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PERFORMANCE ANALYSIS OF ½ CODE RATE CONVOLUTION ENCODED DWT-OFDM SYSTEM WITH DIFFERENT MODULATION SCHEMES

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ABSTRACT

DWT-OFDM has drawn most of the attention in the field of wireless communication. But to provide better efficiency of the communication channel, error correction codes are proposed. In this paper, we investigated the performance of ½ rate convolution encoded discrete wavelet transform based orthogonal frequency division multiplexing system (DWT-OFDM) over Additive White Gaussian noise channel (AWGN). Different orders of QAM and PSK modulations have been used for simulating the system in MATLAB environment. Bit error rate (BER) has been used as measuring parameter to evaluate the performance of proposed system. We have compared the performance of ½ rate convolution encoded DWT-OFDM system with conventional encoded system. It is shown in the results that convolution encoded system performs better than conventional encoded system under all the simulating conditions. Different modulation scheme namely 16-QAM, 32-QAM, 64-QAM, 16-PSK and 32-PSK have been implemented to modulate the encoded data bits. It has been found that convolution encoded DWT-OFDM system performs better with QAM modulation than PSK modulation. Further, performance of the system increases with decrease in the constellation number of modulation scheme.

Keywords: AWGN, BER, DWT, FEC, OFDM

Section-1

INTRODUCTION

In past years, need of quick and accurate transmission of data is increasing at a high rate. Wireless communication is an indispensible part of today's communication system. Orthogonal frequency division multiplexing (OFDM) [1] is one of the most capable multicarrier techniques due to its excellent performance in multipath channel. Although, due to time varying nature of wireless communication channel, inter carrier interference (ICI) and inter symbol interference (ISI) occur. However, ISI and ICI can capably be reduced by the means of cyclic prefix (CP). CP is a part of transmitted data bits which is inserted before each block of data symbols. But, CP can reduce ISI and ICI at the cost of spectral efficiency of the communication system [2]. Conventionally, OFDM is implemented using IFFT and FFT. The conventional Fourier-based complex exponential carriers of a multicarrier system are replaced with ortho normal wavelets in order to reduce the interference[3].

Wavelet transforms is a technique in which signal is studied in joint time and frequency domain. The main advantage of wavelet based transforms is that wavelets do not loss their orthogonality even in noisy channels[4]. Apart from this, wavelets have many other advantages over conventional FFT-OFDM system. More robustness to carrier frequency offset, inter symbol interference (ISI) and inter carrier interference (ICI) are the main benefits of wavelets than FFT based system.

Wireless communication channel is more prone to errors than wired channel. Multipath fading and Doppler's effect are the main causes of error occurrence in wireless communication. This leads to very large BER for the transmitting information data bits. Channel coding is used to combat this problem. 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[5]. During transmission of signal through channel, data often get distorted due to varying channel conditions. At the receiver side, received data is decoded to retrieve the original signal. Various error correcting codes has been proposed to improve the performance of communication channel and to decrease the BER. Low density parity check codes, Golay codes, Reed Solomon codes, Turbo codes are some of the popular codes. Literature of error correcting codes is vast but on the broad level, these are divided into two categories- Automatic Repeat Request (ARQ) and Forward Error Correction (FEC) code. **ARQ[6]** is an error detection and correction scheme in which receiver responds the sender with positive or negative acknowledgement. If correct data is received then receiver sends the positive acknowledgement and vice-versa. Hence, ARQ can be used when reverse channel is available for sending acknowledgement. FEC do not require retransmission of signal. In FEC [7] 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.

