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Comparative Analysis Of OWDM As A Modulation Scheme For DVB T2

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ABSTRACT

Digital Terrestrial Broadcasting (DTT) becomes one of the rapidly growing fields in today's modern world. DVB T2 (Digital video broadcasting second generation terrestrial) is most advanced system used for Digital Terrestrial Television Broadcasting (DTT). To achieve high data rate, DVB T2 utilizes orthogonal frequency division multiplexing (OFDM) as a modulation scheme. To achieve high data rate with proper reliability and efficiency is one of major problems in all modern communication systems. OFDM (Orthogonal frequency division multiplexing) is a good and powerful technique to achieve high data rate. But, OFDM has many limitations and drawbacks like it requires an inherently inflexible and complex IFFT core. OFDM signal also has a noise like amplitude variations and has a relatively high large Peak to Power Ratio (PAPR). OFDM is also sensitive to the inter symbol interference. To reduce the inter symbol interference the OFDM system uses of cyclic prefix which reduces the bandwidth efficiency and increases the system complexity. To overcome these problems a modified DVB T2 system is designed which utilizes OWDM (Orthogonal Wavelet Division Multiplexing) in instead of OFDM. OWDM has lower computational complexity and higher flexibility when compared to OFDM. OWDM also gives a fine spectral containment of the signal over a wide range of the Bandwidth. In this paper OWDM is investigated to be an alternative to OFDM for DVB T2. This paper also provides a comparative analysis of a modified DVB T2 system with a conventional DVB T2 system. The performance of both modified DVB T2 system and a conventional DVB T2 system is analyzed by plotting BER curves under different fading and noisy channels. The PAPR of both techniques is also compared when no reduction technique is applied.

Keywords*:* DVB T2, DTT, OFDM, OWDM, BER, PAPR

1. INTRODUCTION

With the rapid growth in technology, the demand for flexible high data rate services has also increased. The today's wireless systems are supposed to have a better coverage and quality, more reliable and bandwidth efficient, and be deployed in adverse environments. In modern wireless communication systems, bandwidth is one of important commodity. The proper utilization of bandwidth is one of the major challenges in wireless communication system. OFDM is a modulation technique widely used in modern wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and it's also robust to multipath fading without requiring complex equalization techniques. OFDM has been deployed in a number of wireless services. DVB T2 is one of services in which orthogonal frequency division multiplexing (OFDM) uses as a modulation scheme [1-2]. DVB T2 is the latest development of the Digital Video Broadcasting Terrestrial standards. It designs on to provide additional facilities, services and features for development DTT or Digital Terrestrial television market. However, some may see DVB T2 as a competitor to the present DVB T standard, but this is not the case. Whereas DVB T2 represents the next evolution stage for digital terrestrial television, it is designed to operate alongside the existing DVB T standard for many years to evolve the changeover to DVB T2. This evolution should take place in same manner of evolution as it took place for DVB S to DVB S2. As DVB T2 offers additional facilities, it will increase the broadcasters the possibility of offering latest and attractive services to their viewers and ensure their satisfaction. Due to its, development on the success of the current digital television services, DVB T2 is bound to see a significant take-up level in the upcoming years. The performance of OFDM in DVB T2 is satisfactory under both practical and theoretical conditions [2]. There are some basic limitations and drawbacks in OFDM like it requires an inherently inflexible and complex IFFT core. OFDM signal also has a noise like amplitude variations and has a relatively high large Peak to Power Ratio (PAPR). OFDM is also sensitive to the inter symbol interference. To reduce the inter symbol interference the OFDM system uses of cyclic prefix which reduces the bandwidth efficiency and increases the system complexity [3]. To overcome these problems a modified DVB T2 system is designed which utilizes new OWDM (Orthogonal Wavelet Division Multiplexing) modulation scheme in instead of OFDM scheme. For modifying system, the OFDM block was replaced with the OWDM block for same tests run conditions. The main objective of this paper is to identify how the modified DVB T2 system can be performed with a new OWDM modulation scheme. The performance of both the conventional DVB T2 system and the modified DVB T2 system is compared. This paper is also investigate various families of the wavelet with increasing order to ascertain which wavelet transform is the most suited for use in an AWGN channel and fading channels. The performance of both system is analyzed in terms of BER and EbNo for an AWGN and fading environment channels with DVB-T2 parameters of ½ code rate LDPC encoding, QPSK mapping.

2. Digital Video Broadcasting

DVB (Digital Video Broadcasting) is a suite of worldwide accepted open standards for digital television. DVB technology has become an integral part of modern broadcasting systems. The many countries have adopted DVB (Digital Video Broadcasting) standard for digital television systems. DVB standards are maintained by an international industry syndicate with more than 270 members, and are published by a Joint Technical Committee (JTC) of the European Telecommunications Standards Institute (ETSI), European Committee for Electro technical Standardization (CENELEC) and European Broadcasting Union (EBU). The interaction of the DVB sub standards is described in the DVB Cookbook. The DVB standard offers many advantages over the previous analogue standards and has enabled television to make a major step forwards in terms of its technology. Digital Video Broadcasting (DVB) is one of the successful exercises for broadcasting systems. Achievements of DVB are remarkable in the last decade and it is presently used in more than 80 countries all over world, including major part of Europe and also within the USA [17]. It provides an enormous of advantages in terms of quality and reliability with greater efficiency via proper spectrum distribution and power utilization. It also provides more number of applications with large number of channels and the ability to work side by side with present analog services.

2.1 Different Variants of DVB

Even a quick look at DVB will reveal the fact that there are many flavors' of the basic standard. In these days when there are many ways in which television can be carried from the "transmitter" to the "receiver" no one standard can be optimized for all applications. As a result there are many different forms of the Digital Video Broadcasting, DVB, standards, each designed for a given application [2, 17]. The main forms of DVB are summarized below in Table 1:

TABLE 1 VARIOUS VARIANTS OF DVB [2]

DVB Standard	Meaning	Description
DVB-C	Cable	The standard for delivery of video service via cable networks.
DVB-H	Handheld	DVB services to handheld devices, e.g. mobile phones, etc
DVB-RSC	Return satellite channel	Satellite DVB services with a return channel for interactivity.
DVB-S	Satellite services	DVB standard for delivery of television / video from a satellite
DVB-SH	Satellite handheld	Delivery of DVB services from a satellite to handheld devices
DVB-T	Terrestrial	The standard for Digital Terrestrial Television Broadcasting.
DVB-T2	Terrestrial	The standard for Digital Terrestrial Television Broadcasting second generation.

