STM JOURNALS

Research & Reviews: Journal of Physics
ISSN: 2278-2265 (Online), ISSN: 2347-9973 (Print)
Volume 8, Issue 1
www.stmjournals.com

BER Analysis of Convolutional Encoded DWT-OFDM and coded FFT-OFDM under Different Simulation Conditions

***Simmi Garg*[1],*, *Anuj Kumar Sharma*[2], *Anand Kumar Tyagi*[3]**
[1]Department of Physics, I.K. Gujral Punjab Technical University, Kapurthala, Punjab, India
[2]Department of Mathematics, Lajpat Rai DAV College, Jagraon, Punjab, India
[3]Department of Applied Sciences, Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India

Abstract

In this study, we investigated the performance of Convolutional encoded Discrete Wavelet Transform based orthogonal frequency division multiplexing (DWT-OFDM) system over additive white Gaussian noise (AWGN) channel. QAM and PSK modulation have been used for simulations. Performance of Convolutional encoded DWT-OFDM is compared with uncoded DWT-OFDM system and encoded conventional OFDM system. Bit error rate (BER) is used as measuring parameter. Simulations have been done using MATLAB software. It has been found in simulations that Convolutional encoded DWT-OFDM outperforms uncoded DWT-OFDM as well as coded conventional OFDM system. Performance of Convolutional encoded DWT-OFDM system has been studied using different modulation schemes namely 16-QAM, 32-QAM, 64-QAM, 16-PSK and 32-PSK. It is found that BER of encoded DWT-OFDM system improves as we decrease the constellation number and performance of coded DWT-OFDM is better with QAM modulation than with PSK modulation. Different wavelets namely Haar, Dabuchiees, biorthogonal, Symlet are used for simulating the system. Further, impact of different members of same wavelet family is studied over the performance of encoded DWT-OFDM.

Keywords: *OFDM, DWT, FEC, FFT, BER*

****Author for Correspondence*** E-mail: simmigarg89@gmail.com

INTRODUCTION

Current generation demands for high speed data communication. Much of today's services require high speed and reliable data transmission schemes. From early stages till today there are many data transmission schemes that can send data at high speed with very less error rate. Scientists are continuously facing the challenge of improving the performance of current data transmission techniques. Orthogonal Frequency Division Multiplexing (OFDM) is one of the most promising techniques for improving the performance of current communication scenario [1]. OFDM is a multicarrier modulation scheme in which data is divided into large number of sub carriers which are modulated with different frequencies. Each sub carriers are orthogonal to each other. Advantage of OFDM is that it can reduce inter-symbol interference (ISI) and inter carrier interference (ICI) by the use of cyclic prefix (CP). CP is a part of original signal which is sent along with the original signal as a prefix. Generally, the length of CP is one-fourth of the length of data symbol. It must be mentioned here that insertion of CP reduces the band width efficiency. Conventionally, OFDM is implemented using IFFT and FFT [2]. Timing and frequency off set are the major limitations of FFT-OFDM. To conquer such limitations, discrete wavelet transform based OFDM (DWT-OFDM) system is implemented.

Wavelet transforms is a technique in which signal is studied in joint time and frequency domain [3]. Wavelets maintain their orthogonality even in difficult channel conditions. This very property of wavelets makes them most suitable for transmission of signal in noisy channels. Band width efficiency, robustness against ISI and ICI are another advantages of wavelet based OFDM. Response of wireless communication channel is more unpredicted than a wired channel due to many factors namely timing and frequency offset, noise, multi path, Doppler shift etc. So, transmitted data is more likely to consist of number of errors which should be corrected before final reception of signal. Error Detection and Correction (EDAC) is a scheme in which original data is first encoded at the transmitter end before transmission and encoded data is sent on the channel [4]. During transmission of signal through channel, data often get distorted due to varying channel conditions. Received data is first decoded to recover the original signal at the receiver end. Automatic repeat request (ARQ) and Forward error correction (FEC) are the two main types of EDAC. In ARQ, data is re-transmitted again and again until sender receives positive acknowledgement from the receiver. FEC do not require retransmission of signal [5, 6]. In FEC redundant bits are sent along with the original signal at the transmitter end and at the receiver side, the bits are decoded to obtain the original signal [7].

Gupta *et al* analyzed the performance of Wavelet based OFDM and conventional OFDM over AWGN and Rayleigh fading channel [8]. It is found that wavelet based OFDM performs better than conventional OFDM over both the channels. Further, for channel estimation of wavelet based OFDM and conventional OFDM LMMSE estimator perform better than LS estimator. Sharma *et al.* compare the performance of wavelet based OFDM and conventional OFDM using different orders of QAM and PSK modulation schemes in terms of BER over AWGN channel [9]. It is found that performance of both the systems is better with QAM modulation as compare to with PSK modulation scheme. Kaur *et al.* compares the performance of DWT-OFDM with conventional OFDM over fading environment for mobile Wi-max [10]. Joint impact of path loss, multipath fading and noise in mobile Wi-max environment is studied. Different modulation schemes are used with different path loss methods. Chen discusses the principle of FEC. Different types of FEC'S are discussed [11]. This study shows FEC code application in wireless communications. Pollet *et al.* studied the impact of carrier frequency offset on the BER of OFDM system [12]. The aim of this study is to study the performance of convolutional encoded DWT-OFDM and conventional OFDM using Quadrature amplitude modulation(QAM) and Phase shift keying modulation in Additive white Gaussian noise(AWGN) channel with different channel constellation M=16,32 &64. Different wavelets have been used for simulating the system. The schemes used for the implementation of the system are discussed in this section.

FOURIER BASED OFDM

Conventionally, OFDM is implemented using Fourier transforms [13]. Input data is first modulated into symbols. Inverse discrete Fourier transform is performed and CP is added to reduce ISI. The output of IDFT is as follows:

$$s(t) = \frac{\sum_{K=0}^{N-1} S(K) e^{\frac{j2\pi tk}{N}}}{N} \tag{1}$$

Where, s(t), 0<t< N-1 is a sequence in discrete time domain and S(k), 0<k<N-1 are complex numbers in discrete frequency domain. At the receiver end, the cyclic prefix is removed, DFT are performed and demodulation is done to recover original information. The output of DFT is as follows:

$$S(k) = \sum_{t=0}^{N-1} s(t) e^{\frac{-j2\pi tk}{N}} \tag{2}$$

WAVELET BASED OFDM

Conventionally, OFDM is implemented using FFT. But due to many limitations of FFT-OFDM and with the development of wavelet analysis, discrete wavelet transform emerges as an alternative to conventional FFT-OFDM. Wavelet transform is a method for studying the signal in both time and frequency domain. Hence, wavelet transform offers information in time and frequency domain simultaneously. DWT-OFDM do not require cyclic prefix. Hence, DWT-OFDM leads to better band width efficiency. Another advantage of DWT-OFDM over FFT-OFDM is that as the wavelets have better orthogonality so they are not affected by multi path propagation over wireless fading channel. Hence, DWT-OFDM provides more robustness against ICI and ISI. Wavelet based OFDM provide better out of band rejection as compare to FFT-OFDM. In the varying channel conditions, Doppler shift affects the orthogonality of carriers but wavelet based OFDM is less affected by Doppler shift [14]. Further, the order of complexity is very less in DWT-OFDM than FFT-OFDM. Hence, it is easy to implement DWT-OFDM. One another advantage of DWT-OFDM is its perfect reconstruction property [15]. If number of decomposition and reconstruction levels is same, then received data is very accurate copy of decomposed data.

Wavelet transformation is implemented using wavelet filters [16]. These wavelets filters are of different scales. Input signal is passed through high pass and low pass filters. Wavelet filters divide the original signal into two parts namely low pass and high pass sub band. These sub bands can be further divided into two parts. This decomposition process can be repeated up to desired level. The output of low pass filter is known as approximation coefficient. Approximation coefficient provides the smooth version of input signal and denoted as a(n). The output of high pass filter gives us Detail coefficient. Detail coefficient mainly consists of noise component present in input signal and denoted as d(n). At each stage, output of low pass and high pass filters are down sampled [17].