Gupta et al [8] studied the performance of wavelet based FDM system and conventional OFDM system over Rayleigh fading channel and AWGN channel. It is shown in the results that wavelet based OFDM perform better than conventional OFDM. G.M.Kumar [9] et al. studied the performance of conventional OFDM and Wavelet based OFDM system under different channel conditions. It is shown in the results that wavelet based OFDM outperforms then conventional OFDM system. Cimini[10] simulated the digital mobile channel using Orthogonal frequency division multiplexing technique. S.Baib [11] et al. compares the performance of DFT based system, DWT based OFDM system and discrete wavelet packet based OFDM over multipath fading channel. The objective of this paper is to study the performance of ½ rate convolution encoded DWT-OFDM using Quadrature amplitude modulation (QAM) and phase shift keying (PSK) modulation. Additive white Gaussian channel (AWGN) is used as transmission channel. The paper is organized as follows: - section 2 compares conventional and wavelet based OFDM system. Section 3 introduces convolution encoder, section 4 consists of system model and results obtained in simulations. Paper is concluded in section 5.

Section-2

FOURIER VS. WAVELET BASED SYSTEM:

Fourier transformations based OFDM are one of the most popular choices for sending data over transmission channels. In Fourier analysis, the signal is divided into the sum of large number of sines and cosines[12]. The orthogonality property of sines and cosine makes them best suited choices for basics functions. But Fourier-OFDM is applicable to stationary signals only. It does not give the information about time of occurrence of a particular frequency. To overcome this problem, it was suggested to use Short time Fourier transform (STFT). In STFT, the original signal is represented in two dimensions with time and frequency as two components. But this leads to difficulties of localization of time and frequency simultaneously. If we look for better time localization, then the signal should be divided into small sections but small sections will lead to poorer frequency localization. On the other hand, if large sections are made for better frequency resolution it leads to poorer time localization. As in STFT, window length is fixed, so at lower frequency it catches less cycles and at high frequencies, it catches more cycles. This is undesirable. Addition of cyclic prefix wastes the band width. To overcome these difficulties, windows of different lengths should be used. This idea leads to development of Wavelet Transforms.

Wavelet transforms[13] studied the signal in joint time and frequency domain simultaneously. During transmission of the signal, signal is first decomposed into two parts by passing through high pass and low pass filters. Low pass filters pass the components having frequency below the half of highest frequency component. High pass filters pass the components having frequency above the half of highest frequency component[14]. The output of high pass filter is called detailed coefficients and that of low pass filter is called approximation coefficients.

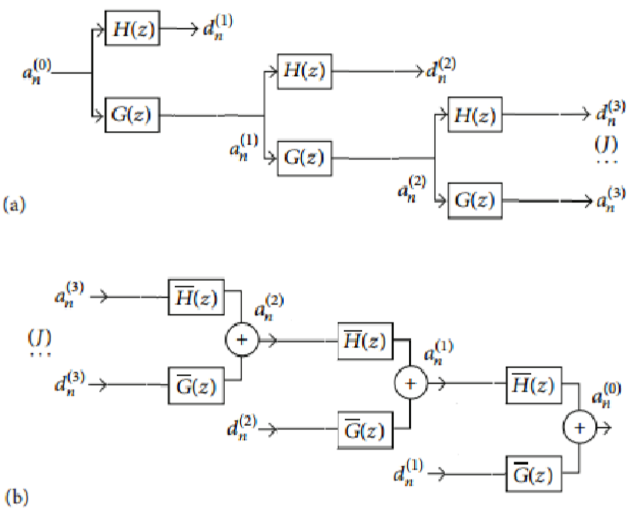

Fig.1- a)decompostion process b) Reconstruction Process

The process can be repeated till desired level is achieved. At the reconstruction stage, the original signal is recovered from the wavelet coefficients[15]. For perfect reconstruction of the original signal, the number of levels of decomposition and reconstruction must be the same.

SECTION 3- CONVOLUTION ENCODING:

Convolution codes are very efficient error correcting codes that can reduce BER to a remarkable limit. In convolution encoding the output data bits depends not only on present input bit but also on previous data bits[16]. There are various types of convolution encoder depending upon the code rate. Code rate is defined as the ratio of number of input bits to the encoder to the number of output bits. For example, a convolution encoder of code rate ½, generate double output bits than the input bits. Hence, convolution encoder increases the number of transmitted bits by inserting redundant bits. These redundant bits improve the performance of wireless communication system on the cost of band width efficiency[17]. A convolution encoder consists of shift register and modulo 2 adder.

