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Robust Image Transmission with LDPC coded DWT-OFDM System

DISSERTATION-II

Submitted By

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In partial fulfillment of the requirement for the

Award of the degree of

Master of Technology in Electronics and Communication

Under the guidance of

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CERTIFICATE

This is to certify that the Thesis titled "Robust Image Transmission with LDPC coded DWT-OFDM System" that is being submitted by " Purnima Banerjee" is in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY DEGREE, is a record of bonafide work done under my /our guidance. The contents of this Thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

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Examiner I **Examiner II**

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Last but not the least, I would thank my parents again and the God Almighty.

Purnima Banerjee

CERTIFICATE

This is to certify that Purnima Banerjee bearing Registration no. 11007680 has completed objective formulation of thesis titled, **“Robust Image Transmission with LDPC coded DWT-OFDM System”** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of Masters of Technology in Electronics and Communication.

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DECLARATION

I, Purnima Banerjee, student of M.Tech under Department of Electronics and Communication of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

The telecommunications' industry is in the midst of a veritable explosion in wireless technologies. Once exclusively military, satellite and cellular technologies are now commercially driven by ever more demanding consumers, who are ready for seamless communication from their home to their car, to their office, or even for outdoor activities. The need for efficient transmission of images is of primary concern with growth in multimedia technology. Image transmission requires larger bandwidth as well as redundancy from noise. Researchers have been proposing various methods regarding transmission of images. Some lay emphasis on decreasing the size of images that is; image compression, some on reducing the noise on channels while some consider reducing the signal power requirements. The main two obstacles are image size and image loss or distortions due to noise in channel. In this thesis, a solution to both these problems is given. Instead of transmitting multiple copies of a single image with incomplete information, a single fused image can be transmitted. Further, its size can be decreased by image compression. The compressed image retains many of the original image's features but requires less bandwidth. The second problem can be solved by forward error correction or channel coding. Using efficient channel codes such as Low density parity check codes help reduce burst errors and distortions due to channel noises. As a result, the overall bit error rate (BER) is also reduced. Channel coding plays a very important role in OFDM systems performance. This is particularly important as wireless communications channels are far more hostile as opposed to wire alternatives, and the need for mobility proves especially challenging for reliable communications. Also, the structure of OFDM systems makes channel coding more effective in confronting fading channels. This thesis analyzes OFDM system and the effect of channel coding in reducing BER. Along with this, transmission of images with FFT-OFDM and DWT-OFDM system is also studied. Besides, performance of LDPC codes in OFDM systems will compare with other channel coding schemes.

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LIST OF ABBREVIATIONS

OFDM-------------------Orthogonal Frequency Division Multiplexing

FDM---------------------Frequency Division Multiplexing

Wireless LAN----------Wireless Local Area Network

DAB---------------------Digital Audio Broadcasting

DFT----------------------Discrete Fourier Transform

RECT pulse-------------Rectangular pulse

FFT-----------------------Fast Fourier Transform

QAM---------------------Quadrature Amplitude Modulation

COFDM-----------------Coded OFDM

CDMA-------------------Code division multiple access

BPSK--------------------Binary phase shift keying

QPSK--------------------Quadrature phase shift keying

CP------------------------Cyclic prefix

FEC----------------------Forward error correction

TDMA-------------------Time division multiple access

SNR----------------------Signal to noise ratio

SER----------------------Symbol error rate

BER----------------------Bit Error rate

LDPC--------------------Low Density Parity Check

STBC--------------------Space Time Block Codes

MIMO-------------------Multiple Input Multiple Output

SISO---------------------Single Input Single Output

PSNR--------------------Peak Signal to Noise Ratio

DWT---------------------Discrete Wavelet Transform

IDWT--------------------Inverse Discrete Wavelet Transform

QMF---------------------Quadrature Mirror Filter

ISI------------------------Intersymbol Interference

ICI------------------------Interchannel Interference

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The need for efficient transmission of data is of primary concern with growth in technology. Different types of data such as image transmission require larger bandwidth as well as redundancy from noise. Encryption data from noise is an important aspect and this can be obtained by channel coding. The main requirement in wireless communication is efficiency of the received data which can be observed by bit error rate and other similar parameters. The principle of multicarrier transmission is to convert a serial high rate input stream into multiple parallel streams of slow rate. The carrier signal is also divided into subcarriers and the sub-streams are then modulated over different sub- carriers. OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique based on frequency division multiplexing. In OFDM, 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. The original signal is then obtained at the receiver after demodulation and recombining. OFDM reduces Inter-symbol Interference as well as Inter-channel Interference. Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission when dispersion is present. The different carriers are totally independent of one another, that is, orthogonal to each other. The problems of the multipath reception can be easily coped with OFDM as it is a wideband modulation scheme. Amongst all various advantages of OFDM, there are some disadvantages of OFDM such as high PAPR (Peak to Average Power Ratio) and high BER (Bit Error Rate). This thesis analyzes OFDM system and the effect of channel coding in reducing BER. Along with this, transmission of images over OFDM is also studied. Besides, performance of LDPC codes in OFDM systems will compare with other channel coding schemes.

1.2 SCOPE OF STUDY

The concept of using parallel data transmission by means of frequency division multiplexing (FDM) first came in mid 60's. Since then, OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires. Some of its common applications are digital television and audio broadcasting, internet access, wireless networks, power-line networks, and 4G (next-generation) mobile communication. The need for efficient transmission of data is of primary concern with growth in technology. Different types of data and image transmission require larger bandwidth as well as redundancy from noise. Encryption data from noise is an important aspect and this can be obtained by channel coding. The main requirement in wireless communication is efficiency of the received data which can be observed by bit error rate and other similar parameters.

Advantages:

– As the number of sub- carriers increase, so does the spectral efficiency due to nearly rectangular frequency spectrum.

– FFT operation makes the digital realization simple.

– Reduced complexity in receivers due to the avoidance of ISI and ICI with a sufficiently long guard interval.