The meaning of down sampling is to remove the alternate samples from the input signal. This is done because after passing through the wavelet filter each sub band consist of only half of number of samples present in original signal. The process is repeated till the desired level is achieved. Figure 1 represents the process of decomposition and reconstruction.

After the desired level, all the coefficients are added to get the output of DWT. The output of DWT of signal s(t) is represented as:

$$S(n,k) = \sum_t s(t) 2^{\frac{n}{2}} \Psi(2^n t\text{-}k) \qquad (3)$$

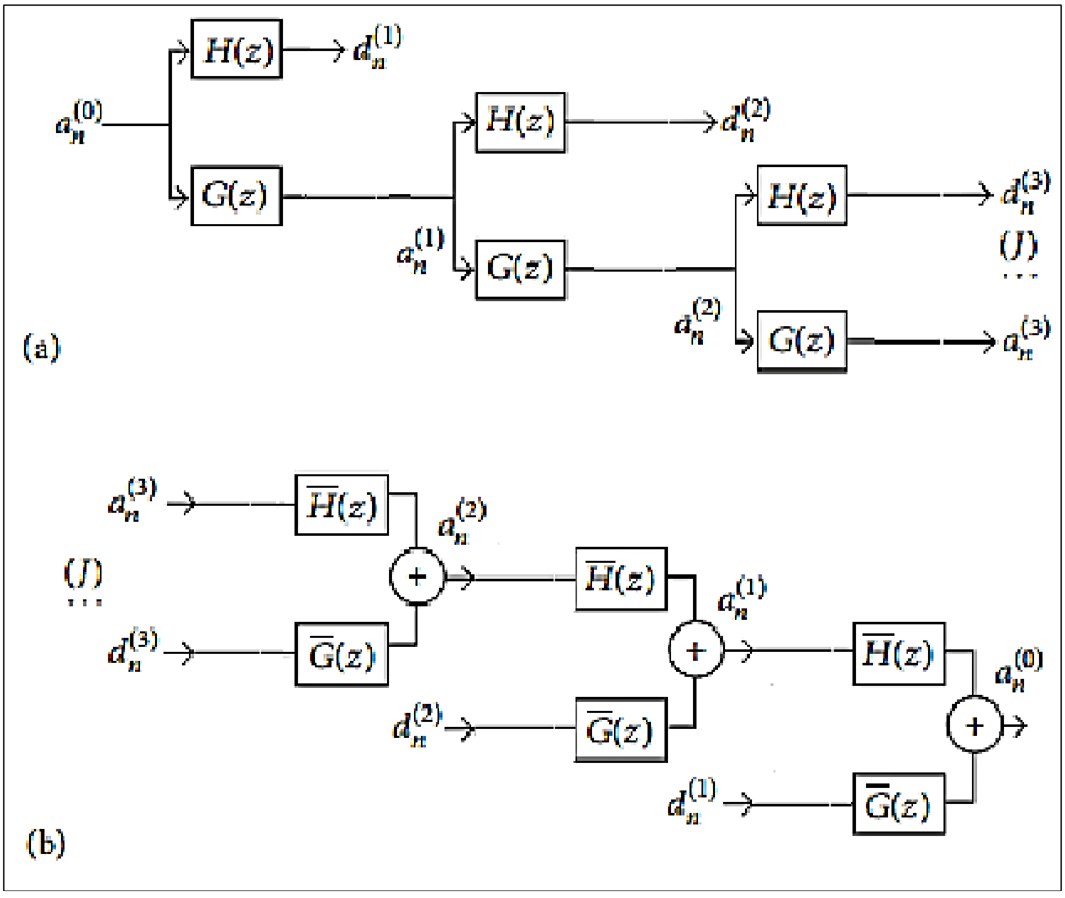

***Fig. 1:** (a) Decomposition Process, (b) Reconstruction Process.*

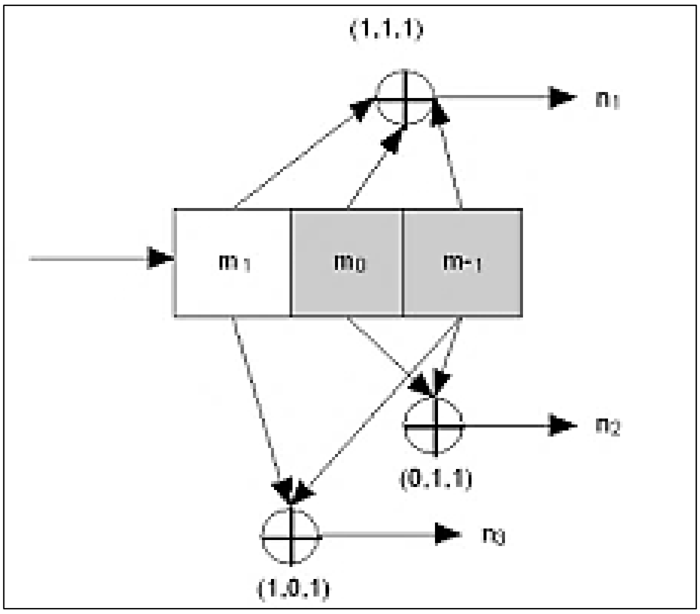

Fig. 2: *1/3 Code Rate Convolution Encoder. Here, the Shaded Registers Represent the Memory of the Encoder.*

At the receiving end, whole process is reversed. Wavelet coefficients are up sampled by a factor of 2. Up sampling means insertion of zeroes at the alternative positions. After the up sampling, wavelet coefficients are passed through low pass filters and approximation coefficients are passed through high pass filters. The outputs obtained are added together to recreate original input signal. Recreated signal is an exact copy of original input signal if number of decomposition and reconstruction levels is same. The output of IDWT is given by:

$$s(t)=\sum_{n=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} S(n,k)2^{\frac{n}{2}}\Psi(2^{n}\,t-k) \quad (4)$$

CONVOLUTIONAL ENCODING

Convolutional encoder consists of shift register and modulo 2 adder [18]. Convolution encoder produces fixed number of output bits from a fixed number of input bits. Output of Convolutional encoder output depends not only on current bit but also on the previous bits. There are many types of convolution encoder depending upon number of shift registers used and code rate [19].

Code rate is the ratio of number of input bits to number of output bits from the encoder. For example, if one input is sent to the encoder and three outputs are obtained from the encoder then code rate is 1/3. Hence, an encoder of 1/3 rate will produce 3 output bits for 1 input bits [20]. The input bits are first stored in shift registers and then modulo 2 adder performs modulo 2 additions to produce output sequences. Decoder of rate 1/3 encoder will perform the reverse operations i.e. it will produce 1 output bit for 3 input bits. Number of output bits depends upon the code rate. For code rate=k/n, n output bits are obtained from k input bits. A Convolutional encoder with code rate 1/3 is shown the Figure 2.

RESULTS AND DISCUSSIONS

Performance of the system is evaluated using MATLAB simulations. Input data stream is encoded using Convolutional encoder. Then, encoded data is modulated. We have used two types of modulation schemes namely QAM and PSK (and their higher orders). After this, IDWT of modulated data is performed using various wavelets. Haar, Dabuchiees, Symlet, biorthogonal and Reverse biorthogonal wavelets are used for evaluating the performance of the system. AWGN channel is used for transmission of data stream. After the insertion of noise by the transmission channel, DWT of received data is done. After this received data is demodulated. Demodulated data is decoded using Viterbi decoder with trackback length 16. For simulating conventional OFDM, IFFT and FFT operations are performed instead of IDFT and DFT operations. Bit Error rate (BER) performance of the system is studied as the function of SNR (Eb/No in dB) over AWGN channel. BER performance of encoded and conventional DWT-OFDM is compared with encoded conventional OFDM (FFT-OFDM). Encoded FFT-OFDM and conventional OFDM has also been studied using MATLAB simulations. Simulation parameters are depicted in Table 1.