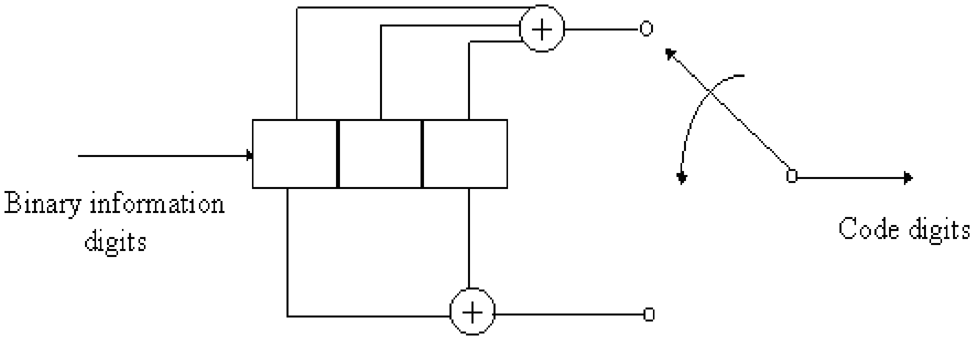

Fig 2: ½ rate convolution encoder

The block diagram of ½ rate convolution encoder is shown in the figure 2. There are three shift registers that are used for encoding the original data bits. Hence, at a time the encoder uses three bits to generate the output bit. The input bits are sent to the encoder and modulo2 adder performs its function. The output bit is generated. Then the bits get shifted sequentially and the process is repeated till the length of the input data bits[18]. Convolution encoder is represented using state diagram, tree diagram or trellis diagram.

a) State diagram: - State diagram represents all the possible states of the convolution encoder. State diagram of convolution encoder represented in diagram is shown in figure 3 below. State diagram for above shown convolution encoder consists of 8 possible states 000, 001, 010, 100, 110, 101, 011, 111. When input bit arrive the encoder jumps from one state to another. The lines joining the different states of the encoder indicates the transition of the states. All the dashed lines represent the incoming of input bit 1 and solid lines represent the event of arrival of input bit 0[19]. The bits written with the incoming bits on the arrows shows the output of the encoder for that particular event.

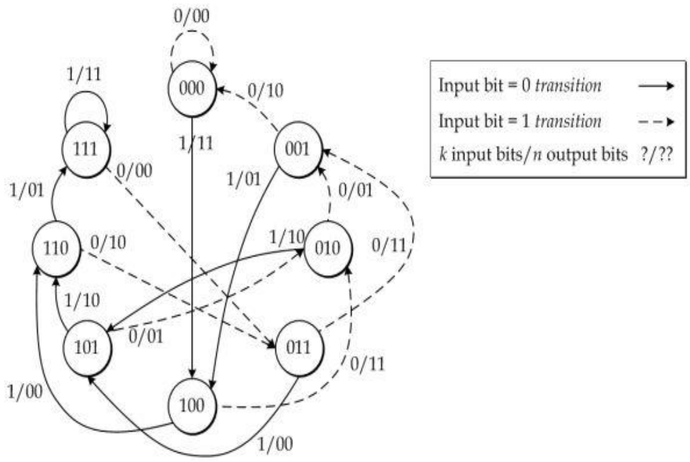

Fig 3: - State diagram of ½ rate convolution encoder with three memory registers

b) Trellis diagram:- Trellis diagrams are little complex than state and tree diagram still they are more preferable for higher constraint length. In the trellis diagram, the all the possible sates of the encoder are represented on the y axis and the incoming bits are shown on the x- axis[20]. Trellis diagram of the encoder shown above is shown in figure 4. all the dashed lines represents the event of coming input bit 0 and all h solid lines represents the event of coming input bit 1. Due to the incoming bit the encoder jumps from one state to another. The bits written in the parenthesis represents the output for the encoder for that particular event