– Flexible spectrum adaptation can be realized, e.g. notch filtering.

– Different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier, e.g. water filling.

Disadvantages:

– Performance degradations and the out-of-band power will be enhanced in multicarrier system due to with high peak-to-average power ratio (PAPR) of multi-carrier signals. High linear amplifiers deal with this.

– Guard interval lead to loss in spectral efficiency.

– More sensitive to Doppler spreads.

–The system performance is also influenced by phase noise caused by the imperfections of the transmitter and receiver oscillators.
–Frequency and time synchronization is required.

1.3 OBJECTIVES OF STUDY

The various objectives of this work are-

- To transmit fused and compressed images over LDPC coded OFDM systems for increasing spectral efficiency without the need of additional power and bandwidth.
- Second objective is to reduce channel noises and Peak signal-to-noise ratio via Low Density Parity Check channel coding scheme.
- Finally, BER will be evaluated and compared for robust image transmission over LDPC coded OFDM system and un-coded OFDM system.
- The main objective of this research was to investigate image transmission with coded OFDM systems by using a LDPC codes and compare its performance to conventional OFDM system. The simulations have been performed using MATLAB.

1.4 THESIS OUTLINE

Following this introduction the remaining part of the thesis is organized as under; Chapter 2 gives a brief literature survey of the work. Chapter 3 provides the fundamental concepts and principles behind OFDM, its basic simulation and DWT concepts. Chapter 4 discusses the different coding techniques and their implementation procedure with OFDM. Also different coded OFDM systems are compared with each other. Chapter 5 discusses the image fusion and compression concept and its implementation on MATLAB followed by Chapter 6 which consists of the research methodology, simulation results, conclusion and future works.

CHAPTER 2

REVIEW OF LITERATURE

2.1 BACKGROUND LITERATURE SURVEY

The concept of using parallel data transmission by means of frequency division multiplexing (FDM) was first introduced in mid 60's [25]. The idea was to use parallel data streams and FDM [6] with overlapping sub channels to avoid the use of high-speed equalization and fully use the available bandwidth spectrum. It could also combat impulsive noises and multipath distortion. The discrete Fourier transform (DFT) was applied to parallel data transmission system as part of the modulation and demodulation process [22]. The initial applications were in the military communications. In the 1980s, OFDM has been studied for high-speed modems [2], digital mobile communications [17] and high-density recording [6]. In 1990s, OFDM has been exploited for wideband data communications over mobile radio channels [17], wireless LAN wireless multimedia communication [16], high-bit-rate digital subscriber lines (HDSL) [8], asymmetric digital subscriber lines (ADSL) [9], very high-speed digital mobile communications [16], medical data transmission purposes [1], etc.

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission when dispersion is present. The different carriers are totally independent of one another, that is, orthogonal to each other. The problems of the multipath reception can be easily coped with OFDM as it is a wideband modulation scheme. Amongst all various advantages of OFDM, there are some disadvantages of OFDM such as high PAPR (Peak to Average Power Ratio) [3] and high BER (Bit Error Rate).

2.2 LITERATURE SURVEY

Naglaa F. Soliman · Yasser Albagory implemented a new technique for progressive image transmission over low-density parity check coded orthogonal frequency division multiplexing (LDPC [7] -OFDM) system in [23]. This technique improves the performance and reduces the peak-to-average power ratio (PAPR) of the OFDM signal by adopting chaotic Baker map. It improves the error resilient ability and also enhances the efficiency of progressive image transmission over frequency selective fading channels. The distinctive feature of the proposed technique in [23], [26] is that the transmitted data sequence has less data correlation, which leads to minimizing the PAPR. This improves the visual quality of the received images and reduces the PAPR of the OFDM signal as well.

A permuted version of a square matrix is generated using the chaotic or Baker map [11]. The Baker map is an efficient tool to randomize a square matrix of data in its discretized form. The discretized map can be represented as an M × M matrix as follows:

$$B(r,s)=\left[\frac{M}{n_i}(r-M_i)+s \bmod\left(\frac{M}{n_i}\right),\frac{n_i}{M}\left(s-s \bmod\left(\frac{M}{n_i}\right)\right)+M_i\right]$$

where $B(r, s)$ are the new indices of the data item at (r, s) , Mi ≤ r < Mi + ni, 0 < s < M and Mi= n1 + n2+...+ni.

Set Partitioning in Hierarchical Trees or SPHIT [1] is an image compression algorithm that uses a special data structure called a 'spatial orientation tree' to define and partition sets in the wavelet decomposed image. This tree comprises of a group of wavelet coefficients that are arranged in a tree rooted in the lowest frequency sub-band with offspring in the same spatial orientation for higher frequency sub-bands. The main idea of SPIHT compression is to sort the wavelet coefficients of the in three stages. They are the List of Insignificant Sets (LISs), List of Insignificant Pixels (LIPs) and List of Significant Pixels (LSPs).

Bit error rate [14], BER is one of the key parameter that is used in evaluating performance of systems that transmit digital data from one location to another. Bit error rate (BER) assesses the full end to end performance of a transmitter, receiver and the medium between them. Therefore, BER enables the actual performance of a system in operation to be tested. Bit error rate [16] is defined as the rate at which errors occur in a transmission system or in other words it is the ratio of number of erroneous bits to the total number of bits sent.

LDPC or Low-density parity-check codes [7] are a class of linear block codes. Their parity-check matrix contains only a few and pre-defined number of 1's in comparison to the amount of 0's. The main advantage of LDPC codes is that they provide a performance which is very close to the capacity for a lot of different channels. They were first introduced in 1960s by Gallager in his PhD thesis. But until about ten years ago they were mostly ignored due to the introduction of Reed-Solomon codes [4] and the computational effort in implementing coder and encoder for such codes.

Images are transmitted via different methods over different noisy channels. For wireless transmission various 2G or 3G techniques such as GSM, CDMA, WLAN, etc have been commonly used. But with rise in wireless multimedia image communication, the topics related to be handled are resource consumption and quality of the image being transmitted without noise.