Figure 3 shows BER performance of encoded DWT-OFDM, DWT-OFDM and encoded FFT-OFDM using Haar wavelet over AWGN channel. Results shows that encoded DWT-OFDM has better performance than DWT-OFDM and encoded FFT-OFDM. For example, to achieve BER of 10^{-3}, encoded DWT-OFDM require 7 db of Eb/No while DWT-OFDM require 9 dB and coded FFT-OFDM needs 10 dB of Eb/No value. Clearly, encoded DWT-OFDM outperforms both the systems in the higher Eb/No range.

Figures 4–7 represent the BER performance of Coded DWT-OFDM, DWT-OFDM and Coded FFT-OFDM using different wavelets implicitly Symlet, Dabuchiees, biorthogonal and Reverse biorthogonal. This is clear from the results that coded DWT-OFDM outperforms DWT-OFDM as well as coded FFT-OFDM with all the wavelets using 16-QAM modulation over AWGN channel. We have also investigated the comparative performance of coded DWT-OFDM system using different members of biorthogonal wavelet family. Results are depicted in Figure 8.

Table 1: *Parameters used for Simulations.*

Parameter	FFT-OFDM	DWT-OFDM
Cyclic prefix	¼ of number of sub carrier	-
Wavelet used	-	Haar, Dabuchiees, Symlet, biorthogonal, Reverse biorthogonal
Type of modulation	BPSK, 16, 32 and 64-QAM	16,32 and 64-QAM, PSK
Channel used	AWGN	AWGN
Code Rate	2/3	2/3
Traceback length	-	16

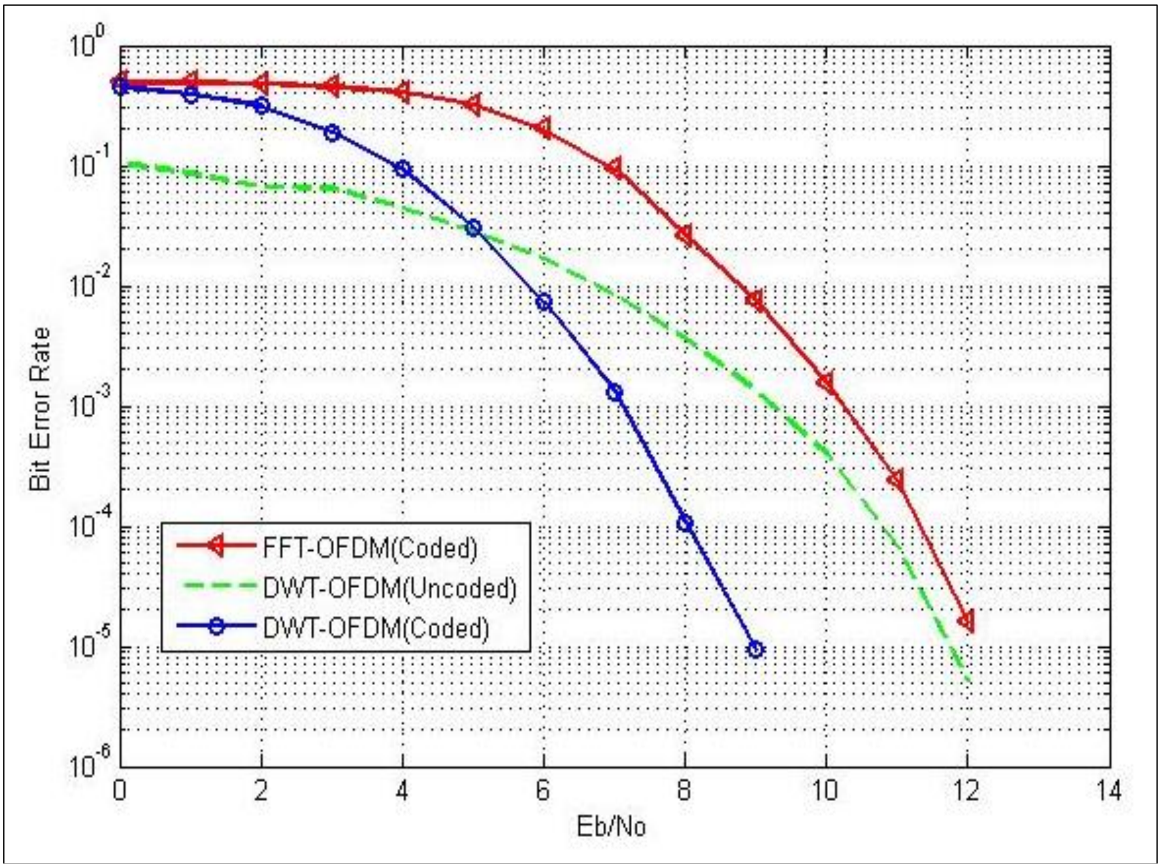

Fig. 3: *Comparison of dwt-coded, dwt-Uncoded and FFT-coded using Haar Wavelet.*

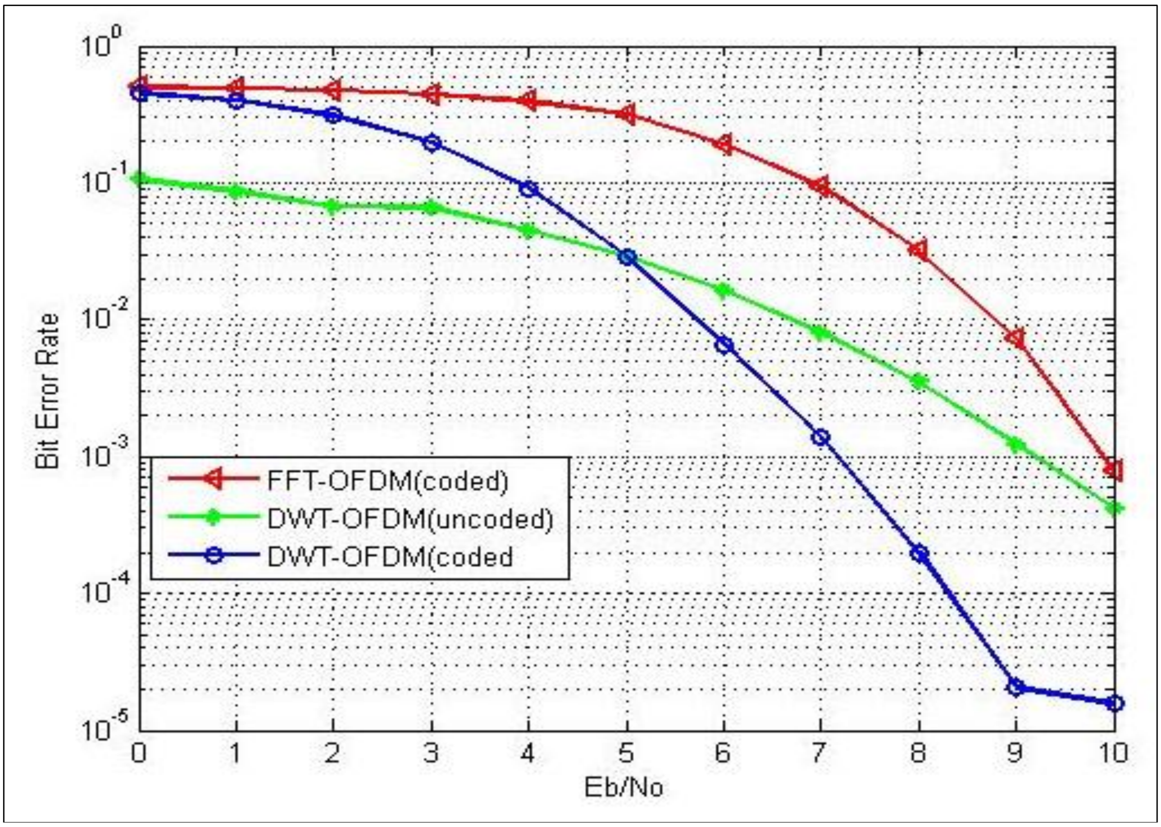

Fig. 4: *Comparison of DWT-coded, DWT-uncoded and FFT-coded using symmlet 8 Wavelet.*