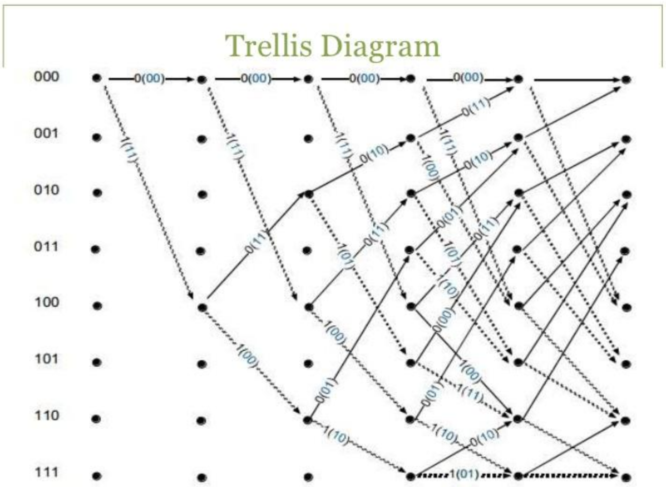

Fig 4: - State diagram of ½ rate convolution encoder with three memory registers

SECTION-4 SYSTEM MODEL AND RESULTS

Block diagram of system model is presented in figure 5. Input data is first encoded using convolution encoder of code rate ½. Then encoded data is modulated using the modulation under consideration. Different types of modulations are used in this paper. QAM and PSK modulation and their higher orders are used for modulating the encoded data bits in this paper. Discrete wavelet transformation of modulated data is done. Haar wavelet is used for simulating the system model. Then the input data is sent through the communication channel. We have used AWGN channel for transmitting the input data bits. Communication channel distort the transmitted data stream. At the receiver side, the demodulation of received data bits is done with the help of demodulator. Finally the decoder decodes the unmodulated data bits to recover the original data bits. To simulate the conventional model, DWT and IDWT blocks are removed by IFFT and FFT blocks and encoded data after modulation is sent through the communication channel.

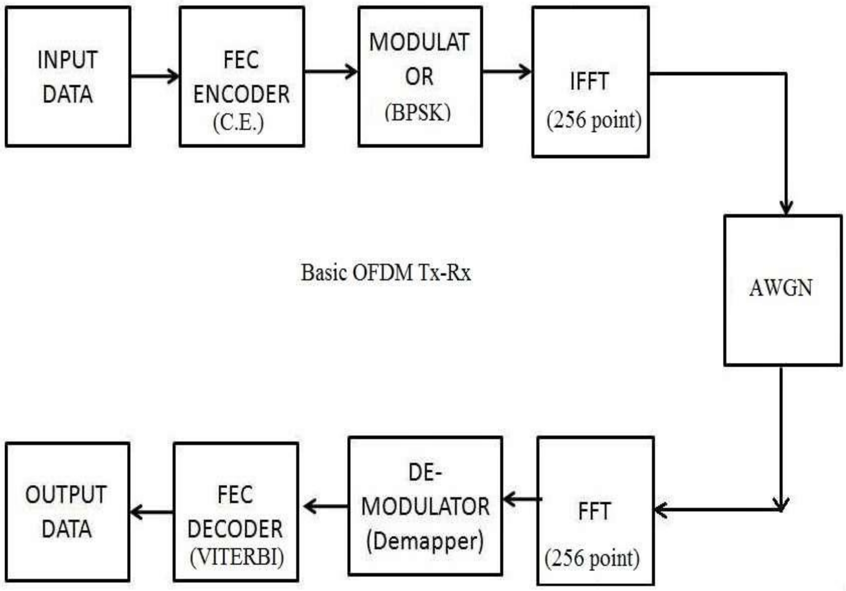

Fig 5:- Block diagram of encoded FFT-OFDM system

Performance of the system is studied in terms of BER as a function of Signal to noise ratio SNR (Eb/No in dB) over AWGN channel. BER performance of encoded DWT-OFDM is compared with conventional encoded system. MATLAB software is used for simulating the proposed system model.