The transmission distortion induced by both channel and instant node failures on the image data are considered [26]. Two techniques are investigated to compensate the multimedia distortion at the expense of incurring additional energy consumption and/or wasting bandwidth resources. First one is a watermarking based error concealment technique that utilizes discrete wavelet transform for embedding downsized replicas of original image into itself and the second one is the conventional Reed–Solomon (RS) coding [4] utilizing additional information bits to correct bit/symbol errors.

Another method [34] that can be used is to compress the image using improved wavelet based polyomino's lossless compression technique. This technique increases the quality of image at receiving end. After compression, the image is transmitted via Energy Efficient High Quality Image Transmission scheme (EEHQIT) which provides energy efficient image transmissions in Wireless Sensor Networks (WSNs). To avoid noise in the compressed image, a scheme of spatial averaging filter is presented and tested on the transmitted compressed image. This approach [6] removes the noise from the transmitted image by way of rebuilding the image to obtain the original image without loss of information. In this approach [6], the wireless image transmission from the source to designation is implemented through a router.

To decrease the communication bandwidth and save the transmitting power in the wireless endoscopy capsule, a new near-lossless image compression algorithm [35] based on the Bayer format image suitable for hardware design is presented. This algorithm provides a low average compression rate (2.12 bits /pixel) with high image quality (larger than 53.11 dB) for endoscopic images. It has low complexity hardware overhead (only two line buffers) and supports real-time compressing. This algorithm [35] provides lossless compression for the region of interest (ROI) and high-quality compression for other regions. This technique produces a bit stream that results in a progressive and ultimately lossless reconstruction of an image similar to what one can obtain with a reversible wavelet codec. This scheme [35] provides near-lossless reconstruction with respect to a given bound after decoding of each layer of the successively refundable bit stream.

The broadband radio channel [15] is characterized by its frequency selective fading due to multipath propagation. In mobile communication applications [21] the radio channel is additionally time-variant due to the movement of the mobile terminal. The Orthogonal Frequency Division Multiplexing (OFDM) transmission technique can efficiently deal with multi-path propagation effects especially in broadband radio channels. OFDM modulation procedure which is particularly important in the uplink of a multi-user system and has a high degree of system flexibility in multiple access schemes, can be combined with the conventional TDMA, FDMA and CDMA [31] approaches.

In OFDM-FDMA schemes carrier synchronization and the resulting subcarrier orthogonality plays an important role to avoid any multiple access interferences (MAI) in the base station receiver. The required amplifier linearity to avoid any non-linear effects caused by a large peak-to-average ratio (PAR) of an OFDM transmission signal is one of the key challenges in system design. Martin Stemick and Hermann Rohling proposed a specific OFDM-FDMA uplink procedure in [20]. A combination of a specific subcarrier spreading scheme and subcarrier selection process can be seen in this.

Present day OFDM system is implemented using IFFT and FFT. However, the FFT (Fast Fourier Transform) uses rectangular window which produces high side lobes leading to interference. In this thesis a replacement of Fourier transform by Wavelet transform is given and it has been observed that the performance of system improves with DWT-OFDM rather than FFT- OFDM. A wavelet is a small portion of a continuous wave and discrete wavelet is the name given to samples which are discretely sampled. It provides both time and frequency domain information. Some of the widely used types of wavelet transforms are HAAR, DAUBECHIES, BIORTHOGONAL, etc. The wavelet Transform decomposes the signal into small wavelets by using the wavelet function and the basis function. Also, the Wavelet Transform should satisfy orthonormal basis property and the perfect reconstruction property. The filters in the Discrete Wavelet Transform have got both low pass and high pass filters which actually acts as the Quadrature Mirror Filters (QMF).

CHAPTER 3

Orthogonal Frequency Division Multiplexing

3.1 INTRODUCTION

This thesis discusses about the evaluation of image transmission with LDPC channel coding in OFDM systems. In order to establish the context and need for the work undertaken, it is necessary to discuss the fundamental concepts behind the work. This chapter discusses the present OFDM system and brings out the need for channel coding in it.

This chapter is organized as follows. Following this introduction, section 2.2 discusses fundamental concepts and basic principles behind OFDM, section 2.3 presents the advantages and disadvantages of OFDM compared with single carrier scheme, section 2.4 explains the OFDM model used along with the various blocks used in it and finally section 2.5 provides some of the basic simulations of OFDM system. Later some of the channel models are explained which are used in this research work.

3.2 BASICS OF OFDM

The principle of multicarrier transmission is to convert a serial high rate input stream into multiple parallel streams of slow rate. The carrier signal is also divided into subcarriers and the sub-streams are then modulated over different sub- carriers.