3. OVERVIEW OF DVB T2 SYSTEM

The DVB T2 standard utilizes an Orthogonal Frequency Division Multiplexing as the basic modulation and demodulation scheme. This type of transmission technique is particularly robust and allows for the reception of data signals (in this case television data) in the presence of some interference or missing channels as a result of effects like multipath. The new DVB-T2 specification provides the facility to select a variety of different options to match the requirements of the network operator. For error correction technology is same which used for DVB-S2 has been incorporated. This includes LDPC (Low Density Parity Check) coding with combination of BCH (Bose Chaudhuri Hocquengham) coding. This combination has been prefect to provide splendid performance in the existence of high noise levels and interference. As before, several options are available in areas such as the number of carriers, pilot signals and guard interval sizes, so that the overheads can be minimized for any given transmission channel. Figure 1 below shows basic block diagram of DVB T2 system.

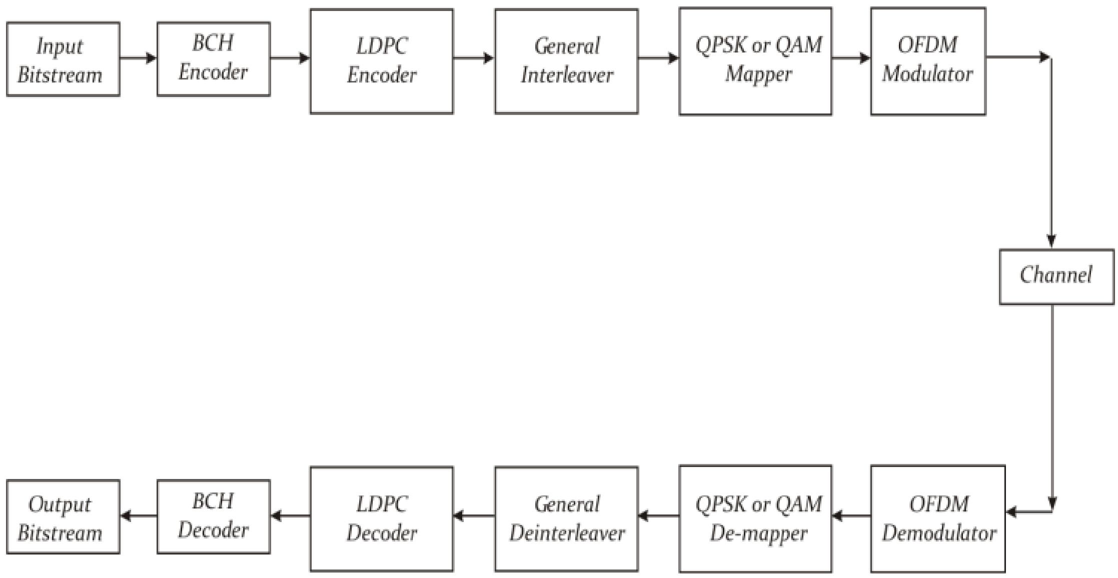

Figure 1 (Basic Block Diagram DVB T2 System)

4. Orthogonal Frequency Division Multiplexing

OFDM has been become one of popular and widely used wireless modulation and transmission technique in last two decades. It is been adopted in various world class wireless applications such as DVB T2 [2]. Figure 2 below shows block diagram of an OFDM system. OFDM is the technique of transmitting data that splits the serial high data rate streams into a large number of low data rate parallel data streams.Orthogonal Frequency Division Multiplexing is a type of multi carrier modulation, which splits the available spectrum into a number of parallel subcarriers and each subcarrier is then modulated by a low rate data stream at different carrier frequency. The traditional OFDM system makes use of IFFT and FFT for multiplexing the signals and reduces the complexity at both transmitter and receiver. OFDM is comprised of a blend of modulation and multiplexing. The original data signal is split into many independent signals, each of which is modulated at a different frequency and then these independent signals are multiplexed to create an OFDM carrier. As all the subcarriers are orthogonal to each other, they can be transmitted simultaneously over the same bandwidth without any interference which is an important advantage of OFDM. With the help of OFDM, a large number of overlapping narrowband subcarriers, which are orthogonal to each other, are transmitted parallel within the available transmission bandwidth. Thus, in OFDM, the available spectrum is utilized efficiently OFDM makes the high speed data streams robust against the radio channel impairments. OFDM is an efficient technique to handle large data rates in the multipath fading environment which causes ISI (Inter Symbol Interference) [8]. According to Ramjee [28], OFDM has been presented to resolve the multipath issue without the need for a complex equalizer at the receiver side through the inclusion of a guard interval and a cyclic extension of the transmitted signal. OFDM can suffer from Inter Symbol Interference (ISI). However, it reduces this by dividing the bandwidth into N non overlapping narrow subcarriers and it modulates the signals over these subcarriers. Subsequently these N subcarriers are frequency multiplexed to be sent in parallel to produce the OFDM symbol. FFT is sensitive to the changes of any of the following:

- Integer number of cycles during any symbol's period.
- The integer number of cycles that separate the subcarriers.

The generalization of the OFDM is summarized in the following function:

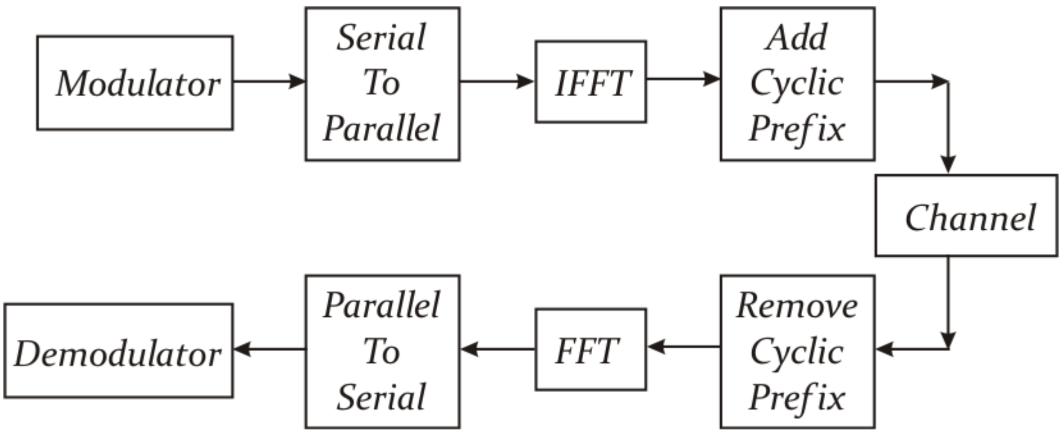

Figure 2 (OFDM BLOCK Diagram)

$$a(n) = \sum_{k=0}^{N-1} a_k e^{\frac{j2\pi kn}{N}} \quad n = 0,1, \ldots N-1 \quad (1)$$

Where:

a(n) is IDFT of *ak*.

ak :*k*=1,…..,N: successive bits stored.