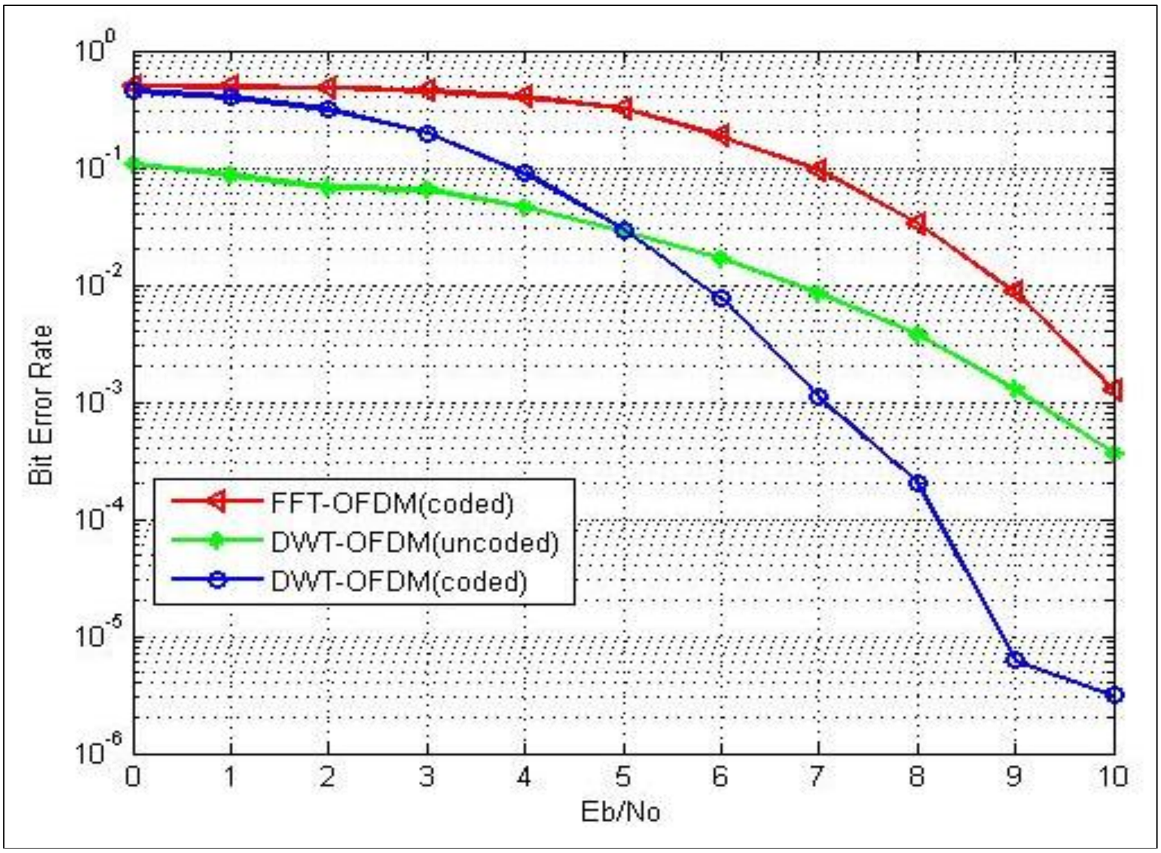

Fig. 5: *Comparison of DWT-coded, DWT-uncoded and FFT-coded using db8 wavelet.*

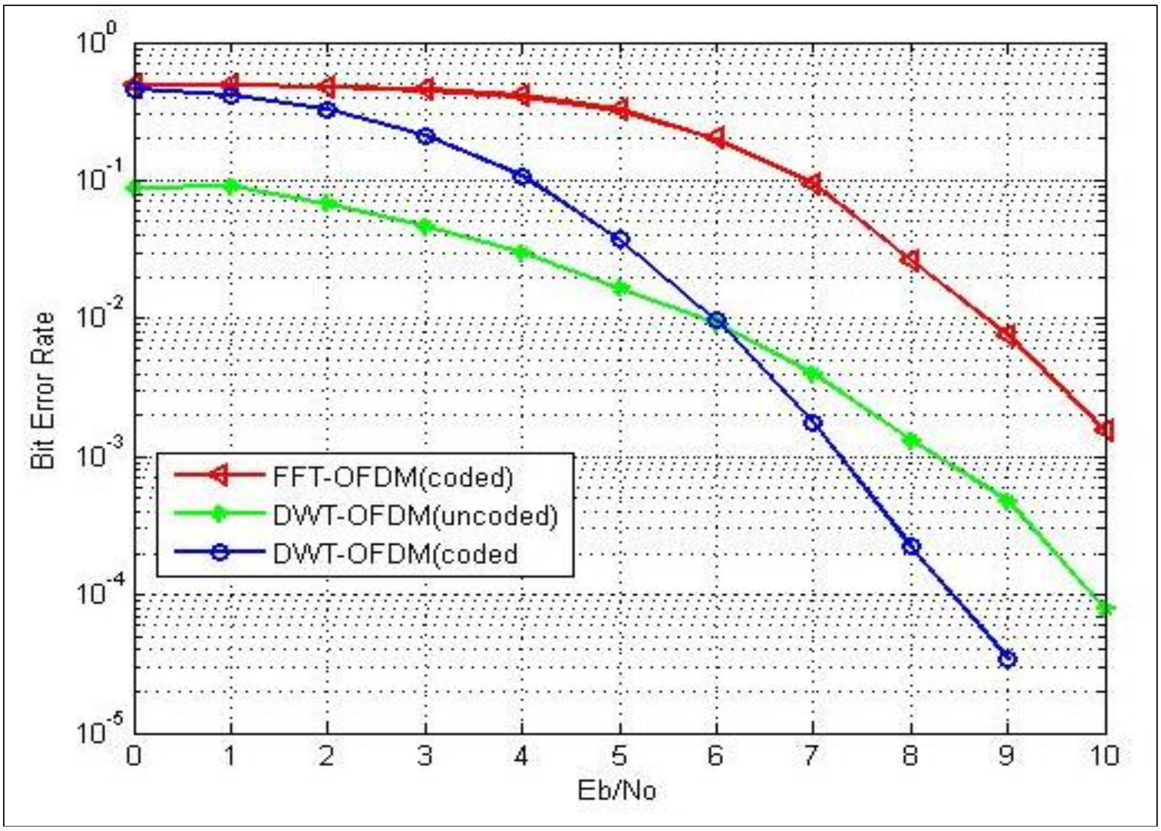

Fig. 6: *Comparison of DWT-coded, DWT-uncoded and FFT-coded using Bior 5.5 Wavelet.*