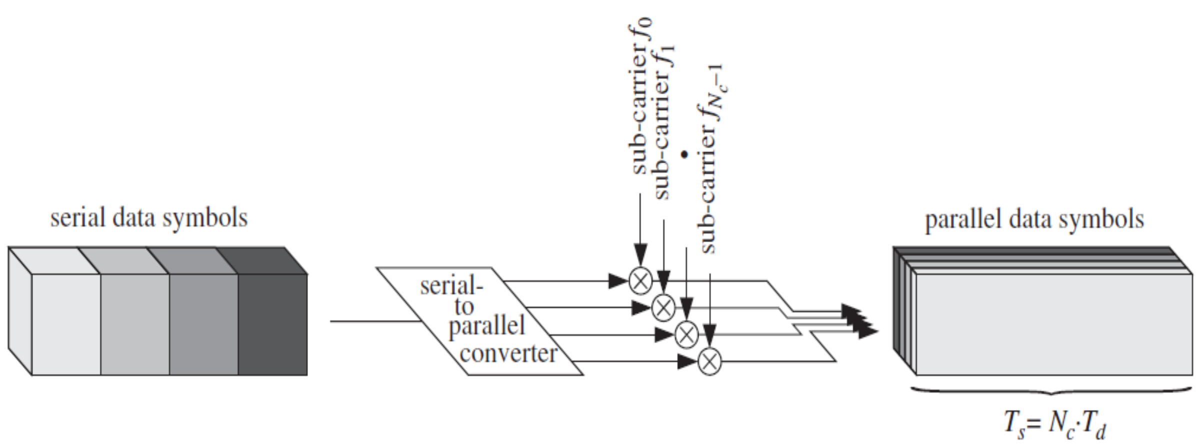


Figure 3-2-1 Multi-carrier modulation system with N_C = 4 sub-channels

Orthogonal Frequency Division Multiplexing is a multicarrier technique based on frequency division multiplexing. In OFDM, 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 are then demodulated and recombined to obtain the original signal at the receiver. Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission when dispersion is present. OFDM reduces Inter-symbol Interference (ISI) as well as Inter-channel Interference (ICI). The different carriers are orthogonal to each other and therefore; are totally independent of one another. OFDM is a wideband modulation scheme which can cope with the problems of the multipath reception.

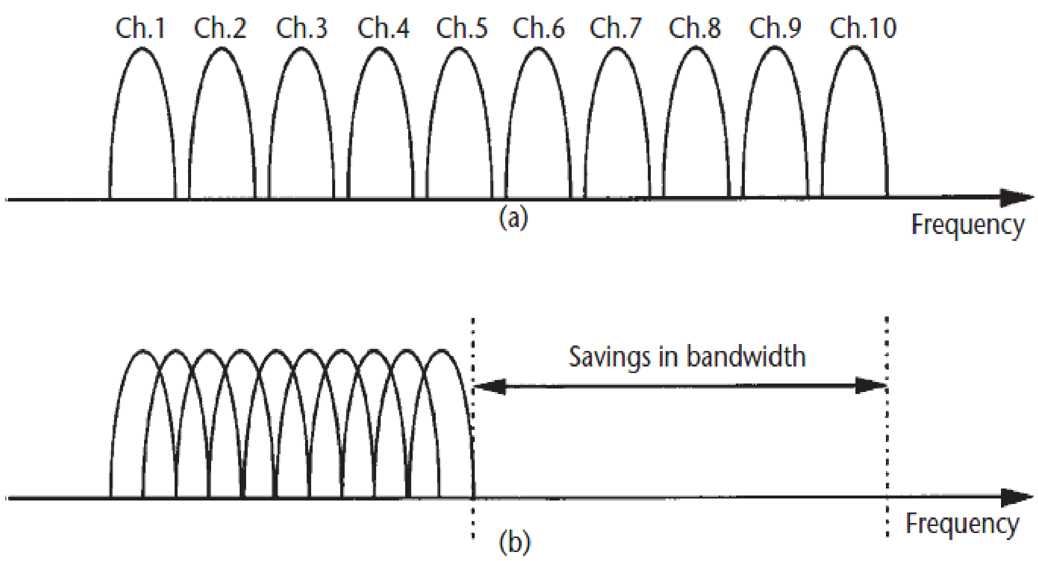


Figure 3-2-2 Concept of the OFDM signal: (a) FDM and (b) OFDM

3.3 ADVANTAGES AND DRAWBACK OF OFDM

OFDM actually brings some specific advantages to the wireless communication. The advantages would be listed as following:

(i) Multi-path Delay Spread Tolerance

As it has been already explained one of the main effects of the multicarrier modulation is its robustness against ISI which mostly comes from the multipath delay spread. The increase in the symbol time of the OFDM symbol by N times is the reason of this robustness. Further, using the cyclic extension process and proper design, one can completely eliminate ISI from the system.

(ii) Effectiveness against Channel Distortion

Usually, there is variation in the channel and no ideal case of having flatness amplitude distortion which gives rise to the ISI as explained before. In single carrier transmission such as twisted pair in telephone lines, complex equalizers are needed to mitigate the effect of the channel which does not response effectively in some high frequencies.

However, in OFDM systems, the bandwidth of each carrier frequency is relatively small so the amplitude response over this narrow bandwidth will be basically flat and it can be assumed that the phase response is linear, too. Even if the situation of the distorting channel is severe, then just a simple equalizer is enough to solve the problem.

(iii) Throughput Maximization (Transmission at Capacity)

Subcarriers modulation improves the flexibility of OFDM to channel fading and distortion. This technique is known as channel loading. It increases the capacity of transmission. If the subcarrier with a particular frequency is going to be distorted in the channel is known and the sample duration is relatively greater than the channel changing then the system would be designed somehow, so scale down/up the modulation and coding scheme for the particular subcarrier. This attempt would result in an increase in the whole capacity of the transmission system against the fading distortion.

(iv) Robustness against Impulse Noise

Impulse noise is an interference caused by atmospheric phenomena such as lightening in channels like twisted pair or wireless channels. To give an example how a transmission system would come up with impulse noise, let's assume to have a 10Mbps system with the symbol duration of 0.1μs, then an impulse noise waveform which last for a couple of micro seconds would be able to cause a burst of errors which would not be corrected by the error-correction coding.

However, in OFDM system, the symbol duration is much larger than the corresponding single carrier one and it is not likely that impulse noise be a treat in this case, all that make simplicity in the design and implementation of OFDM systems.

(v) Frequency Diversity- OFDM is the best technique in frequency diversity. In a combination of FDM and CDMA which is called MC-CDMA transmission technique, frequency diversity is already present in the system.

There are also some drawbacks in the OFDM system:

(i) Peak- to- Average power ratio (PAPR)

(ii) Sensitivity to frequency errors

3.4 OFDM MODEL:

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier system where data bits are sent simultaneously after encoding them on multiple sub-carriers. 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. OFDM is a technique with very less complexity which is used to modulate multiple sub-carriers efficiently by using digital signal processing. To ensure that the signal of one channel does not overlap with the signal from an adjacent one, a gap or guard band is left between each user.