If we let $K < N$ successive binary digits to be stored, generating one of 2^k possible QPSK signals. Each signal corresponds to a complex number ak. It is noticed that equation 1 is the form of Inverse Discrete Fourier Transform (IFFT) [4], and can be easily evaluated using FFT.

As in DVB-T2, which is used as an example in this paper, uses coded OFDM (COFDM). A wider range of OFDM parameters is offered in DVB T2. There are 1K, 2K, 4K, 8K, 16K, and 32 K FFT sizes, and each subcarrier, in each symbol, is modulated using QPSK or QAM constellations. A range of options is available for payload data is depends on constellation mapping: QPSK, 4 QAM, 16 QAM, 64 QAM, and 256 QAM [17]. The combination of modulation with the BCH+LDPC forward error correction coding provides an excellent performance in adverse channel environments. Guard interval fractions: 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4. The extension range of COFDM parameters allows very significant reductions in overhead to be achieved by DVB T2 compared with DVB, which taken together with the improved error correction coding allows an increase in capacity of up to nearly 50 % to be achieved for MFN operation and even higher for SFN operation [15]. However, in order to adapt the OFDM system for the terrestrial channel, the subcarrier spacing and the Guard Interval fractions have to be adjusted. The application have 1.116 kHz subcarrier spacing is used in 8k mode for VHF and UHF band operations where as 2.232 kHz subcarrier spacing is used in 4k mode for VHF and UHF band are operations. The adaptation to the different bandwidths required by the Commercial requirements is reached by means of adjusting the number of used OFDM subcarriers. Table 2 below shows DVB T2 COFDM Parameters in 8MHz channel bandwidth [17].

TABLE 2 DVB T2 COFDM PARAMETERS IN 8MHZ CHANNELBANDWIDTH [17]

FFT Size	Symbol Duration [ms]	Carrier Spacing [kHz]
32K	3.584	0.279
16K	1.792	0.558
8K	0.896	1.116
4K	0.448	2.232
2K	0.224	4.464
1K	0.112	8.929

5. Orthogonal Wavelet Division Multiplexing

DWT based OWDM is an efficient approach to replace conventional FFT based OFDM systems. DWT OWDM is employed in order to remove the use of cyclic prefix which decreases the bandwidth wastage and the transmission power is also reduced by the use of wavelet transform. The spectral containment of the channels in OWDM is better than OFDM. In Wavelet transform, the signal of interest is decomposed into set of basis waveforms, known as wavelets, which provide the way for analyzing the signals by investigating the coefficients of wavelets. DWT is used in several applications and has become very popular among engineers, technologists and mathematicians. The basic functions of wavelet transform are localized both in time and frequency and possess different resolutions in both domains which makes the wavelet transforms a powerful tool in various applications. Different resolutions correspond to analyze the behavior of the process and the power of the transform. Since wavelet transform has many advantages such as flexibility, lesser sensitivity against channel distortion and interference as well as better utilization of spectrum, it has been proposed to design the sophisticated wireless communication systems [3]. Wavelets are beneficial in various aspects such as channel modelling, data representation, transceiver design, and source and channel coding, data compression, interference minimization, energy efficient networking and signal de-noising in wireless communication systems. A low pass filter and high pass filter is employed to operate as QMF (Quadrature Mirror Filters**)** and satisfies perfect reconstruction and orthonormal properties. In wavelet based OWDM, the modulated signal is transmitted using zero padding and vector transposing. DWT is known as a flexible and highly efficient method for decomposition of signals. DWT-OWDM uses wavelet carriers at different scales (j) and positions on the time-axis (k). These functions are generated by the translation and dilation of a unique function, known as the "wavelet mother" denoted by $\psi\ (t)$ and is given by equation (2) [26],

$$\psi_{j,k}(t) = 2^{-\frac{j}{2}}\psi(2^{-j}t - k) \quad (2)$$

The scale index (j) and time location index (k) affects the orthogonality of the subcarriers and exhibits better time- frequency localization as compared to the complex exponentials used in FFT based OFDM systems [32]. The orthogonality is achieved if it satisfies the following condition, according to equation (3),

$$\langle\psi_{j,k}(t), \psi_{m,n}(t)\rangle = \begin{cases} 1 & if\ j = m, k = n \\ 0 & otherwise \end{cases} \quad (3)$$

The scaling function $\varphi\ (t)$ is used to obtain a finite number of scales and is generated using equation (4) [32],

$$\varphi_{j,k}(t) = 2^{\frac{j}{2}}\varphi\left(2^{j}t - k\right) \quad (4)$$

Higher the value of j, higher is the resolution. The lower resolution function, denoted by $\varphi(t)$ can be represented as the weighted sum of shifted versions of some scaling functions at next higher resolution i.e. $\varphi\ (2t)$, given by equation (5),

$$\varphi(t) = \sum_{k} h(k)\sqrt{2}\varphi\,(2t - k) \quad (5)$$

To better describe the important features of a signal, another set of functions given by $\psi_{j,k}(t)$ is defined which is also represented in terms of the scaling function, given by equation (6) as follows,

$$\psi(t) = \sum_{k} g(k)\sqrt{2}\varphi\,(2t - k) \quad (6)$$

The set of $g(k)$ coefficients are known as the wavelet function coefficients.