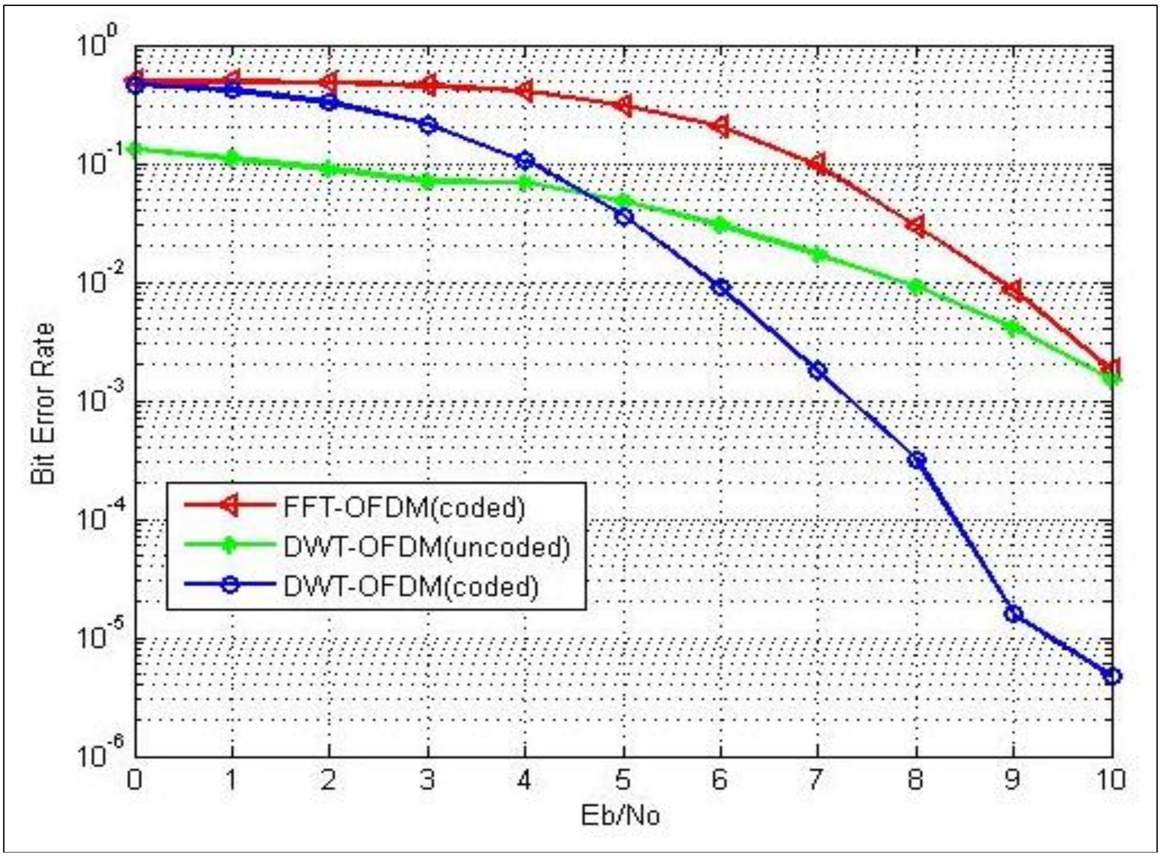

Fig. 7: *Comparison of DWT-coded, DWT-uncoded and FFT-coded using Rbio5.5 Wavelet*

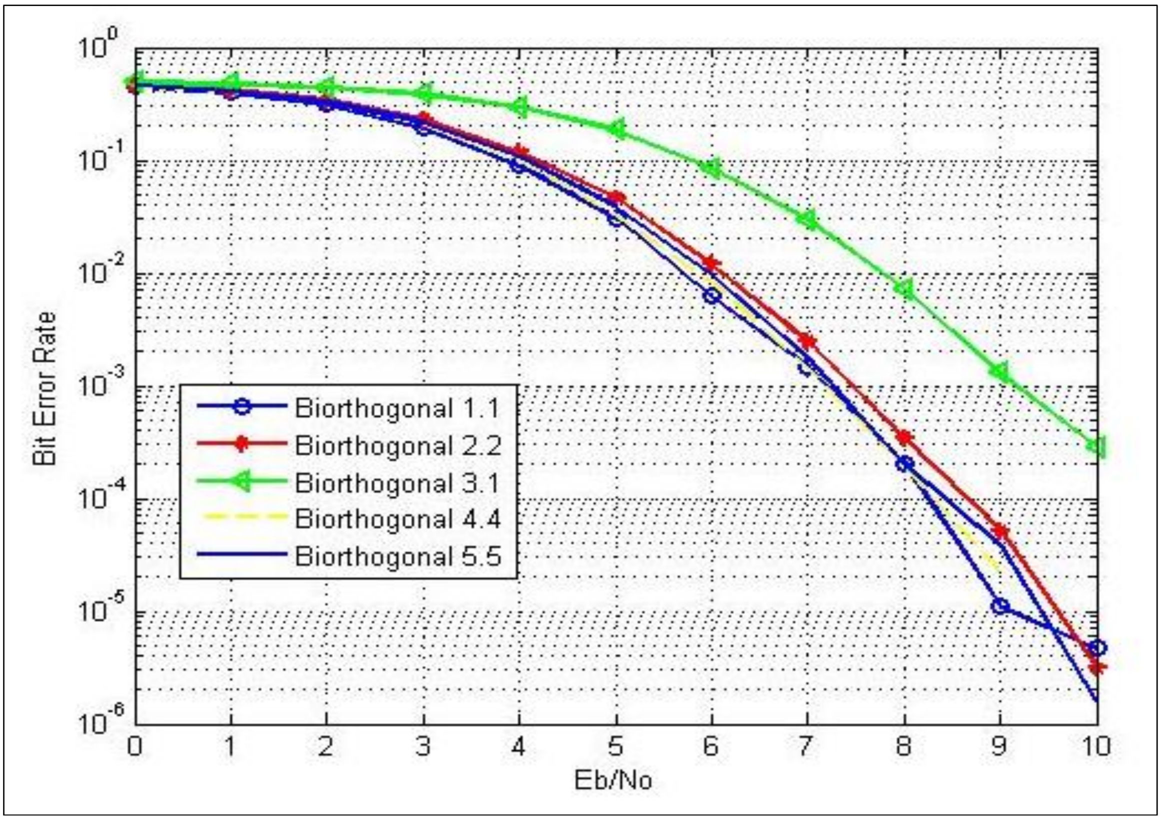

Fig. 8: *Comparison of DWT-coded, using Different Orders of Bior Wavelet.*

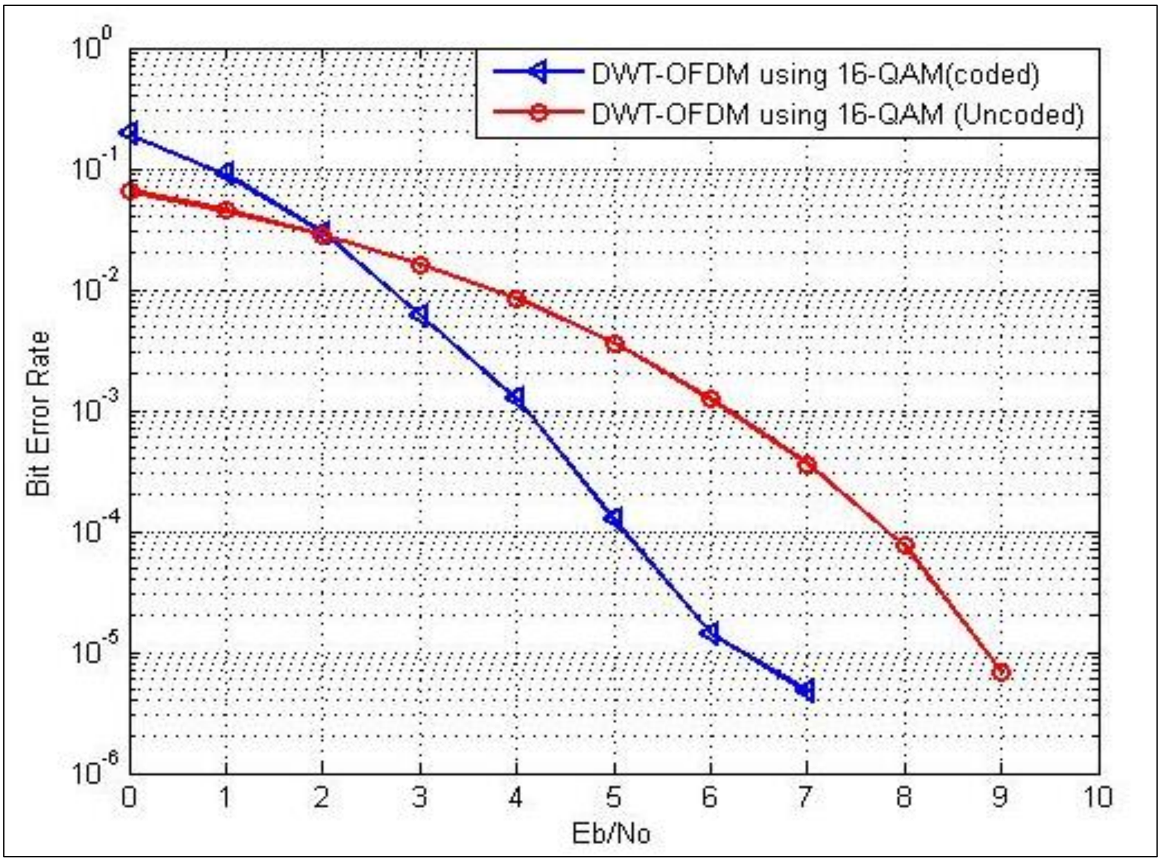

Fig. 9: *Comparison of DWT-coded, DWT-uncoded using 16-QAM Modulation.*

Figures 9–11 show the BER performance of coded DWT-OFDM and DWT-OFDM using 16-QAM, 32-QAM and 64-QAM modulation respectively over AWGN channel using Haar wavelet. From the results it is clear that with the increase in the order of QAM modulation, the performance of coded DWT-OFDM decrease.

