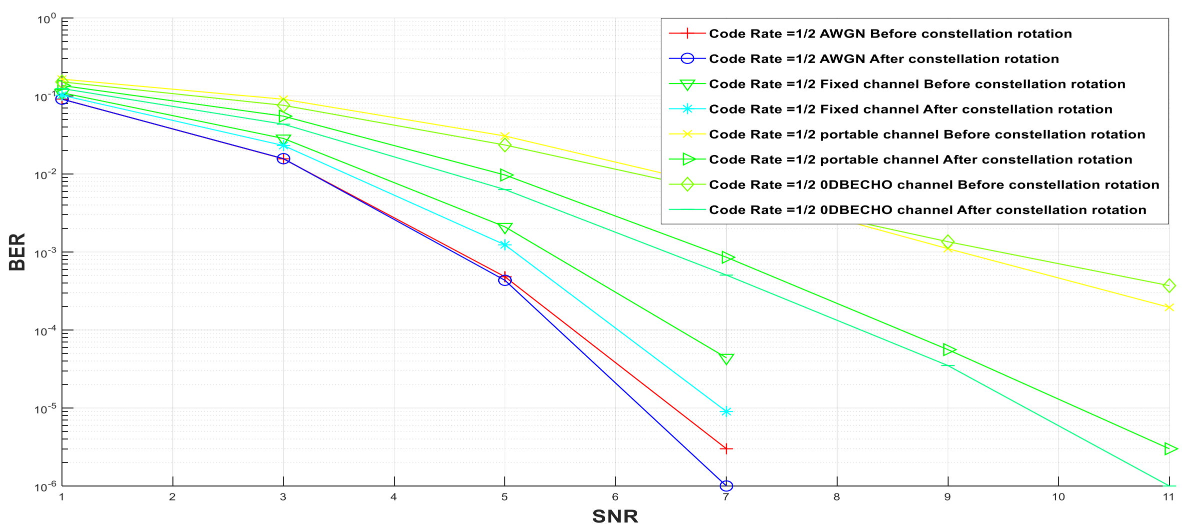


Figure 5: DVB-T2 Lite BER for all Channels with QPSK Modulation and Code Rate of 1/2

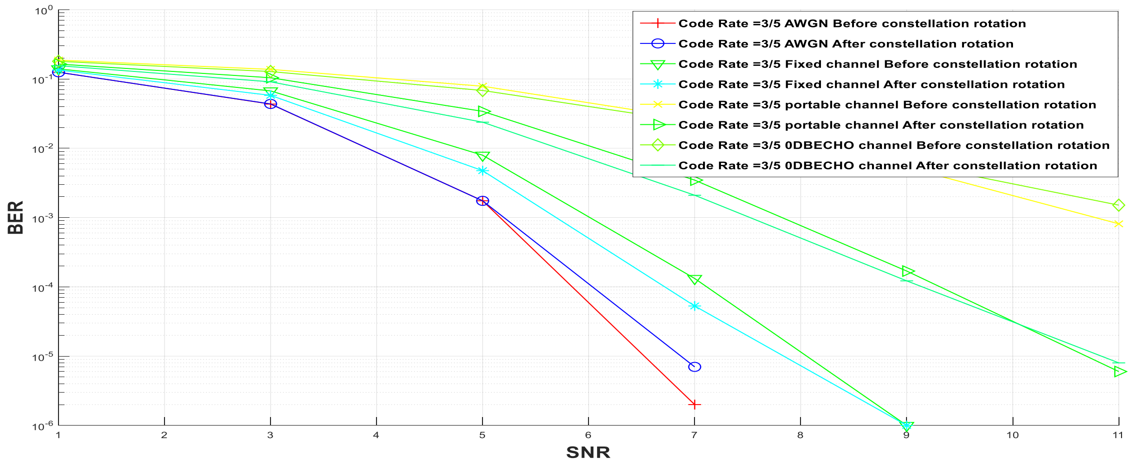


Figure 6: DVB-T2 Lite BER for all Channels with QPSK Modulation and Code Rate of 3/5

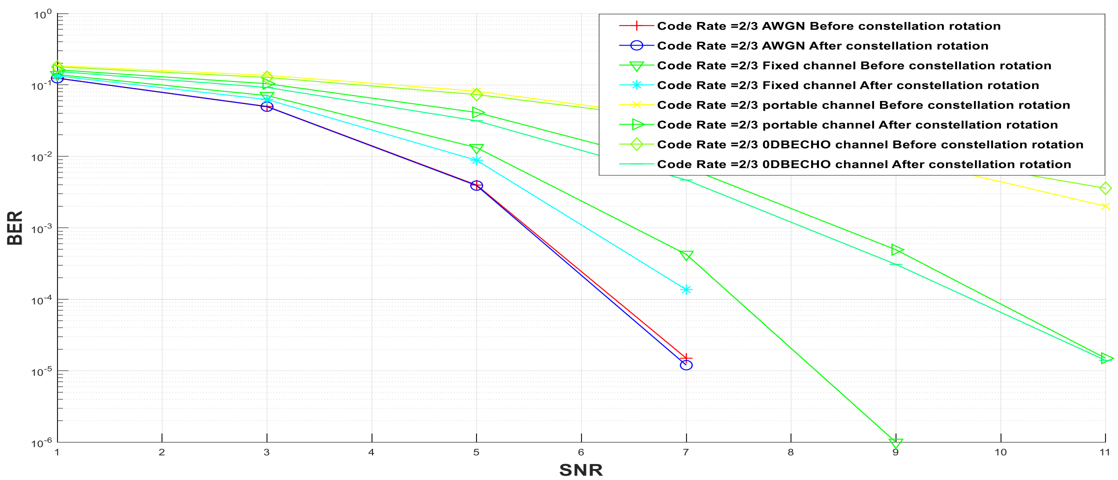


Figure 7: DVB-T2 Lite BER for all Channels with QPSK Modulation and Code Rate of 2/3

The code rate has a significant effect on BER due to its effect on throughput and coding. Decreasing code rate leads to a decrease in the throughput as well as BER decreasing, so the BER in figure (5) is generally less than BER in figure (6) and (7) for the reasons mentioned above. The channel and constellation rotation also have a significant effect on BER for each code rate. As its clear, there is a tradeoff between three effective parameters, which are; code rate, BER, and throughput.

7 Conclusion

This paper examined the DVB-T2 lite performance of the rotated constellation to that of non-rotated constellation. Four fading channels were used in this study AWGN, Rayleigh, 0 dB Echo, and Ricean, each with a different parameter configuration. A good gain performance can be achieved using the rotating constellation features under extremely poor fading circumstances as has been shown. Also, the type of channel and the code rate have a clear impact on the BER and thus the performance of the system. The maximum gain can be achieved by this technique was 0.3 dB.

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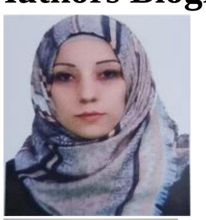
Authors Biography



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