6. PROPOSED SYSTEM

In this paper OWDM is investigated to be an alternative to OFDM for DVB T2. Figure 3 below show basic block diagram for DVB T2 System with OWDM. The OFDM system is the baseline for the comparison with the proposed modulation technique, OWDM. The implementation of this system has taken the DVB T2 standard [2] as a baseline of design. The number of filter bank levels, in OWDM, is directly proportional to the length of IFFT, in OFDM, it follows: $\log_2(N)$ where N is IFFT length [3]. OWDM modulator with identical bandwidth of OFDM is used in modified. Therefore, it is possible to perform a "like-for-like" comparison. The use of filters in the wavelet domain has been predominantly used for multi-resolution analysis of time varying signals. The big difference between OFDM and OWDM is that in OFDM, the FFT performs sub band decomposition with a specific number of sub bands at well defined intervals. Whereas OWDM, it is possible to dynamically allocate the number of sub bands and the bandwidth of each sub bands. The data generator first generates a serial random data bits stream. This data stream is passed through the combination of encoders which consists of outer BCH and inner LDPC encoder followed by the bit interleaver. The bits are first encoded with help of LDPC encoder and interleaver and then the data is processed using modulator to map the input data into symbols based on the modulation technique used. The DWT OWDM symbol $s(t)$can be represented as equation (7) [26],

$$s(t) = \sum_{j \le J} \sum_{k} W_{j,k}(t)\psi_{j,k}(t) + \sum_{k} a_{j,k}\varphi_{j,k} \quad (7)$$

The orthogonality of these carriers relies on time location (k) and scale index (j). This symbol is clearly the weighted sum of wavelet and scale carriers which is similar to the Inverse Wavelet Transform (IDWT). In DWT-OWDM, the input data is processed same as in FFT-OFDM but the advantage in this case is that the cyclic prefix is not required because of the overlapping nature of wavelet properties. The data is processed in the IDWT block, whose output can be given as equation (8),

$$d(k) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} D_m^n 2^{\frac{m}{2}} \psi\,(2_k^m - n) \quad (8)$$

where k is the number of subcarriers ($0 \leq k \leq N-1$), D_n^m are the wavelet coefficients which represents the signal in scale and position on time-axis and $\psi(t)$ is the wavelet function with compressed factor m times and shifted n times for each subcarrier [34]. At the receiver side, the process is reversed. The output of discrete wavelet transform (DWT) is represented by equation (9),

$$D_m^n = \sum_{k=0}^{N-1} d(k)\, 2^{\frac{m}{2}} \psi(2_k^m - n) \quad (9)$$

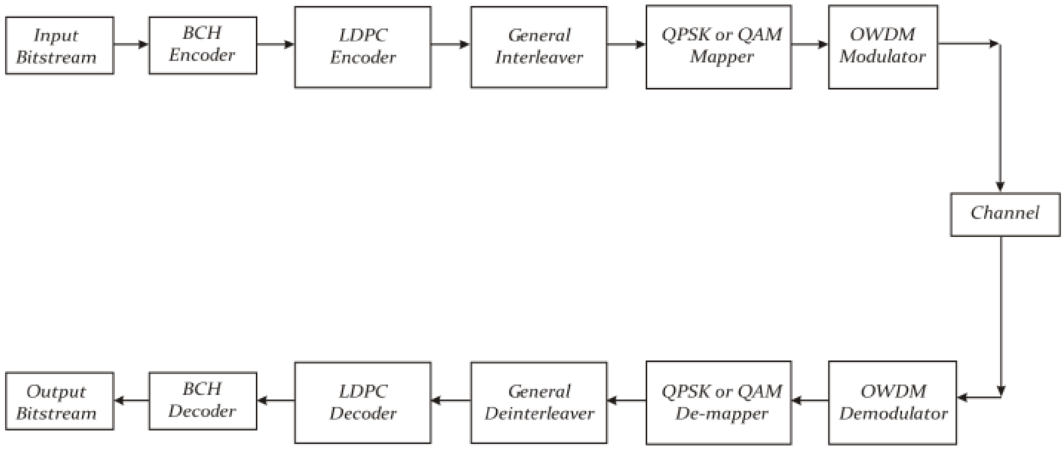

Figure 3(Block Diagram of Proposed DVB T2 System)

6.1 Advantage of using OWDM

- Increase in flexibility: There are a small number of parameters that can be changed in OFDM but they are fixed throughout one symbol. OWDM, on the other hand, allows each subcarrier to have different coding and different modulation depending on the channel requirements
- Increase in resilience to frequency selective fading by increasing the error correction on the effected sub bands
- Decrease in computational complexity from $ON = N\log_2 N \ to \ ON = N$ [35]

7. SIMULATION AND RESULTS

In this paper, the conventional DVB T2 system (which has an ODFM as modulation scheme) has been compared with modified DVB T2 system (which has an OWDM as modulation scheme). The BER performance of conventional DVB T2 system and modified DVB T2 system is examined over AWGN channel and fading channels. The PAPR performance of conventional DVB T2 system and modified DVB T2 system is also examined when no PAPR reduction scheme is applied in both the systems. MATLAB simulation has been carried out to compare the performance of conventional DVB T2 system with modified DVB T2 system and to find best wavelet family the different wavelet families of OWDM technique are also compared. The simulation of both DVB T2 techniques is done with same test run parameters. These parameters are listed in below Table 3. Figure 4 below show BER performance of conventional DVB T2 technique in AWGN channel with effect of CFO (Carrier Offset Frequency). Figure 5 below show BER performance of conventional DVB T2 technique in fading channel (Rayleigh and Rician channels). Figure 6 to 11 shows comparison of different wavelet families of OWDM based DVBT2 system with conventional DVB T2 system. Figure 12 and 13 shows BER comparison of conventional system and best wavelet families of OWDM under fading environment channels (Rayleigh and Rician). Figure 14 shows PAPR comparison of convention DVB T2 System and haar, bior3.1 and rbio3.1 families of modified OWDM based DVB T2 systems when no PAPR Reduction Technique is applied.

TABLE 3 PARAMETER USED FOR SIMULATION [1, 35]

Sr. No.	Parameter	OFDM DVB T2	OWDM DVB T2
1	Input Interface	Single Transport Stream	Single Transport Stream
2	Modes	Variable Coding	Variable Coding
3	Inner Coding	LDPC Coding	LDPC Coding
4	Outer Coding	BCH Coding	BCH Coding
5	Code Rate	½	1/2
6	Modulation	OFDM	OWDM
7	Mapping Schemes	QPSK	QPSK
8	Cyclic Prefix	¼	NA
9	Transform Type & Size	FFT, 4K	Haar, bior, Daubechies, 4k
10	Pilots	0.35 %	0.35 %
11	Channel Type	AWGN Rayleigh Rician	AWGN Rayleigh Rician
12	Symbol duration[us]	448	448
13	Carrier Spacing [kHz]	2.232	2.232
14	Signal Bandwidth [MHz]Normal mode	7.61	7.61
15	Channel Bandwidth [MHz]	6	6

