

Performance Analysis of LDPC Coded OFDM System

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Abstract

The need for efficient transmission of information is of primary concern with growth in multimedia technology. Some use various filters while some use source or channel coding schemes for efficient data transmission. Modern wireless communications system demands higher data rate environment and reliable transmission. OFDM is suitable for high data rate transmission at reasonable complexity in wireless channels and when combined with channel coding scheme for improving reliability of system is called COFDM. Coding scheme chosen for a system satisfy requirements of high data rate as well as good error capability. In this paper, the performance analysis [4] of OFDM based system using turbo and LDPC coding technique is presented under AWGN fading channel in wireless communication. This paper compares LDPC coded OFDM with OFDM and study shows that COFDM outperforms than OFDM with respect to reliable transmission, fading/noisy environment, BER performance and bandwidth efficiency.

Keywords: OFDM (Orthogonal Frequency Division Multiplexing), FEC (Forward Error Correction), LDPC, BER (bit error rate), Channel Coding

I. INTRODUCTION

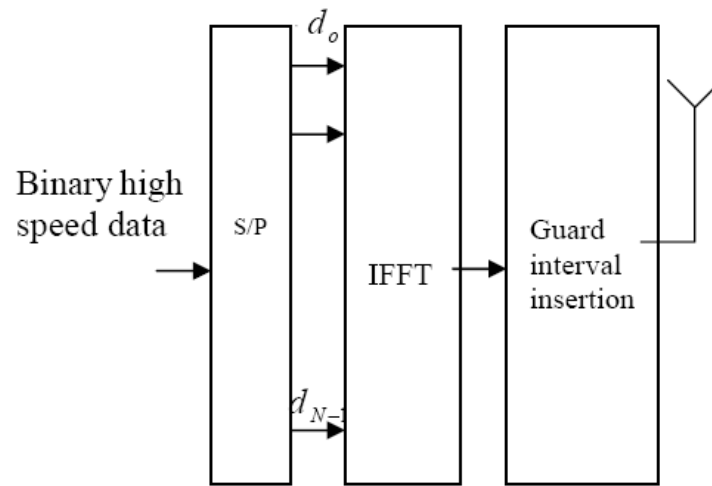
OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique based on frequency division multiplexing. In OFDM [7], the message or input stream is being divided into N parts and transmitted over N subcarriers which are orthogonal to each other. Each of these signals are individually modulated and transmitted over

the channel. These signals at the receiver end are fed to a de-multiplexer where they are demodulated and recombined to obtain the original signal. Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel [1]. Here the different carriers are orthogonal to each other, meaning they are totally independent of one another. OFDM reduces Inter-symbol Interference as well as Inter-channel Interference. Orthogonal Frequency Division Multiplexing (OFDM) is a wideband modulation scheme that is designed to cope with the problems of the multipath reception. There are some disadvantages of OFDM also such as high PAPR (Peak to Average Power Ratio) and BER (Bit Error Rate). To overcome these problem of OFDM based systems, different forward error correction techniques can be used. In this paper, channel codes [9] such as

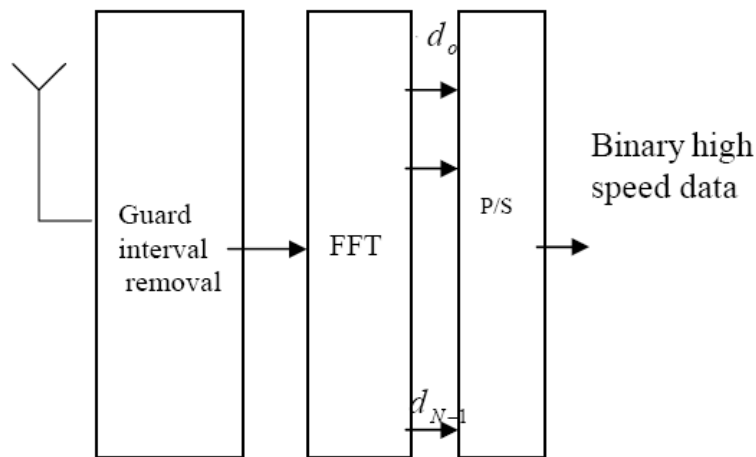
Hamming code and Low Density Parity Check (LDPC) [10] are implemented with OFDM system to reduce the overall bit error rate (BER). The sensitivity of devices used in OFDM transmitter such as DAC (Digital to Analogue Convertor) and HPA (High Power Amplifier) [11] is very harsh to the signal processing loop, which may impair system performance.