Parameters used for simulation are

Parameter	Conventional encoded system	DWT-OFDM
Number of input data bits	100000	100000
Wavelet used	-	Haar,
Type of modulation	16,32 and 64-QAM, 16,32 and 64-PSK	16,32 and 64-QAM, 16,32 and 64-PSK
Channel used	AWGN	AWGN
Code Rate	1/2	½
Eb/No range (in dB)	0 to 15	0 to 15

Fig. 6 shows BER performance of encoded DWT-OFDM and conventional encoded system using Haar wavelet over AWGN channel. 16-QAM modulation is used for modulating the data bits. Results shows that encoded DWT-OFDM has better performance than conventional encoded system. For example, to achieve BER of 10^{-2} , encoded DWT-OFDM require 8 db of Eb/No while conventional encoded system needs 11 dB of Eb/No value.

Fig. 7-8 represents the BER performance of coded DWT-OFDM and conventional coded system using 32-QAM and 64-QAM modulation scheme respectively. Haar wavelet is used for simulating the system over AWGN channel. It is clear from the graphs that encoded DWT-OFDM system outperforms with both modulation schemes.

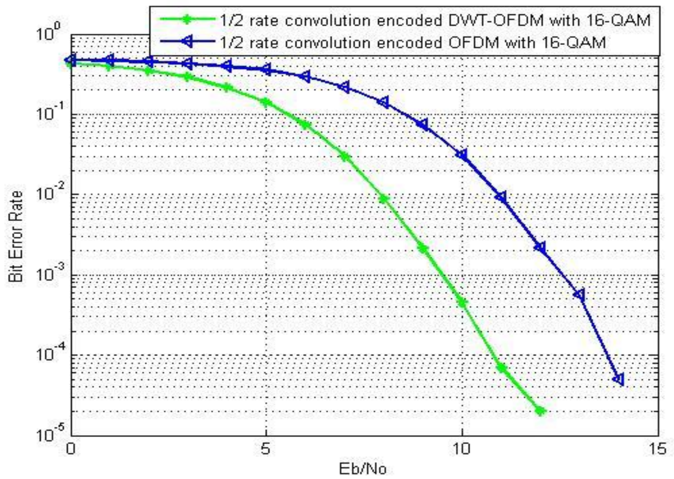

Fig 6: - Performance of ½ rate convolution encoder with 16-QAM modulation

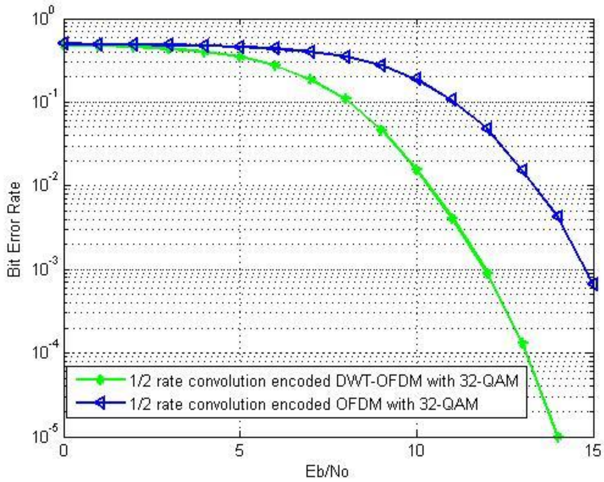

Fig 7: - Performance of ½ rate convolution encoder with 32-QAM modulation