Figure 12 depict the BER performance of coded DWT-OFDM using 16,32 and 64-QAM modulation using Haar wavelet. It has been found that coded DWT-OFDM perform better with lower order of QAM modulation. For example, to achieve BER of 10^{-4}, coded DWT-OFDM require 8 dB of Eb/No value while DWT-OFDM require 11 dB and coded FFT-OFDM require 13 dB of Eb/No. Hence, to achieve same BER coded DWT-OFDM requires very less Eb/No value. Figure 13 shows the performance of coded DWT-OFDM using 16, 32 and 64-QAM modulation using reverse biorthogonal 5.5 wavelet over AWGN channel. It is observe that results are similar as we obtain with Haar wavelet. But there is a remarkable difference between two results is that reverse biorthogonal 5.5 involve more Eb/No value to achieve same BER over AWGN channel as compare to with Haar wavelet.

Further, the work is investigated by using PSK modulation schemes. Figure 14 depict the BER performance of coded DWT-OFDM system over AWGN channel using Haar wavelet with 16,32 QAM and PSK modulations. It has been found the system perform better with QAM modulation than with PSK modulation. Further, to achieve a particular BER, required Eb/No is more with PSK modulation than with QAM modulation. For example to achieve a BER of 10^{-5}, coded DWT-OFDM with 16-QAM modulation requires 9 dB, while with 16-PSK modulation it requires 15 dB. This shows clearly that performance of Coded-DWT-OFDM is better with QAM modulation than PSK modulation. Further, coded DWT-OFDM with 32-QAM modulation requires 12 dB, while with 32-PSK modulation it requires 20 dB. This result again shows that with the increase in the order of modulation the performance of the system reduces.