II. LITERATURE REVIEW

Orthogonal Frequency Division Multiplexing (OFDM) [6] is a multicarrier system where data bits are encoded on multiple sub-carriers, while being sent simultaneously. Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non-overlapping frequency ranges or channels to different signals or to each user of a medium. To ensure that the signal of one channel does not overlap with the signal with the adjacent one, a gap or guard band is left between each of these channels. Mathematically, [14] modulating a waveform and adding is equivalent to taking its IFFT. This is because the time domain representation of OFDM is made up of different orthogonal sinusoidal waveforms which are nothing but inverse Fourier transform. The transmitted data are the “frequency” domain coefficients and the samples at the output of the IFFT stage are “time” domain samples of the transmitted waveform.



(a) Transmitter



(b) Receiver

Fig. 1. OFDM System Model.

Let $X = \{X_0, X_1, \dots, X_{N-1}\}$, denote the length data symbol block. The IDFT [5] of the data block X yields the time domain sequence $x = \{x_0, x_1, \dots, x_{N-1}\}$, i.e.,

$$x_n = \text{IFFT}_N\{X_k\}(n)$$

A cyclic prefix or suffix is appended to the sequence X to mitigate the effects of channel delay spread as shown in Fig. 2. In case of a CP, the transmitted sequence with guard interval is

$$X_n^g = x_{(n)N}, n = -G, \dots, -1, 0, 1, \dots, N-1$$

where G is the guard interval length in samples, and $(n)_N$ is the residue n of modulo N .

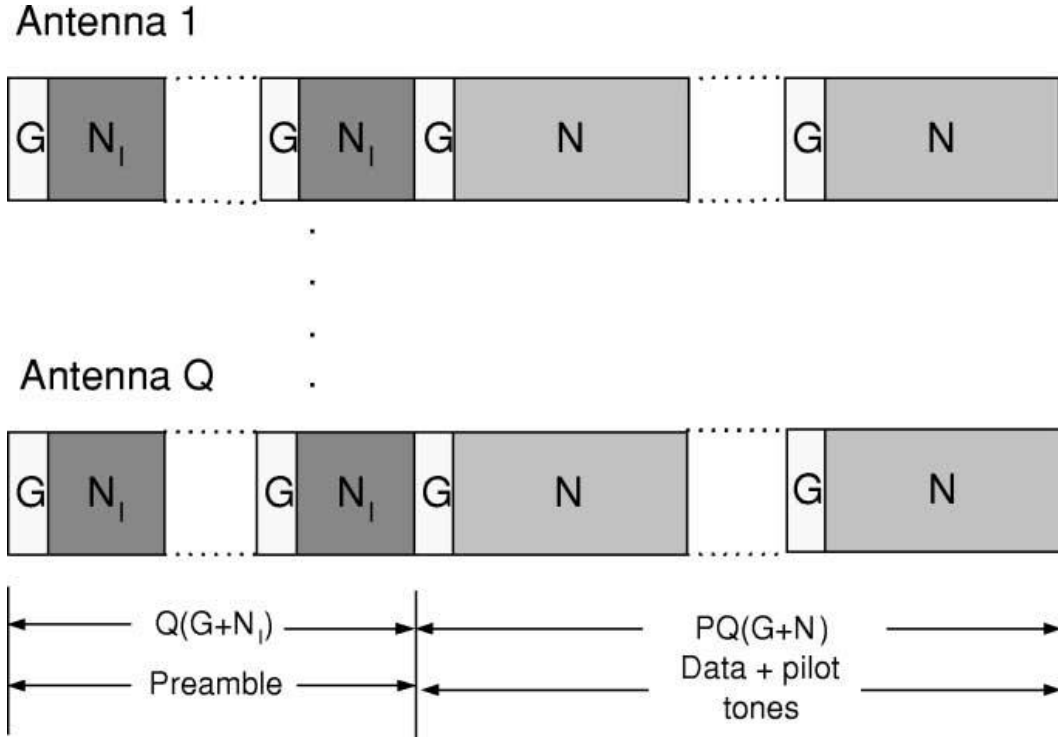


Fig. 2. Frame structure for the Q _ L OFDM system.