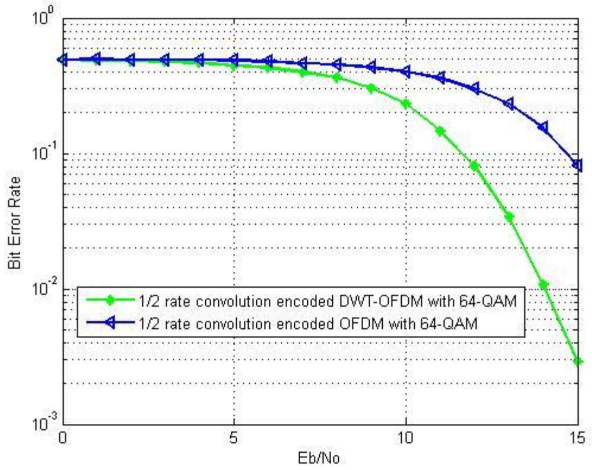

Fig 8: - Performance of ½ rate convolution encoder with 64-QAM modulation

Fig. 9 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^{-2}, coded DWT-OFDM require 8dB of Eb/No value for 16-QAM modulation, 10 dB for 32-QAM modulation and 14 dB of Eb/No value for 64-QAM modulation scheme. Clearly, the perfromance of coed DWT-OFDM improves with decrease in order of modulation.

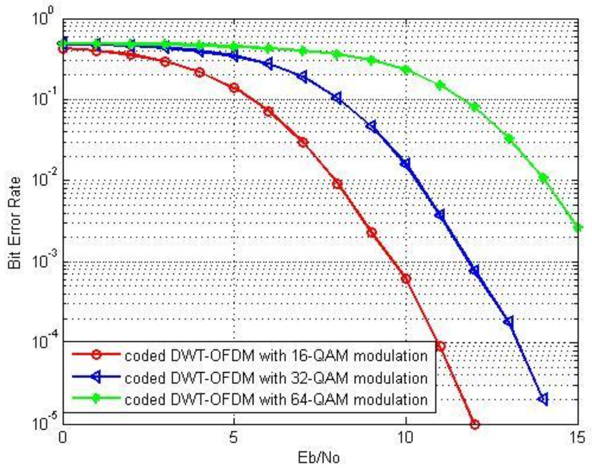

Fig 9: - Performance of ½ rate convolution encoder with 16, 32 and 64-QAM modulation

Further, the work is extended to study the performance of convolution encoded DWT-OFDM system using Haar wavelet over AWGN channel with different orders of PSK modulation. Fig 10 and 11 depict the performance of ½ rate convolution encoded DWT-OFDM using 16-PSK and 32-PSK modulation scheme. It is depicted the graphs that encoded DWT-OFDM system outperforms conventional encoded system with both of modulation schemes. With 16-PSK modulation scheme, to achieve BER of 10^{-3} encoded DWT-OFDM require 12 dB value of Eb/No while encoded conventional system require 15 dB of Eb/No value. Clearly, the performance of coded DWT-OFDM is better than conventional system. Similar results are with 32-PSK modulation scheme.