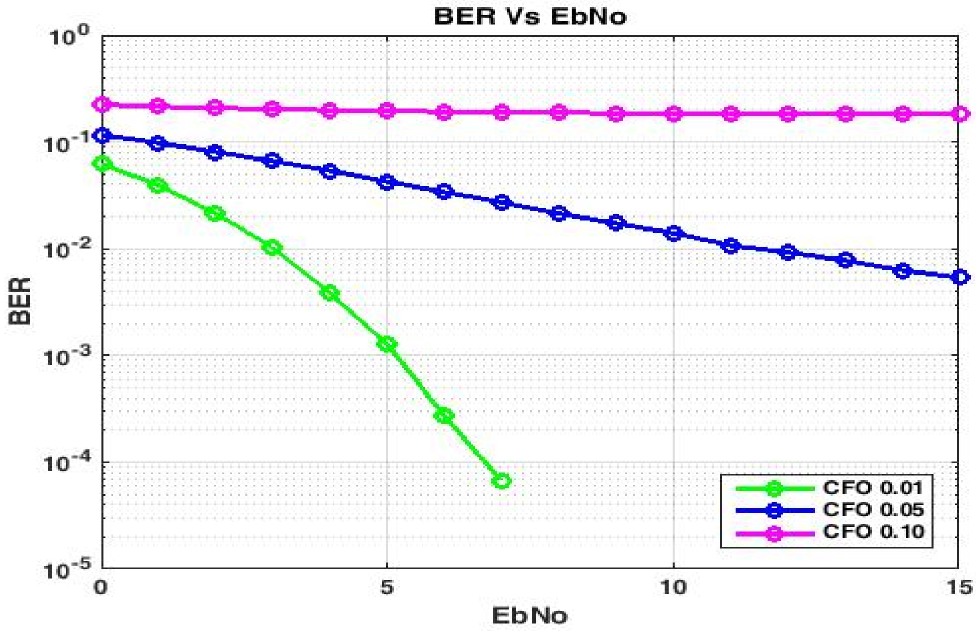

Figure 4 BER Performance comparison of convention OFDM based DVB T2 System in AWGN under effect of CFO (Carrier Frequency Offset)

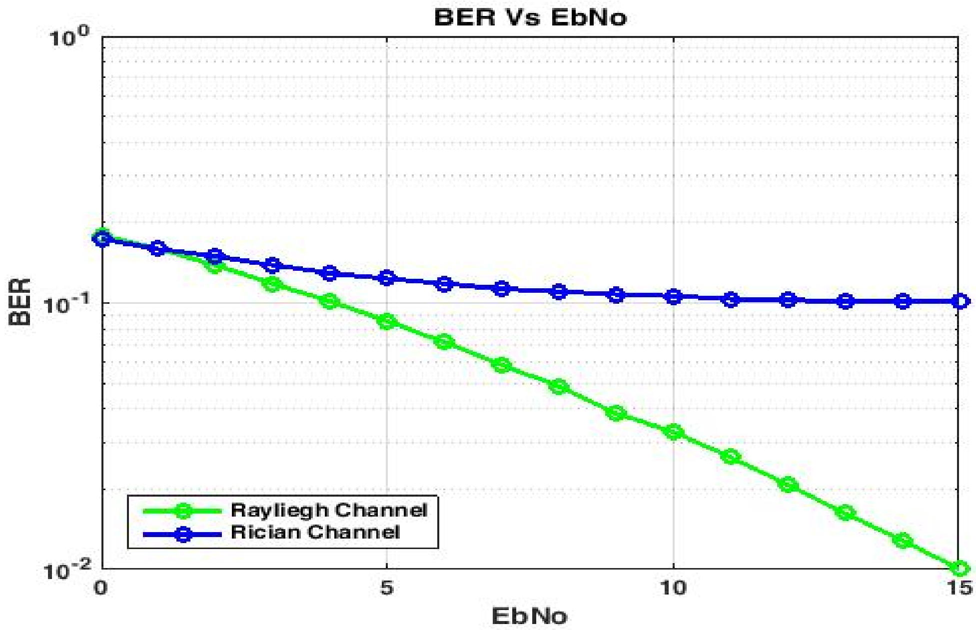

Figure 5 BER Performance comparison of DVB T2 System in Rician and Rayleigh Channel with Doppler frequency =100Hz and Crest factor=3 for Rician channel

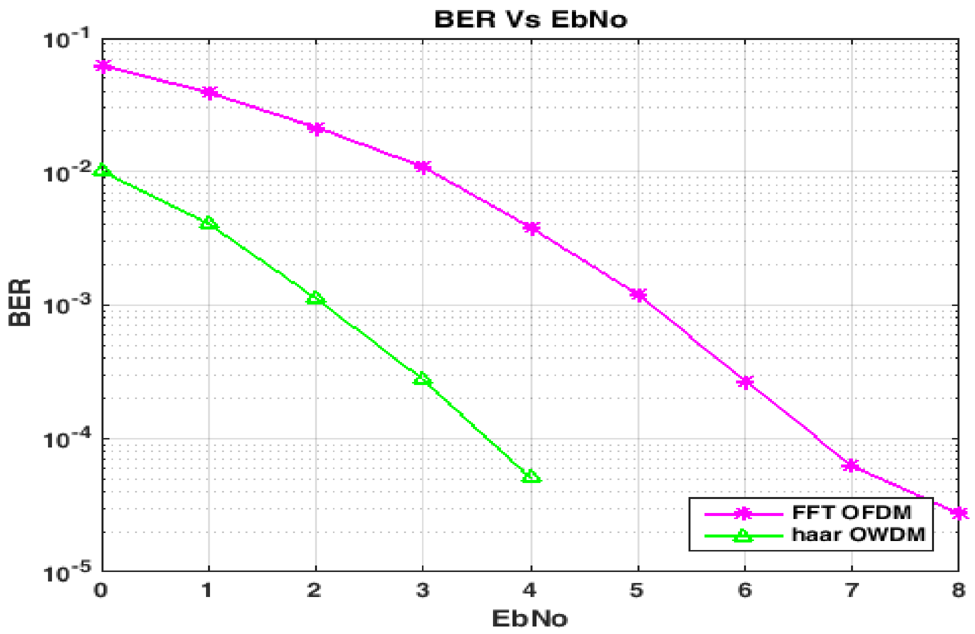

Figure 6 BER Performance comparison of convention OFDM based DVB T2 System and modified haar OWDM based DVB T2 system in AWGN channel with CFO=0.01