III. CHANNEL CODING

Channel Coding or Forward Error Correction (FEC) is a technique used for controlling errors in data transmission over unreliable or noisy channels. Channel Coding [3] provides protection from transmission errors.

A. Hamming Codes:

The binary Hamming codes have Generator matrix of size

$$(n, k) = (2^m - 1, 2^m - 1 - m),$$

where m is any positive integer. For example, for $m=3$ we have a (7,4) Hamming codes [13]. The parity check matrix hamming codes has $n-k$ rows and n columns. An (n,k) hamming code converts k - bits input symbol to n - bit code.

B. Low Density Parity Check (LDPC) Codes

An LDPC code $C(n, k)$ is a special class of linear block codes [11] whose parity check matrix $H[n - k, n]$ has mainly '0's and only a small number of '1's, i.e. is sparse, where each block of k information bits is encoded to a codeword of size n . Today, LDPC codes are part of several standards (e.g. DVB-S2, WiMAX- IEEE 802.16e, and

IEEE 802.11n). Consider a LDPC code [10] of size $n = 8$, information bits $k = 4$, and parity bits $m = n - k = 4$. This code has rate 1/2 and can be specified by the following parity check matrix H :

$$H = \begin{matrix} & \begin{matrix} n_1 & n_2 & n_3 & n_4 & .. & .. & n_8 \end{matrix} \\ \begin{matrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{matrix} & \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \end{bmatrix} \end{matrix}.$$

Parity check equations imply that for a valid codeword, the modulo-2 sum of adjacent bits of every check node has to be zero. In other words, the vector \mathbf{x} is a part of the codeword \mathbf{C} if it satisfies the following condition:

$$HxT = 0, \forall x \in C.$$

The number of '1's in each column of this matrix H is only 2, which makes this matrix sparse. Due to this sparse property [12][15], the same code can be equivalently represented by a bipartite graph, called a 'Tanner' graph, which is illustrated in Figure. This graph connects each check equation (check node) to its participating bits (bit nodes). A connection between a bit node n_i and a check node m_j is established if there is a '1' in the column of the matrix H .

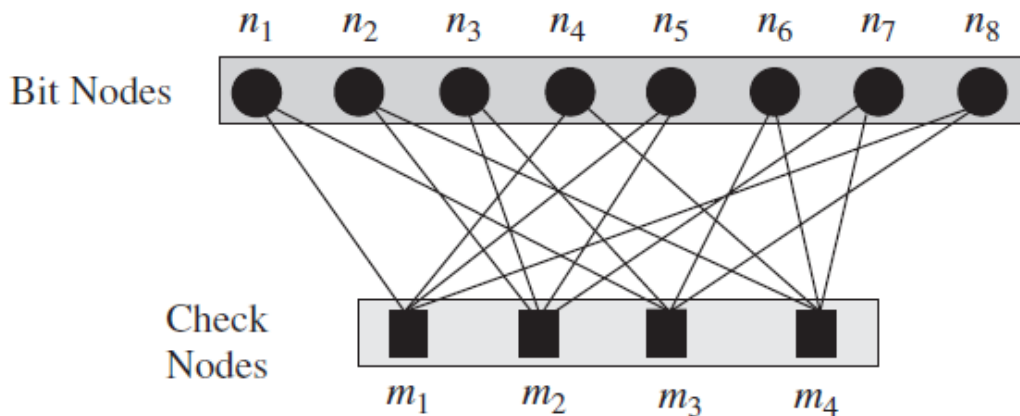


Fig. 3. The Tanner graph representation of the LDPC code

The ‘Tanner graph’ code representation enables the LDPC codes to have a parallelizable decoding implementation, which consists of simple operations such as addition, comparison, and table look-up. The degree of parallelism is tunable, which makes it easy to find a tradeoff between throughput, decoding delay, and the overall complexity

IV. SYSTEM MODEL AND SIMULATION

The block diagram for LDPC coded OFDM system is shown in figure 4. The performance of OFDM and LDPC coded OFDM is measured by calculating the bit error rates. The code rate of LDPC is $R=1/2$.