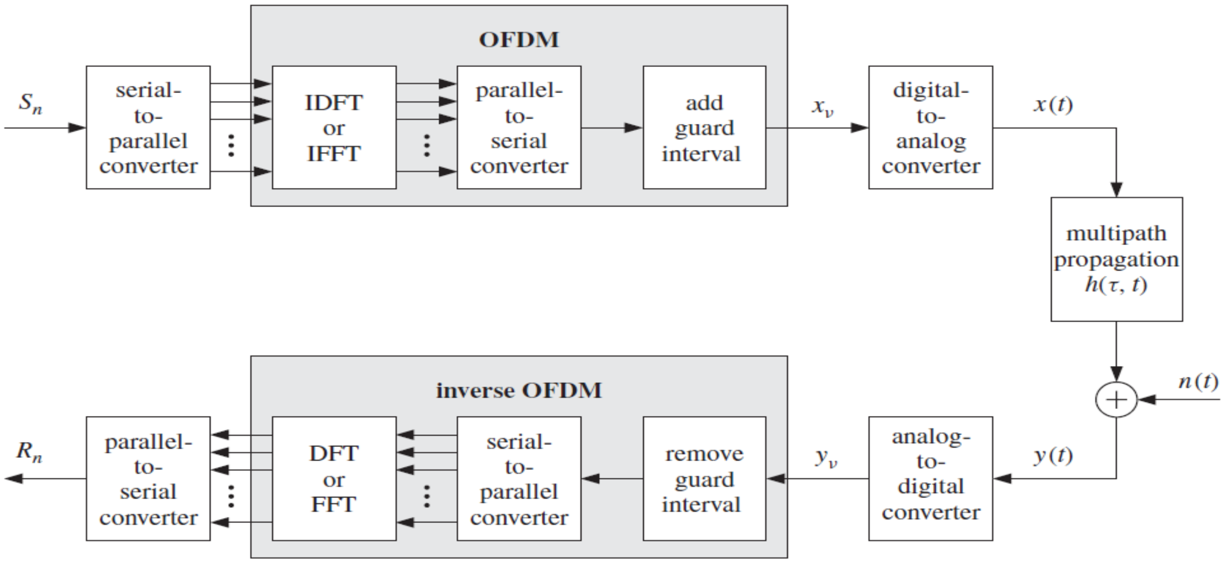


Figure 3-4-1 Digital multi-carrier transmission system applying OFDM

3.4.1 FFT Implementation

Mathematically, 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.

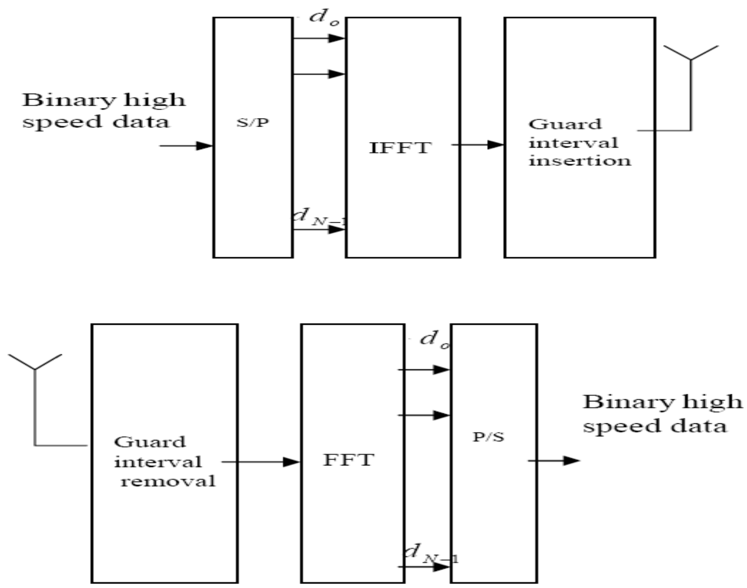
Let X= $\{X_0, X_1, \ldots, X_{n-i}\}$, denote data symbol block of length n. The IDFT of the date block X yields the time domain sequence x=$\{x_0,x_{1,\ldots,}x_{n-1}\}$, i.e.,

$$x_n=IFFT_N\{X_k\}(n)$$

To mitigate the effects of channel delay spread, a guard interval comprised of either a cyclic prefix or a suffix that is appended to the sequence X. In case of a CP, the transmitted sequence with the guard interval is

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

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



a) Transmitter **b)Receiver**

Figure 3-4-2 OFDM System Model

3.5 MATLAB SIMULATION

Basic simulation have been done for OFDM system with 128 subcarriers over AWGN channel using MATLAB.