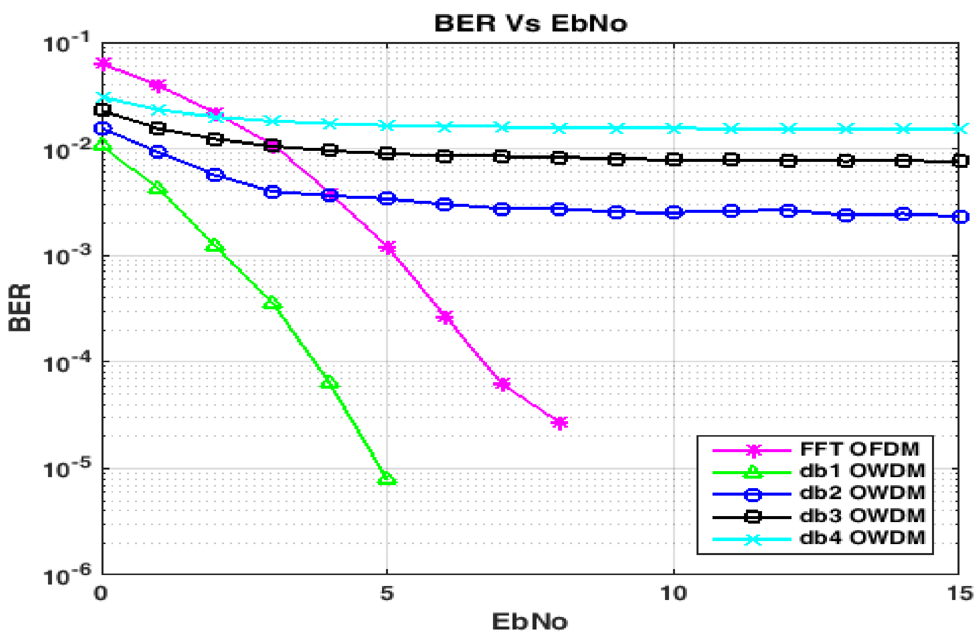

Figure 7 BER Performance comparison of convention OFDM based DVB T2 System and modified dbN OWDM based DVB T2 system in AWGN channel with CFO=0.01

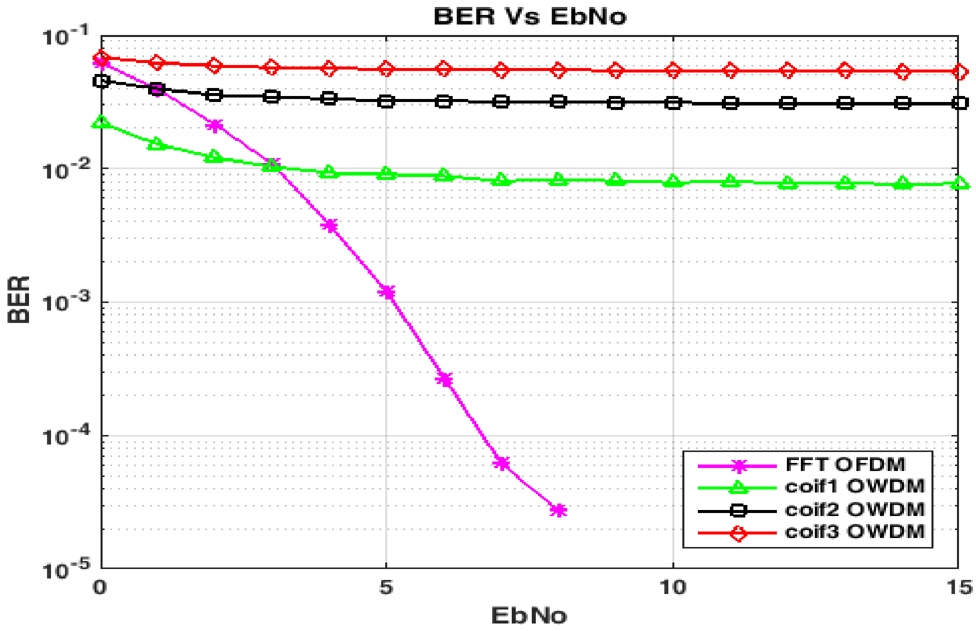

Figure 8 BER Performance comparison of convention OFDM based DVB T2 System and modified coif OWDM based DVB T2 system in AWGN channel with CFO=0.01

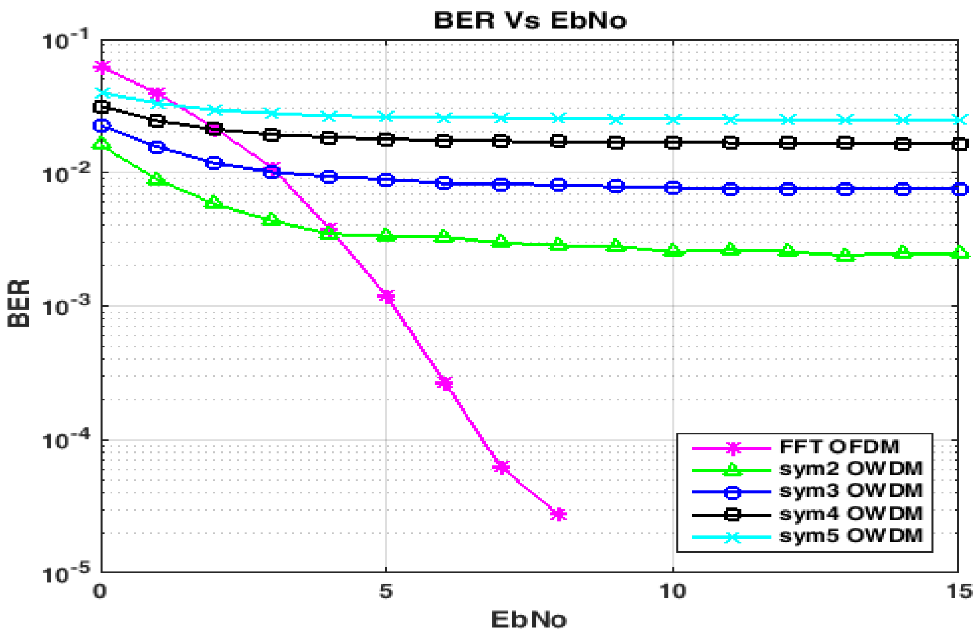

Figure 9 BER Performance comparison of convention OFDM based DVB T2 System and modified sym OWDM based DVB T2 system in AWGN channel with CFO=0.01