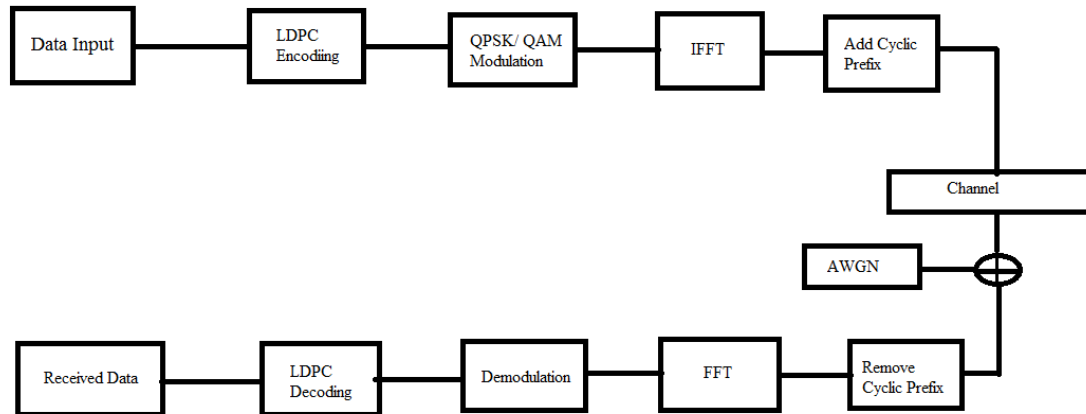


Fig . 4. LDPC coded OFDM System

It is well known that OFDM signal suffers from various distortions due to large bit error rates and high correlations between the data frames. The simulation procedure proceeds as follows. Firstly, the random binary bit stream is taken as input and encoded using LDPC encoder with the specified parity check matrix and code rate of $R=1/2$. Then using, IFFT or IDFT, the bits are transformed into time-domain signals to generate OFDM signals. Each block is padded with cyclic prefix of length longer than the channel response to mitigate the inter symbol interference. LDPC channel encoding helps resist the AWGN noise introduced in the channel. We assume that the signals are transmitted over an AWGN channel. The noise in the channel is a Gaussian random variable with zero mean and variance σ^2 . At the receiver side, the reverse operations are performed that is; removing cyclic prefix, FFT, demodulation and LDPC decoding to decode the received sequence. Finally, the numbers of erroneous bits are counted for performance analysis of the system.

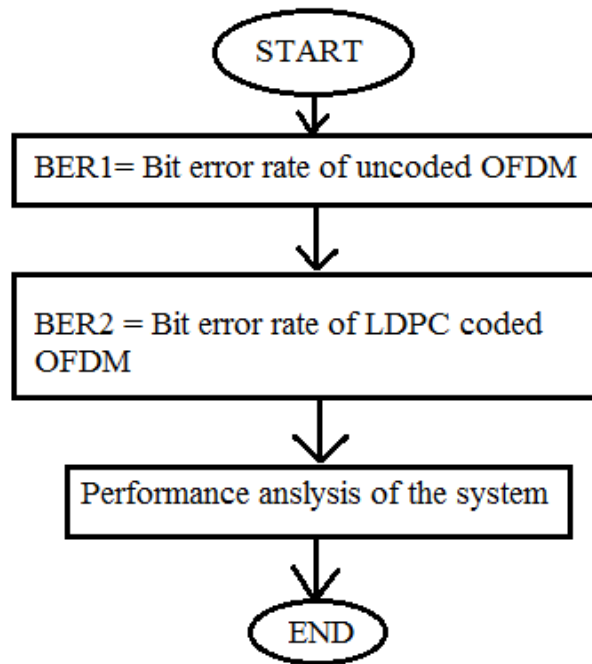


Fig 5. Flowchart of Simulation Procedure

A comparison of the performance of un-coded OFDM, Hamming coded OFDM and LDPC coded OFDM is considered. The various parameters that are used for schematic evaluation are given in Table below:

TABLE I. Simulation Parameters

PARAMETER	VALUE
Digital Modulation	QPSK, 16-QAM
LDPC code rate	$\frac{1}{2}$
Channel Model	AWGN channel
CP Length	16 bits
FFT size	128

V. RESULT AND ANALYSIS

A performance of the OFDM system with and without LDPC coding is for different channel conditions and signal-to-noise ratio is measured and the bit error rate is calculated and plotted for 64, 128 and 256 FFT using MATLAB. The result obtained shows that there is a decrease in overall bit error rate when channel coding is used. Also, a performance of OFDM system with Hamming coding and LDPC coding is measured for different SNR values and bit error rate (BER) is plotted. It is observed that the performance of LDPC codes is better than Hamming codes. Iteration for LDPC coding has been varied from 1 to 20.

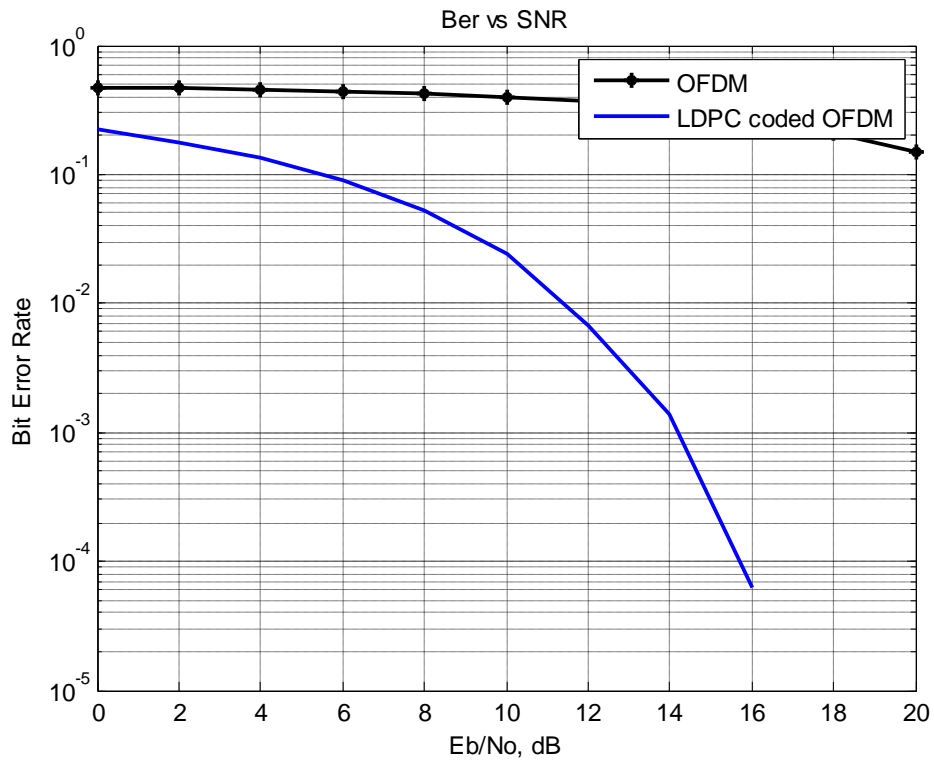


Fig.6. Performance Analysis of OFDM and LDPC coded OFDM with 64 FFT

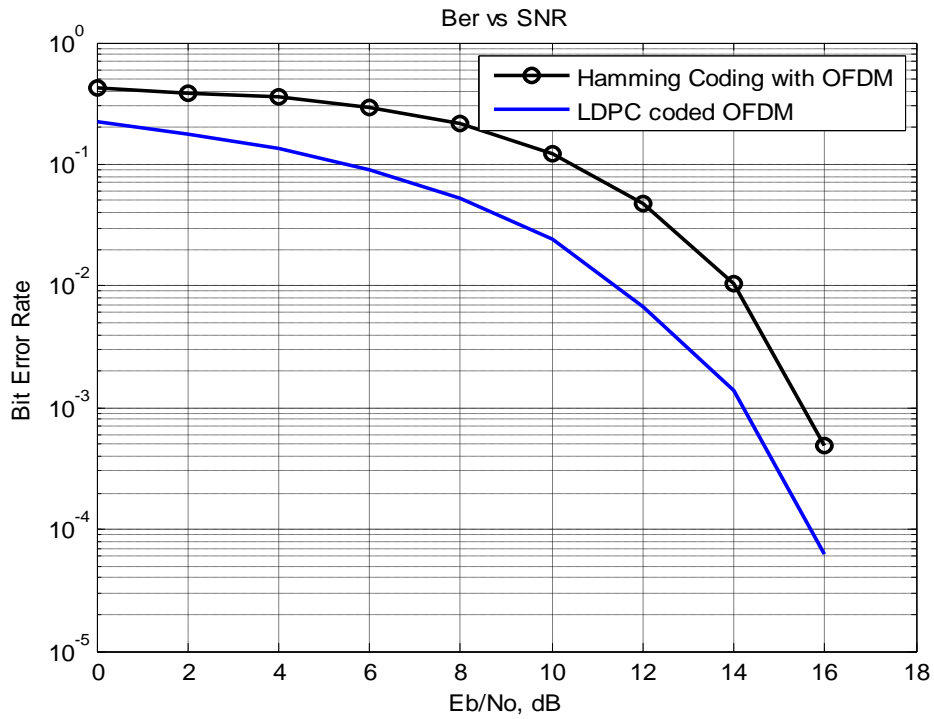


Fig 7. Performance Analysis of Hamming COFDM and LDPC coded OFDM with 64 FFT

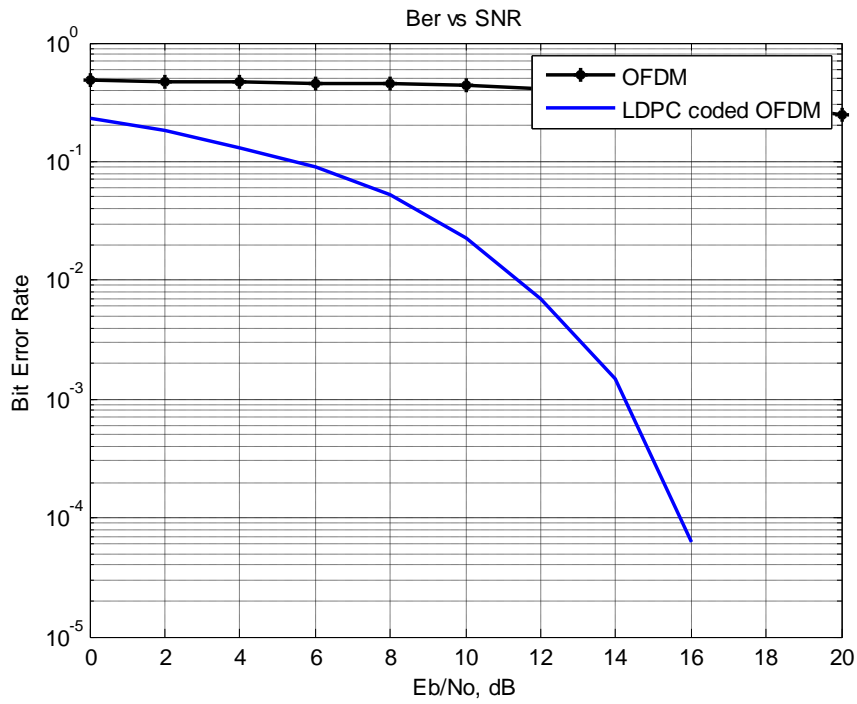


Fig 8. Performance Analysis of OFDM and LDPC coded OFDM with 128 FFT

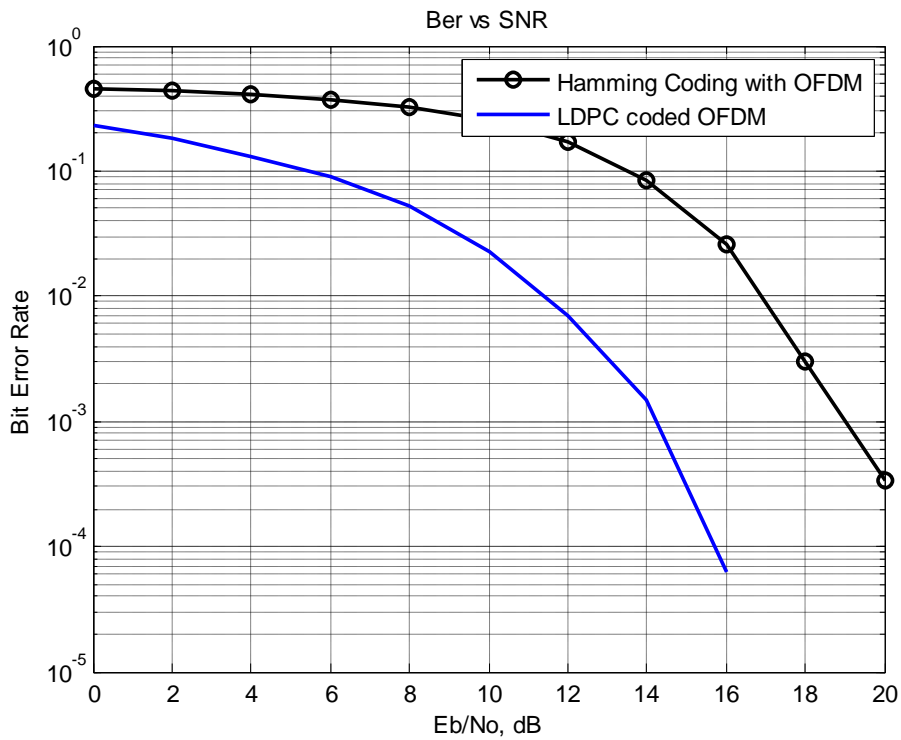


Fig 9. Performance Analysis of Hamming COFDM and LDPC coded OFDM with 128 FFT

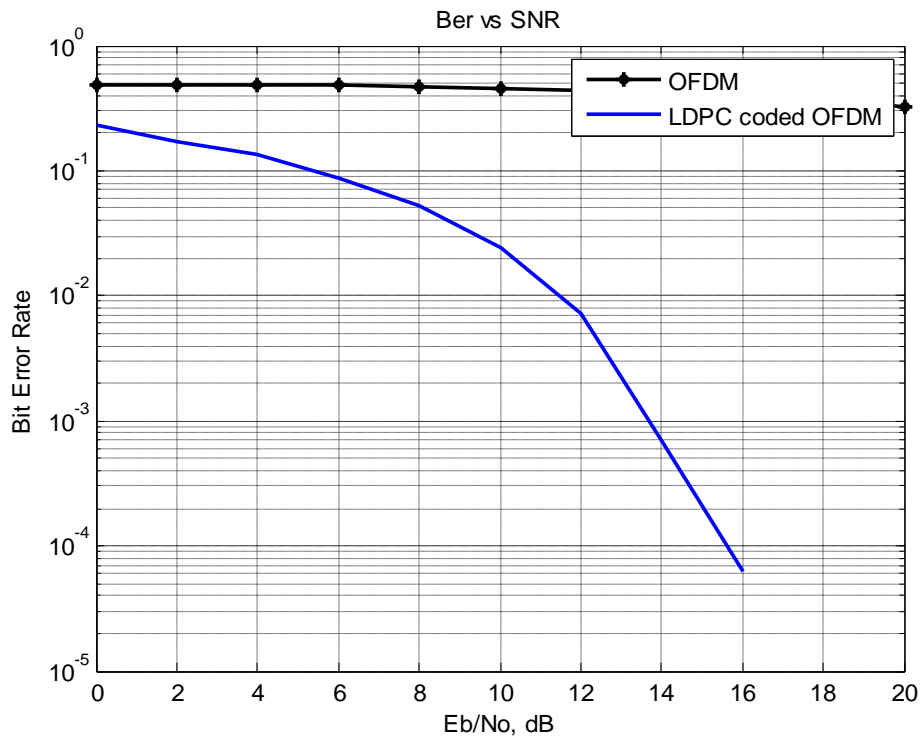


Fig. 10. Performance Analysis of OFDM and LDPC coded OFDM with 256 FFT

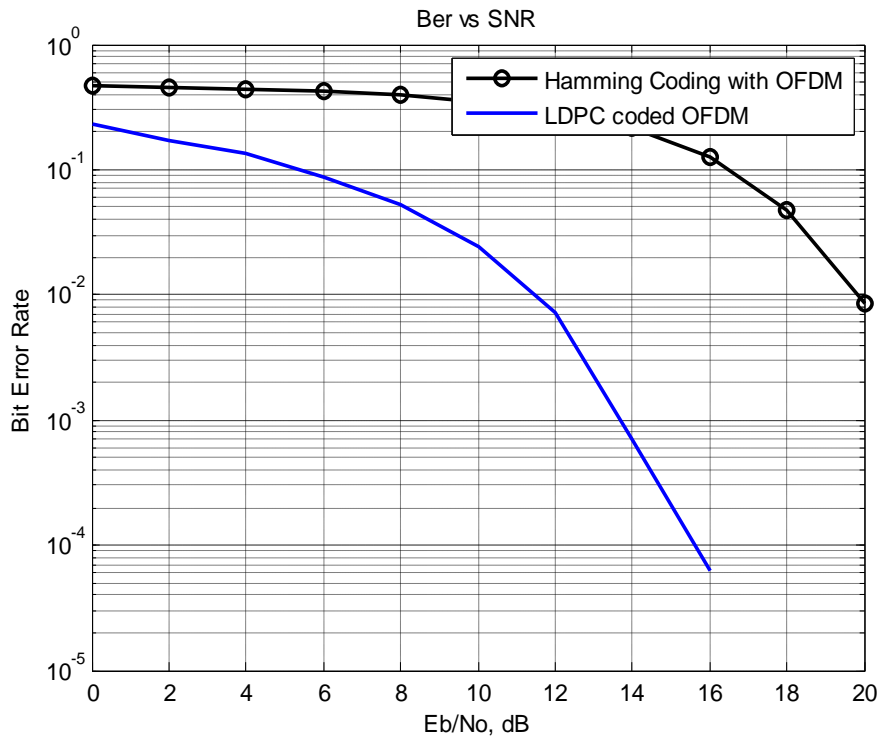


Fig.11. Performance Analysis of Hamming COFDM and LDPC coded OFDM with 256 FFT

The first two graph fig. 6 and fig. 7 give performance analysis of OFDM, Hamming coded OFDM and LDPC coded OFDM with FFT size of 64. Similarly fig. 8 and fig. 9 give performance for 128 FFT and fig. 10 and fig. 11 give performance analysis for 256 FFT. In each graph, a curve of bit error rate and signal-to-noise ratio is plotted. The figures demonstrate that the performance of un-coded OFDM increase with forward error correction.

VI. CONCLUSIONS

In this paper, we have considered the performance analysis of LDPC coded OFDM with un-coded OFDM has examined and results shows that COFDM is more suitable choice which provides high spectral efficiency and reliable transmission and outperforms than OFDM with respect to BER, bandwidth efficiency and fading environment. Study also shows that LDPC code is a better channel coding scheme than Hamming codes. It fulfills the requirement of high data rate transmission and has good error capability with negligible delay. The simulation has been performed for different FFT sizes 64, 128 and 256.

VII. FUTURE WORK

There can be further various improvement possible in LDPC coded OFDM system. It can be implemented with various MIMO system and different code rates In future different channel coding algorithms and interleaving schemes will be used on OFDM-MIMO system before transmitting the data on different subcarriers for more efficient transmission and bit error rate reduction.

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