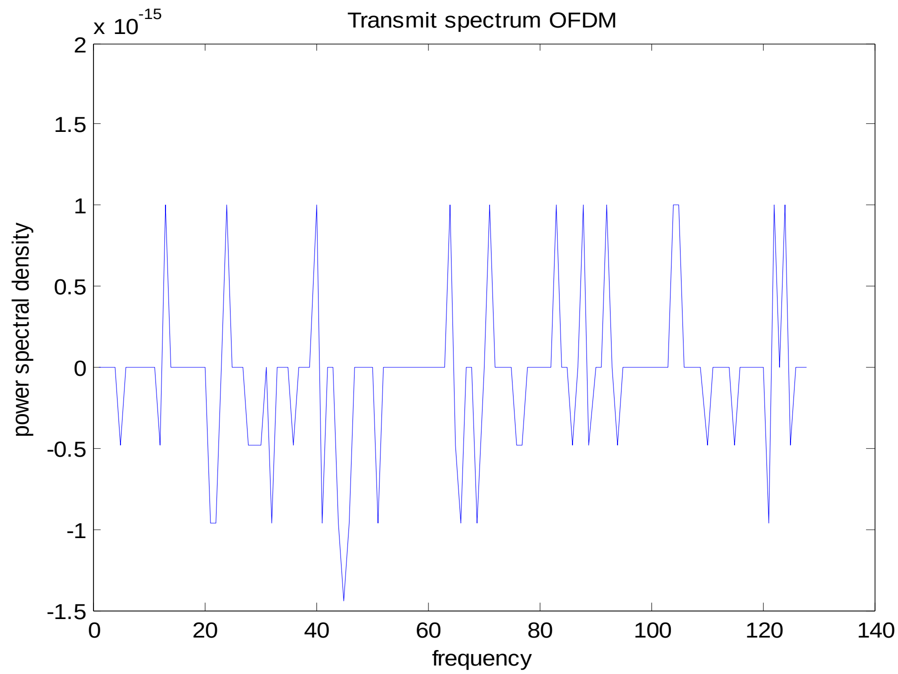


Figure 3.5.1 Transmit Spectrum of OFDM

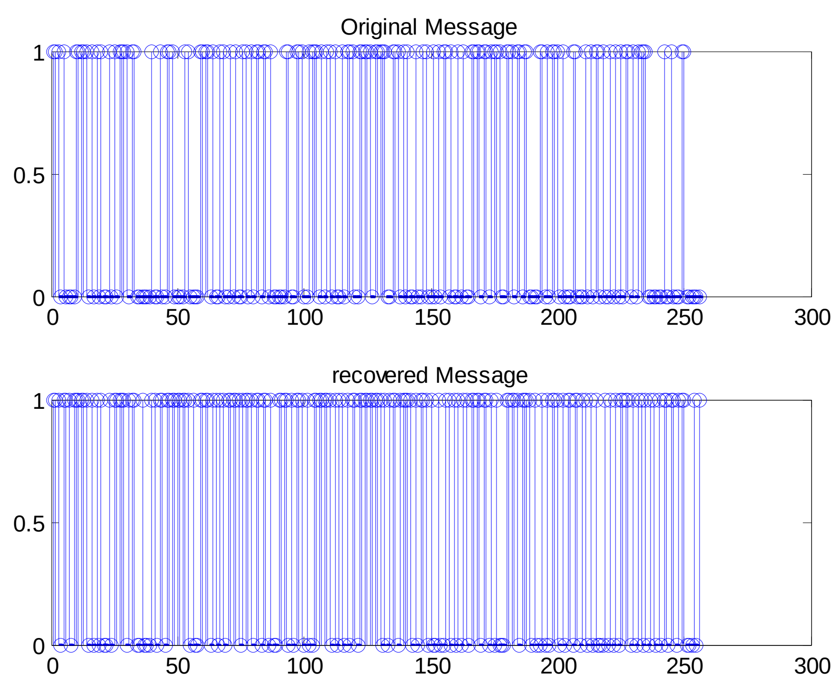


Figure 3.5.2 Original and Recovered Data from OFDM

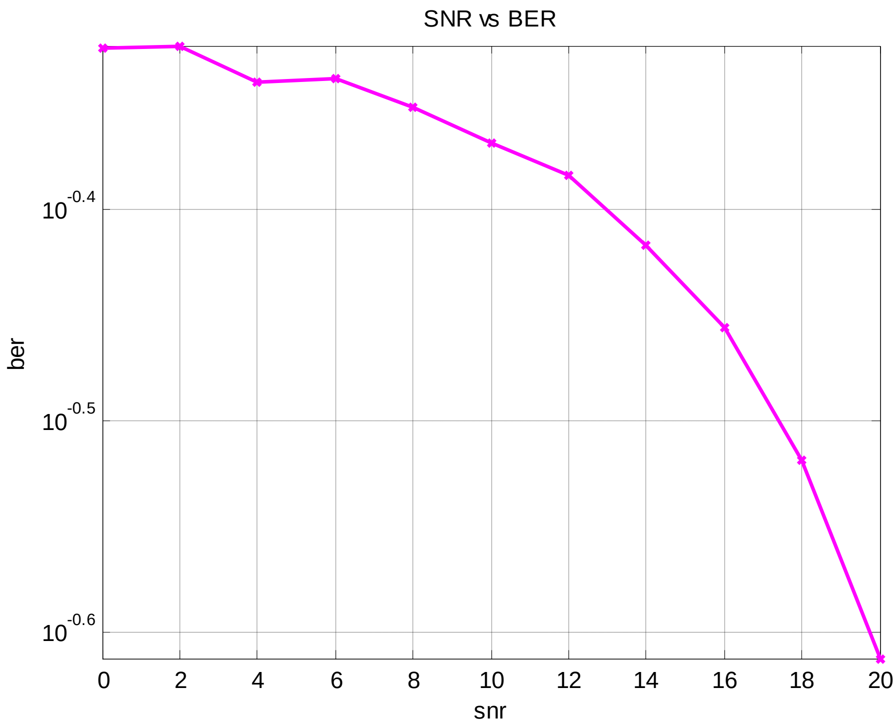


Figure.3.5.3 Performance Analysis of the OFDM System

3.6 DISCRETE WAVELET TRANSFORM

Present day OFDM system is implemented using IFFT and FFT. However, the FFT (Fast Fourier Transform) uses rectangular window which produces high side lobes leading to interference. In this thesis a replacement of Fourier transform by Wavelet transform is given and it has been observed that the performance of system improves with DWT-OFDM rather than FFT- OFDM.