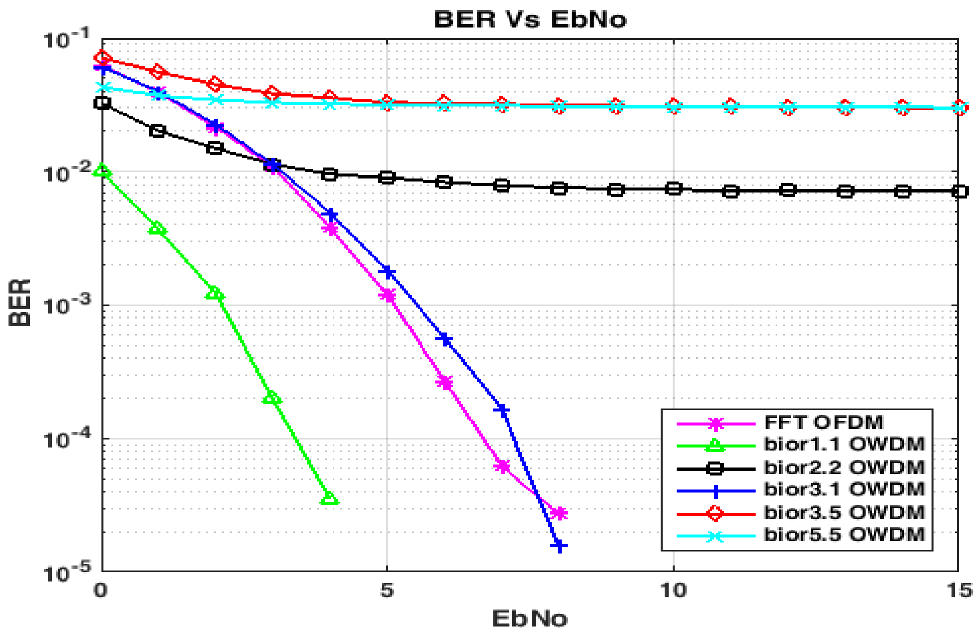

Figure 10 BER Performance comparison of convention OFDM based DVB T2 System and modified bior OWDM based DVB T2 system in AWGN channel with CFO=0.01

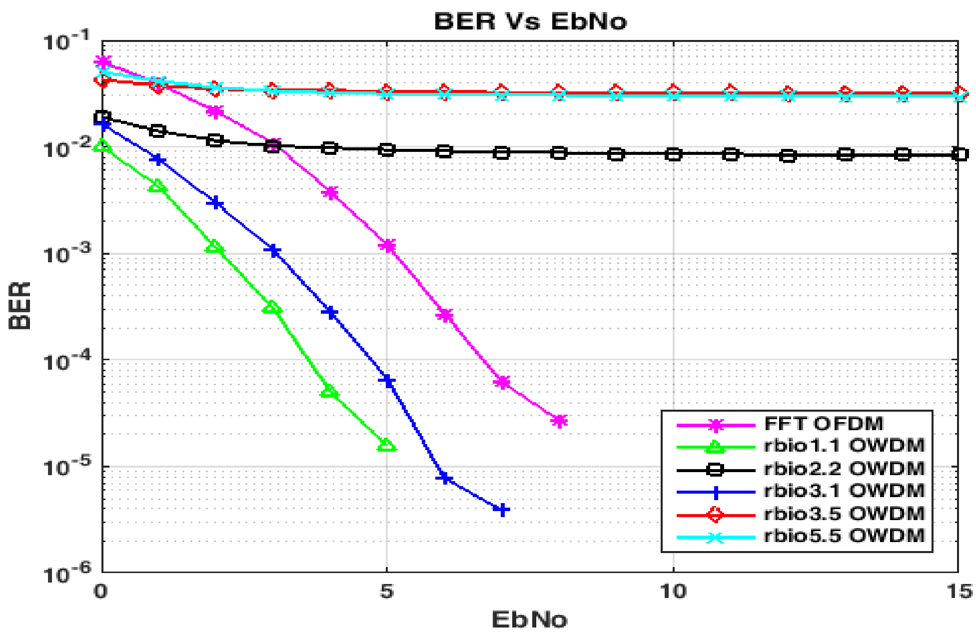

Figure 11 BER Performance comparison of convention OFDM based DVB T2 System and modified rbio OWDM based DVB T2 system in AWGN channel with CFO=0.01

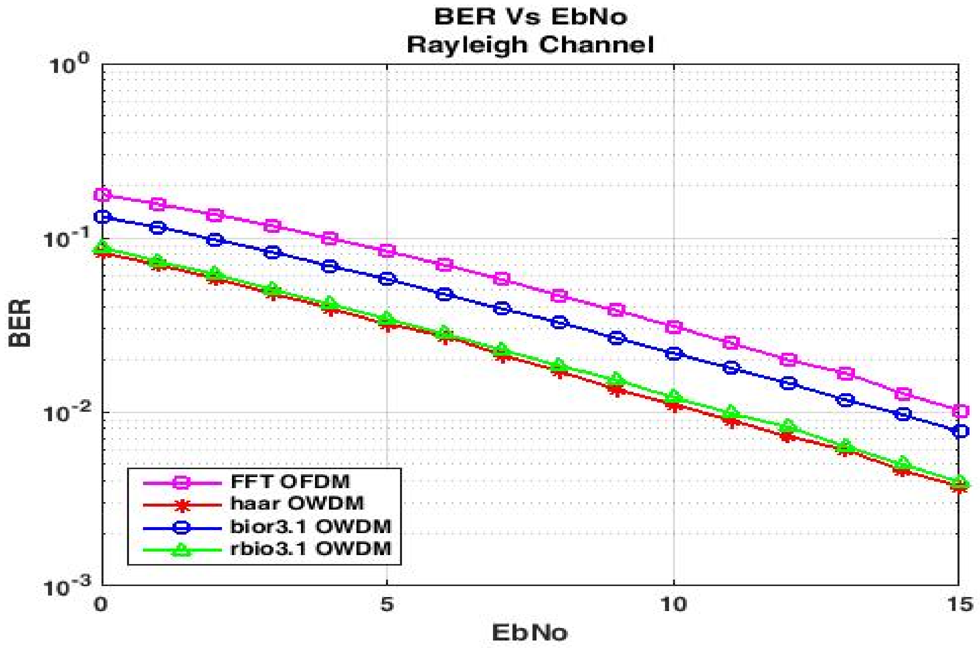

Figure 12 BER comparison of convention OFDM based DVB T2 System and efficient modified OWDM based DVB T2 systems in Rayleigh channel with Doppler shift=100Hz