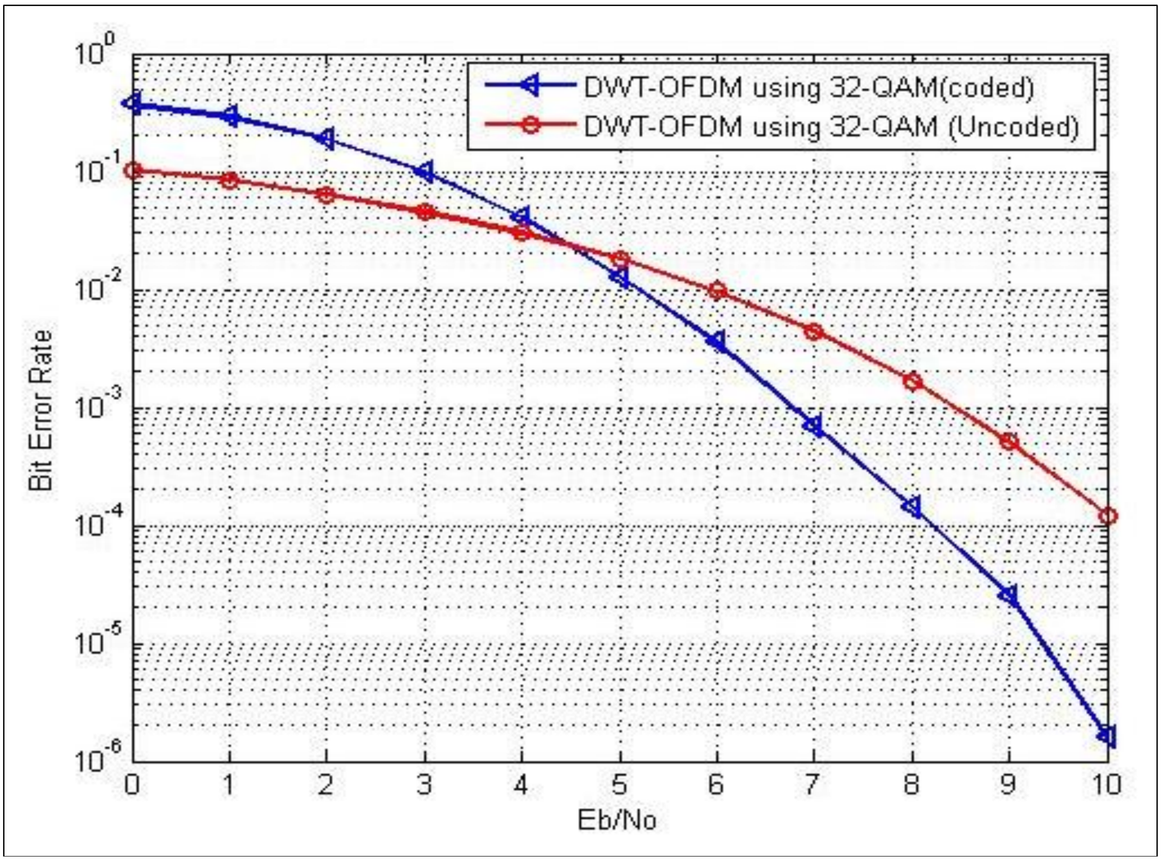

Fig. 10: *Comparison of DWT-coded, DWT-uncoded using 32-QAM Modulation.*

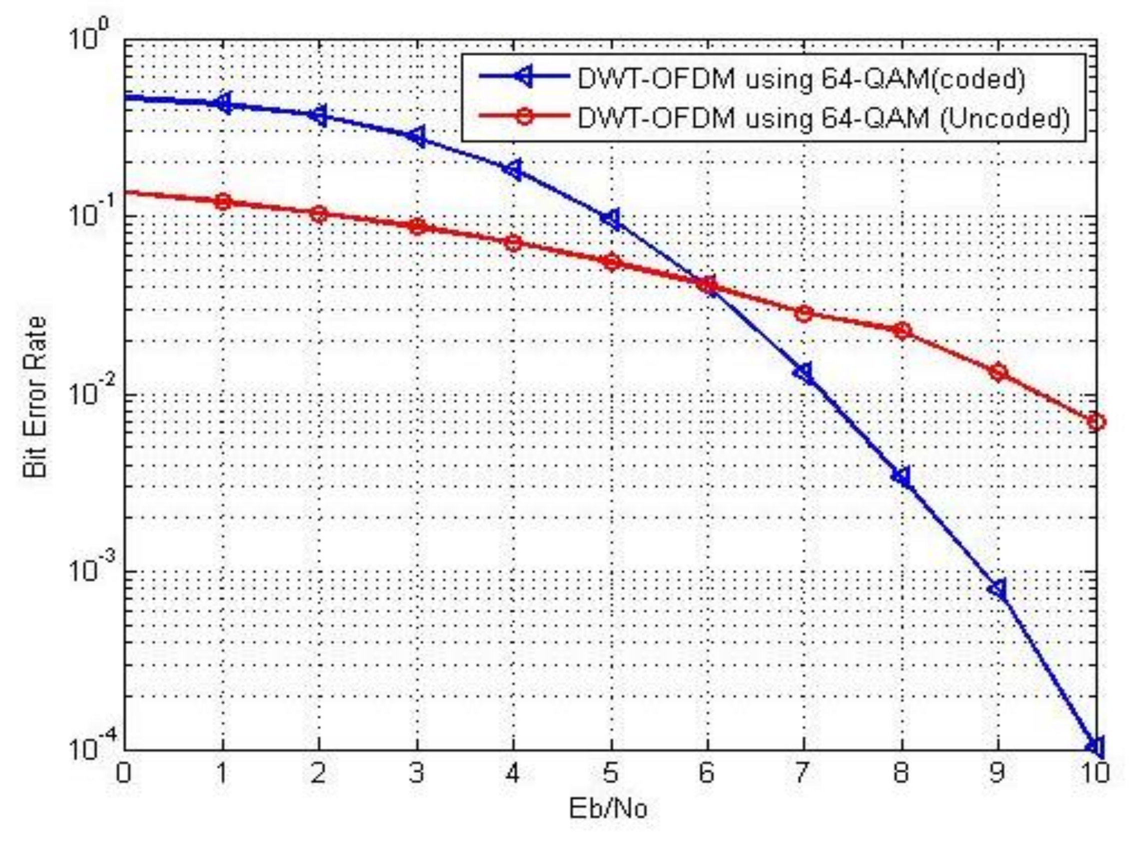

Fig. 11: *Comparison of DWT-coded, DWT-uncoded using 64-QAM Modulation.*

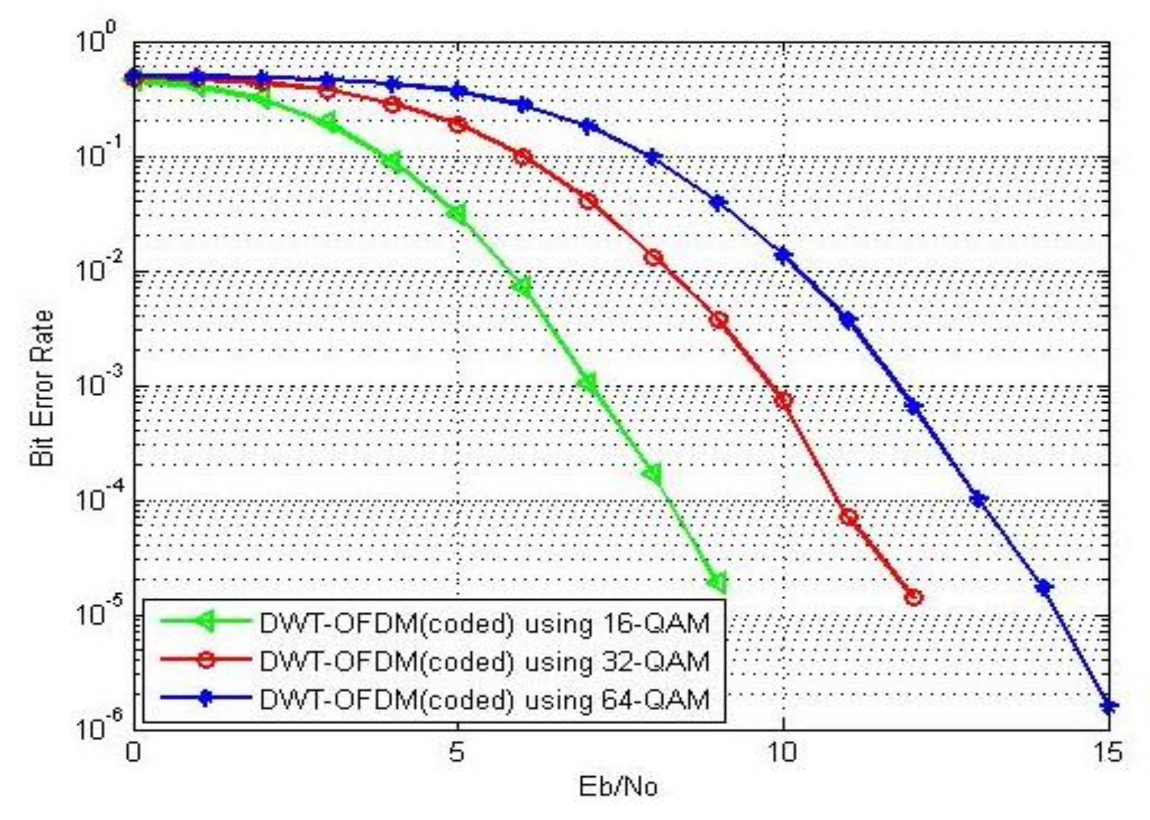

Fig. 12: *Comparison of DWT-coded using 16, 32, 64-QAM Modulation with Haar Wavelet.*

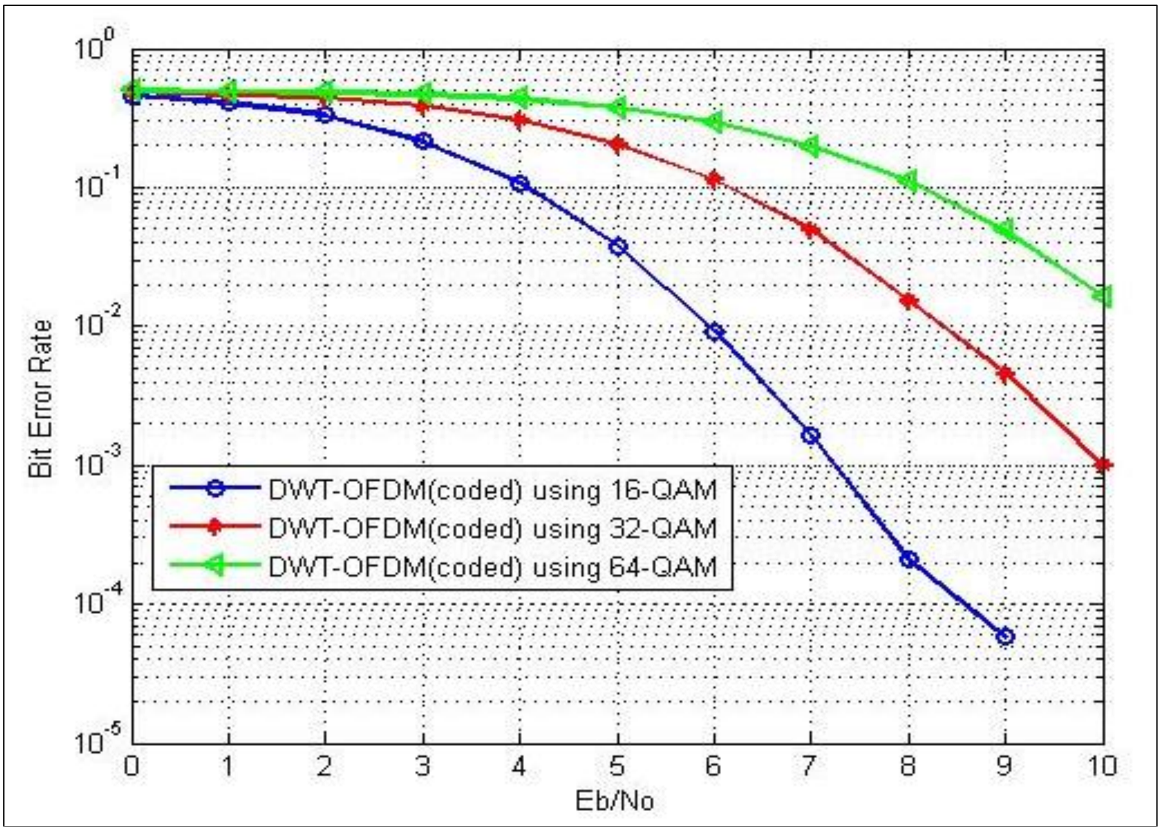

Fig. 13: *Comparison of DWT-coded using 16, 32, 64-QAM Modulation with Rbio5.5 Wavelet.*