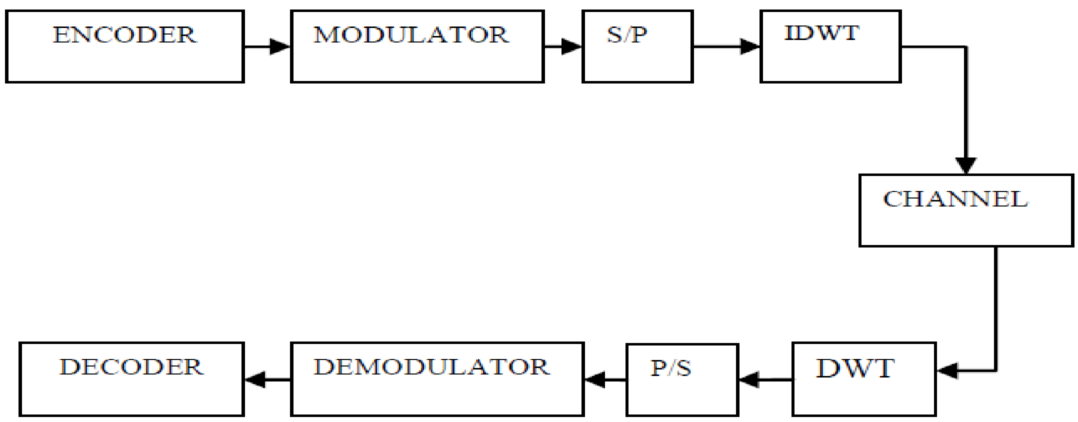


Figure 3-6-1Block diagram for DWT-OFDM

A wavelet is a small portion of a continuous wave and discrete wavelet is the name given to samples which are discretely sampled. It provides both time and frequency domain information. Some of the widely used types of wavelet transforms are HAAR, DAUBECHIES, BIORTHOGONAL, etc. The wavelet Transform decomposes the signal into small wavelets by using the wavelet function and the basis function. Also, the Wavelet Transform should satisfy orthonormal basis property and the perfect reconstruction property. The filters in the Discrete Wavelet Transform have got both low pass and high pass filters which actually acts as the Quadrature Mirror Filters (QMF). The low pass filter coefficients is called as approximated coefficients and the high pass filter coefficients is called as detailed coefficients.

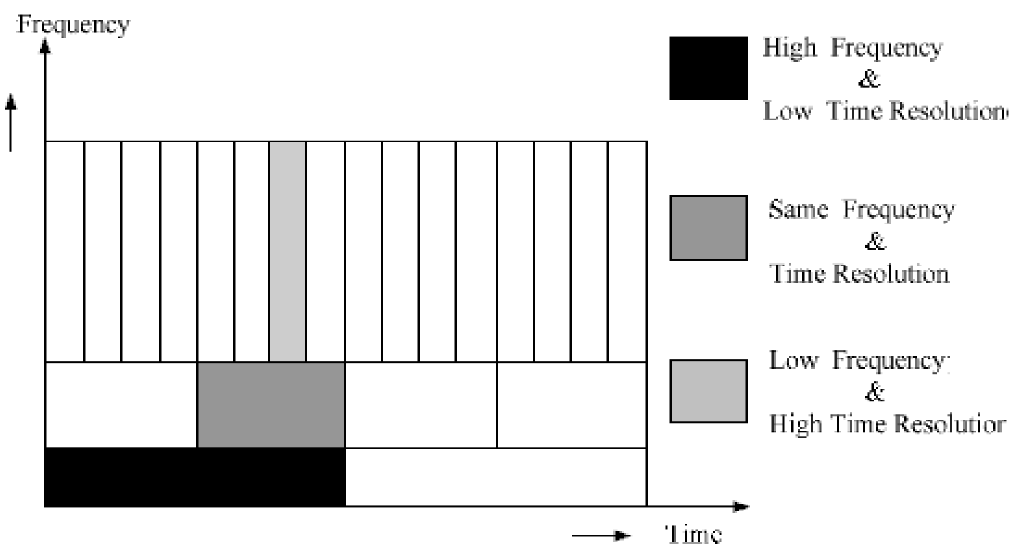


Figure 3-6-2 Wavelet Basis Function

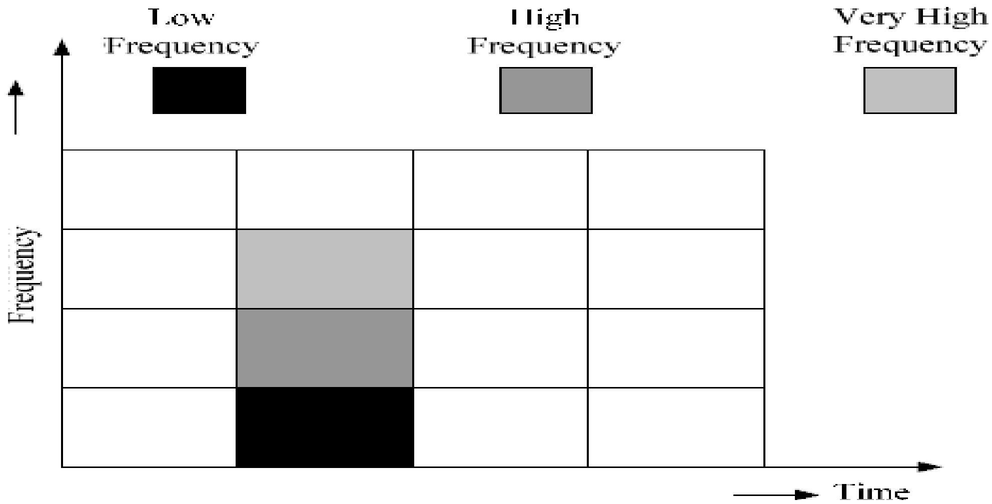


Figure 3-6-3 Fourier Basis Function

DWT and IDWT can be represented mathematically by equations (1) and (2) respectively:

$$D_k = \sum_{k=0}^{N-1} d(k)\psi(2k-1) \qquad (1)$$

$$d(k) = \sum_{m=0}^{\alpha}\sum_{n=0}^{\alpha} D_k\psi(2k-1) \qquad (2)$$

Here, D_k id the kth OFDM symbol after modulation and O(k) is a zero vector with same size as that of OFDM symbol. These two are first up-sampled, filtered through a low pass filter and combined together. The IDWT block is the inverse process of the DWT block. To implement the IDWT only two filters are required a low-pass and a high-pass filter.