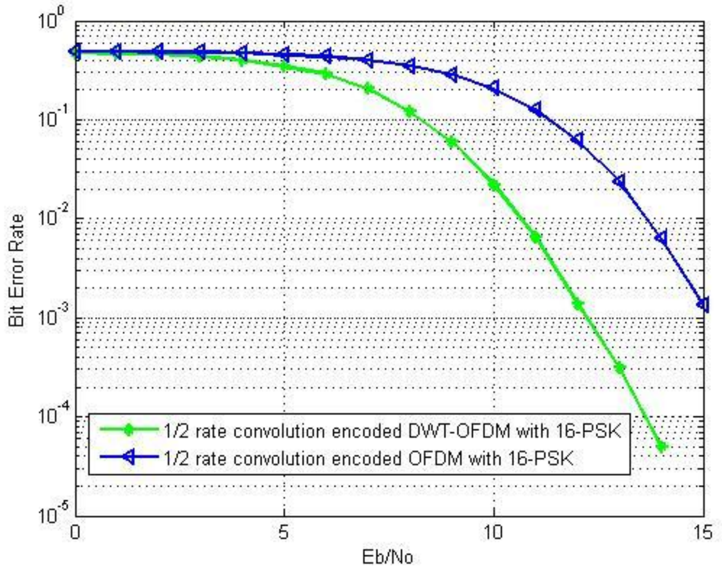

Fig 10: - Performance of ½ rate convolution encoder with 16-PSK modulation

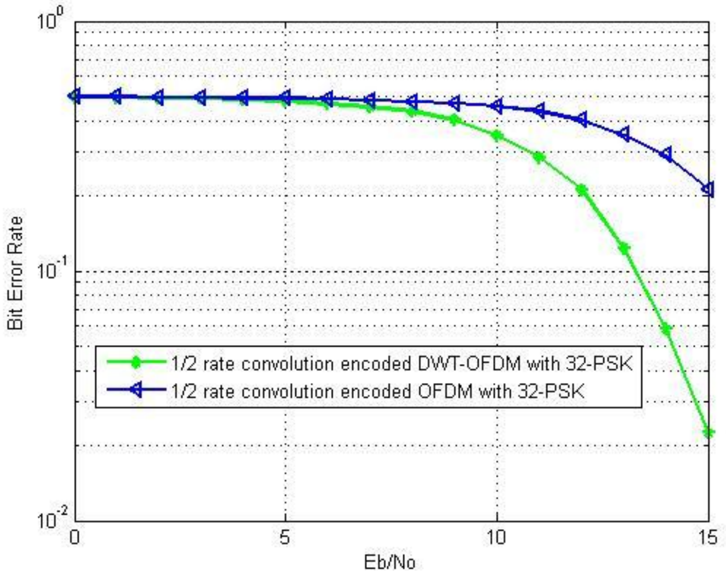

Fig 11: - Performance of ½ rate convolution encoder with 32-PSK modulation

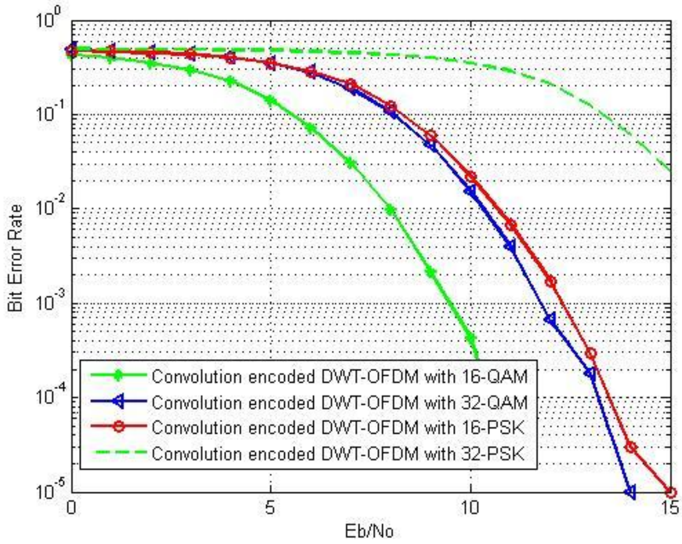

Fig 12: - Performance of ½ rate convolution encoder with 16,32-QAM and 16,32-PSK modulation

Fig. 12 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 less with QAM modulation than with PSK modulation. Fig 15:- comparison of dwt-coded using 16,32-QAM and 16,32-PSK modulation with 'haar' wavelet

SECTION-5 CONCLUSIONS

This paper investigated the perfromance of ½ code rate convolution encoded DWT-OFDM system under different simulation conditions. We have compared the performance of ½ rate convolution encoded DWT-OFDM system with that of encoded system. Simulations are performaed for different orders of QAM modulation. It is found that encoded DWT-OFDM performs better than conventional encoded system with all 16-QAM , 32-QAM and 64-QAM modulation schemes over AWGN channel. Futher, the performance of convolution encoded DWT-OFDM is best with 16-QAM modulation over AWGN channel. Also the effect of different orders of PSK modulation scheme is studied over the performance of ½ rate convolution encoded DWT-OFDM system. It is concluded that the performance of ½ rate convolution encoded DWT-OFDM system increases with decresase in order of modulation schem. Further, it is shown in the reslts that the performance of convolutuon encoded DWT-OFDM is better with QAM modulation scheme than with PSK modulation over AWGN channel.

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