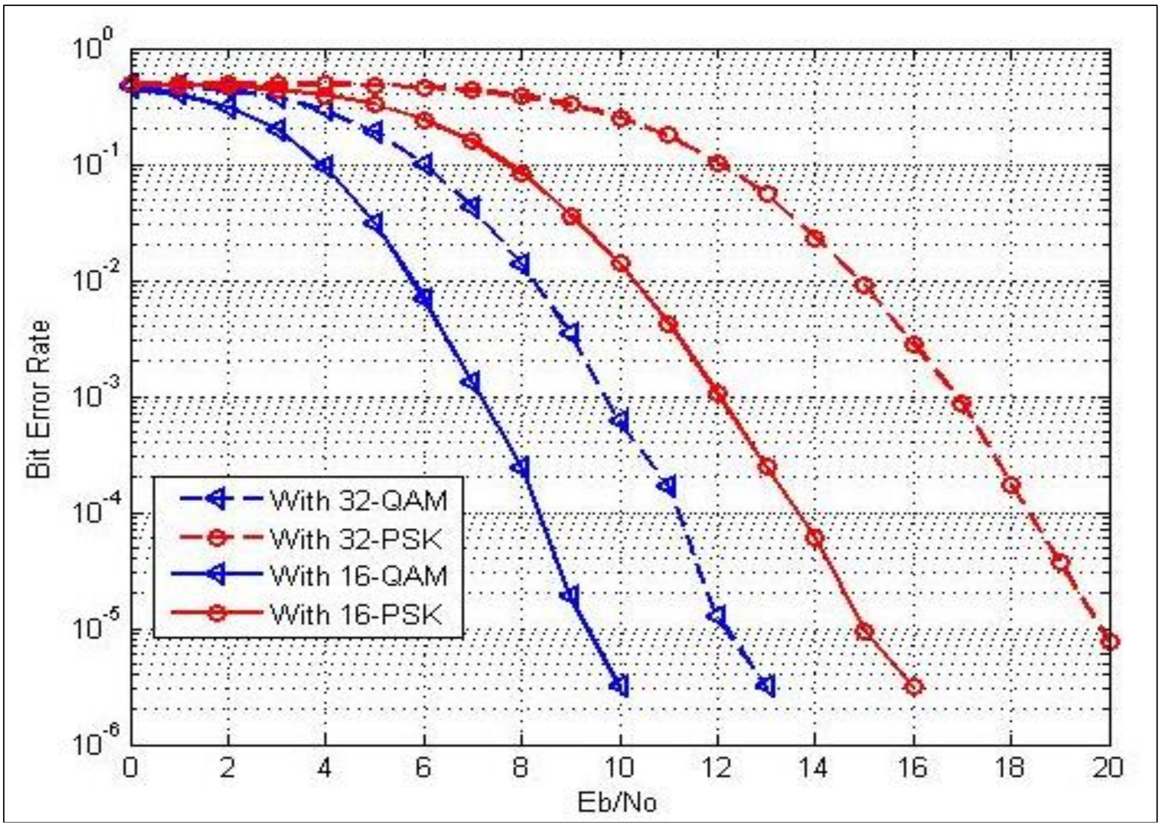

Fig. 14: *Comparison of DWT-coded using 16, 32-QAM and 16,32-PSK Modulation with 'Haar' Wavelet.*

CONCLUSIONS

In this study, we analyzed the performance of convolutional coded DWT-OFDM system and compare its performance with that of DWT-OFDM and coded conventional FFT-OFDM. The simulations shows that performance of convolutional coded DWT-OFDM is better than DWT-OFDM as well as coded FFT-OFDM over AWGN channel irrespective of the type of wavelet used. Simulation is also done for various members of biorthogonal family. It is found that performance of coded DWT-OFDM is best with 16-QAM modulation among 32 and 64 QAM modulations. The simulations are also performed for different orders of PSK modulations. The performance of coded DWT-OFDM system is found to be better with QAM modulation.

ACKNOWLEDGEMENTS

Authors are thankful to anonymous reviewers for their careful reading and useful comments for the improvement of the present research work. Also, authors gratefully acknowledge the support provided by the I.K. Gujral Punjab Technical University, Kapurthala, Punjab, India.

REFERENCES

1. Weinstein S, Ebert P. Data transmission by frequency division multiplexing using the discrete Fourier transform. *IEEE Transactions on Communications*. 1971; 19: 628–634p.
2. Chang R, Gibby R. Theoretical study of performance of an orthogonal multiplexing data transmission scheme. *IEEE Transaction on Communication Technology*. 1968; 16:529–540p.
3. Soman K, Resmi N, Ramachandran K. Inside into Wavelet-from theory to practice. New Delhi: Prentice Hall; 2004.
4. Hamming R. Error detecting and error correcting code. *The Bell System Technical Journal*. 1950; 29(2):147–160p. DOI: 10.1002/j.1538-7305.1950.tb00463.x
5. Lin S, Costello D, Miller M. Automatic repeat request error control schemes. *IEEE Communication Magazine*. 1984; 22(12): 5–17p.
6. Yamamoto H, Itoh K. Viterbi decoding algorithm for Convolutional codes with repeat requests. *IEEE Transaction Information theory*. 1980; 26: 540–547p.
7. Mizuochi T. Recent progress in forward error correction and its interplay with transmission impairments. *IEEE Journal on Selected Topics in Quantum Electronics*. 2006; 12(4). DOI: 10.1109/JSTQE.2006.876597.
8. Gupta M, Tiwari S. Performance evaluation of conventional and wavelet based OFDM system. *International Journal of Electronics and Communications*. 2013; 67: 348–354p.
9. Sharma V, Singh G. BER assessment of conventional OFDM and wavelet based OFDM over AWGN channel. *Optic*. 2014; 125: 6071–6073p.
10. Kaur H, Kumar M, Sharma A, Singh H. Performance analysis of DWT based OFDM over fading environment for mobile Wi-max. *Optik*. 2016; 127: 544–547p.
11. Chen T. Analysis of forward error correcting codes. *Proceedings of IEEE International Conference on Design and Manufacturing Informatization*. 2011, p. 329–332.
12. Pollet T, Bladel M, Moeneclaey M. BER sensitivity of OFDM systems to carrier frequency offset and Wiener phase noise. *IEEE Transactions Communication*. 1995; 43: 191–193p.
13. Zhang H, Yuan D, Jiang M, Wu D. Research of DFT-OFDM and DWT-OFDM on different transmission scenarios. *Proceedings of IEEE ICITA*. 2004.
14. China H, Fazel K and Papke L. On the performance of convolutionally-coded CDMA/OFDM for mobile communication system. *Proceedings of IEEE PIMRC,* 1993, Yokohama, Japan, p. 468–472.
15. Lakshmanan M, Nikkokar H. A review of wavelets for digital wireless communication. *Journal on Wireless Personal Communication*. 2006; 37:387–420p.
16. Kumbusar V, Kucur O. Performance comparison of wavelet based and conventional OFDM system in multipath Rayleigh fading channels. *Digital Signal Processing*. 2012; 22: 841–846p.

17. Haque M, Ullah S, Ahmed M. Performance evaluation of a wireless Orthogonal Frequency Division Multiplexing system under various concatenated FEC channel-coding schemes. *Proceedings of the 11th International conference on Computer and Information Technology*; 2008 Khulna, Bangladesh.
18. Rashed M, Kabir M, Reza M, Islam M, Shams R, Saleh M, Ullah S. Transmission of Voice Signal: BER Performance Analysis of Different FEC Schemes Based OFDM System over Various Channel. *International Journal of Advanced Science and Technology*. 2011; 3.
19. Gupta M, Sharma V. To improve bit error rate of turbo coded OFDM transmission over noisy channel. *Journal of Theoretical and Applied Information Technology*. 2009; 8: 162–168p.
20. Dwivedi V, Gupta A, Kumar R, Singh G. Performance Analysis of coded OFDM system using various coding scheme. In: *Progress in Electromagnetics Research Symposium Proceedings*, Moscow, Russia, 2009, p. 1249–1253.

Cite this Article
Simmi Garg, Anuj Kumar Sharma, Anand Kumar Tyagi. BER Analysis of Convolutional Encoded DWT-OFDM and coded FFT-OFDM under Different Simulation Conditions. *Research & Reviews: Journal of Physics*. 2019; 8(1): 7–19p.