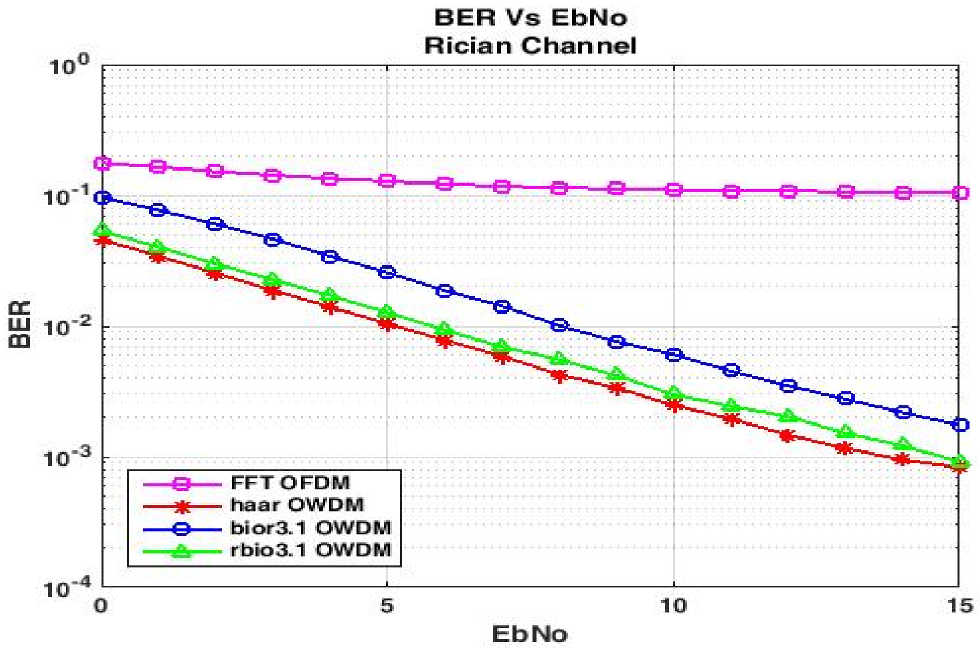

Figure 13 BER comparison of convention OFDM based DVB T2 System and efficient modified OWDM based DVB T2 systems in Rician channel with Doppler shift=100Hz and Crest Factor= 3

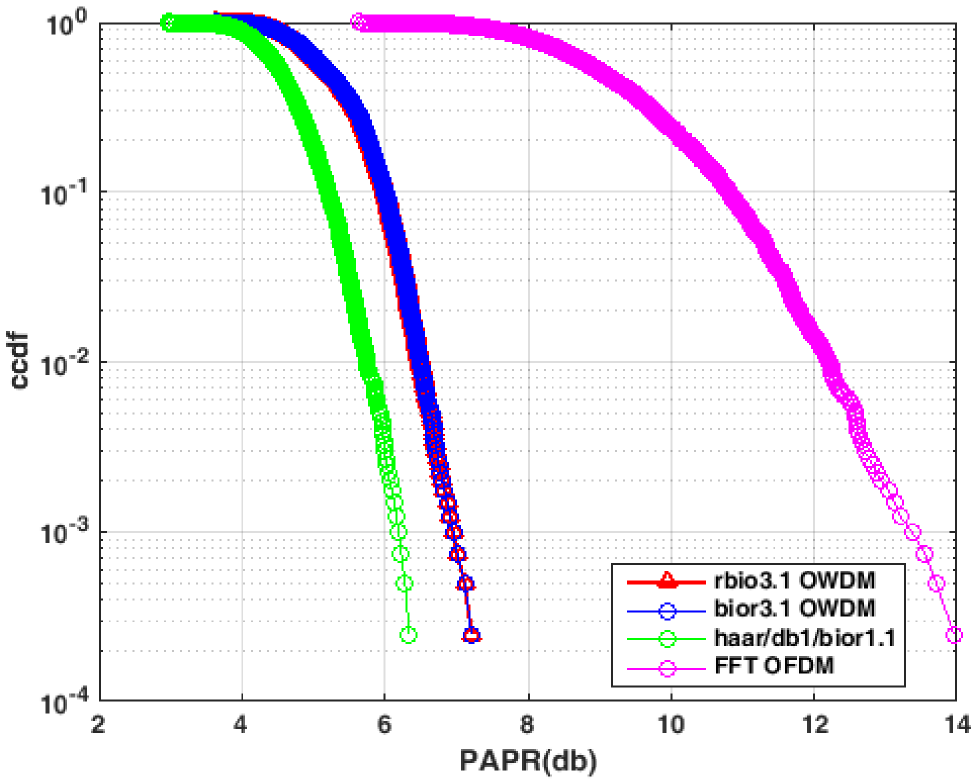

Figure 14 PAPR comparison of convention OFDM based DVB T2 System and haar, bior3.1and rbio3.1 families of modified OWDM based DVB T2 systems when no PAPR Reduction Technique is applied.

8. CONCLUSION AND DISCUSSIONS

Since it was launched, DVB T2 has shown that it is an extremely flexible and very functional system. The huge amount of configuration options allows the broadcasters to configure the system in the best way to maximize the robustness and capacity according to their intended reception scenarios. DVB T2 is the world's most advanced digital terrestrial television (DTT) system, offering more robustness, flexibility and at least 50% more efficiency than any other DTT system [1]. But, the current implementations of DVB T2 do not fully exploit all the capabilities. There are still several avenues and drawbacks which have to be explored. One of the drawbacks which DVB T2 technique takes into account is use of OFDM modulation scheme. The problem with the OFDM technique is that it is inherently, inflexible and requires a more complex IFFT core and OFDM signal also has a noise like amplitude variations and has a relatively high large Peak to Power Ratio (PAPR). This impacts the RF amplifier efficiency as the amplifiers need to be linear and accommodate the large amplitude variations and these factors mean the amplifier cannot operate with a high efficiency level. Another problem with OFDM is that it is sensitive to carrier offset and drift. To reduce the inter symbol interference OFDM system uses of cyclic prefix which reduces the bandwidth efficiency and increases the system complexity. As we discussed above many key factor in DVB T2 technique remains unsolved to research. This provides a good opportunity for researchers to work on system make it more robust and reliable for manufacturing industry. The results show that there were some OWDM schemes which outperformed an OFDM in BER comparison. The Haar wavelet appears to the best due to higher immunity to noise in channel and followed by the rbio3.1 and bior3.1 family. Daubechies family, while the Symlet wavelet is the least suited. In results also show that the PAPR value of OWDM system is smaller than OFDM system. The simulation of peak to average power ratio (PAPR) in an OWDM and an OFDM system shows that PAPR of OWDM is smaller than OFDM system about ± 7dB for OWDM with haar and ± 6 dB for OWDM with bior3.1. Thus OWDM techniques can be chosen as a best replacement to overcome the problems of OFDM techniques.

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