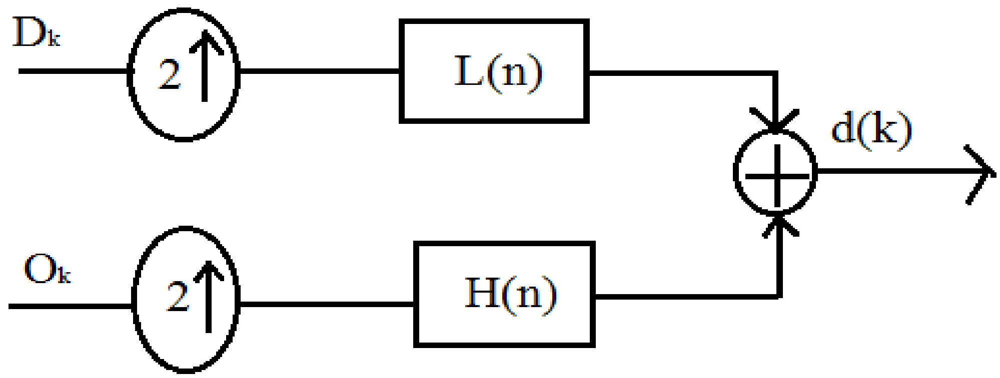


Figure 3-6-4 IDWT Implementation

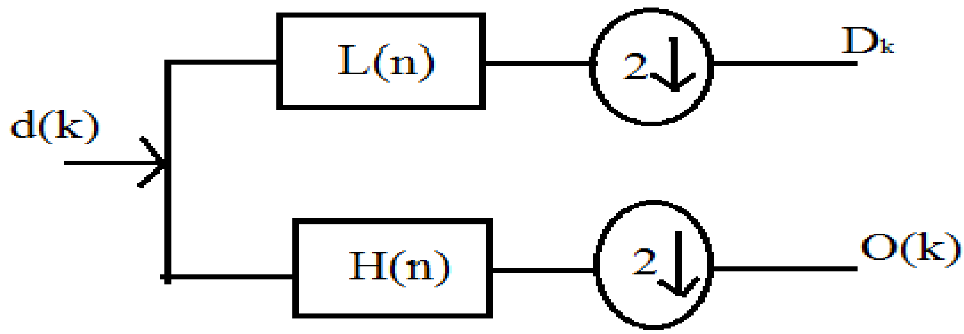


Figure 3-6-5 DWT Implementation

To implement DWT, the same two filters must be used. The received signal is filtered twice with a low pass and high pass filter respectively and then down-sampled. Further, the received signal is split into two halves and the output of high- pass filter is ignored since it contains a very small amount of information.

Simulations were done for DWT- OFDM and FFT- OFDM system and it was observed that DWT based OFDM system gives better performance than FFT based OFDM system.

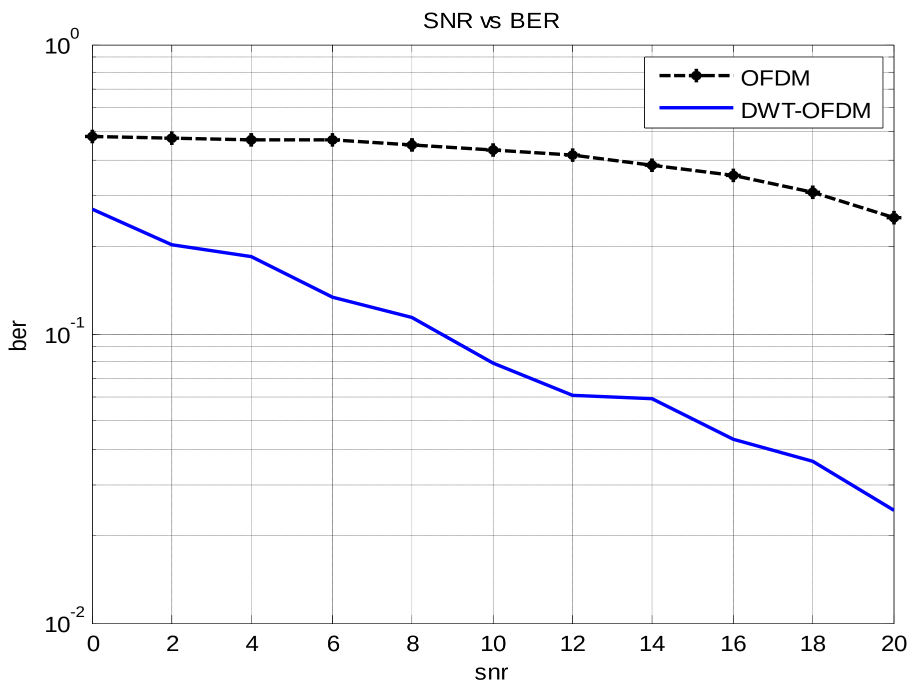


Figure 3-6-6 Performance analysis of FFT- OFDM and DWT-OFDM systems

3.7 DIFFERENT CHANNEL MODELS

Three different channels are used in this thesis for performance evaluation. They are Additive White Gaussian Noise (AWGN), Rayleigh and Rician [16]. If we have the model information of the medium between the transmitter and the receiver, the profile of received signal can be then easily obtained from that of the transmitted signal. This model of the medium is called channel model.

3.7.1 AWGN CHANNEL

The simplest mathematical model for a channel is additive noise channel. In this model, the transmitted signal s(t) is corrupted by an additive random noise process n(t). If the noise is introduced primarily by electronic components and amplifiers at the receiver, it may be characterized as thermal noise. This type of noise is characterized statistically as a Gaussian noise process. Hence, the resulting mathematical model for the channel is usually called the additive Gaussian noise channel. This model does not account for fading, frequency selectivity, interference, non-linearity or dispersion. The received signal after passing through a noisy channel is then:

$$r(t) = s(t) + n(t)$$

where r(t) is the received signal, s(t) is the transmitted signal and n(t) is the noise introduced in the channel.

3.7.2 RICIAN CHANNEL MODEL

Rayleigh channel model is a stochastic model for radio propagation. It is caused by partial cancellation or loss of the radio signal by itself when the signal arrives at the receiver by several different paths. When one of the paths is much stronger than the others, Rician fading is observed. This path is typically a line of sight signal. The amplitude gain is characterized by a Rician distribution. The small scale fading envelope distribution is Rician when there is a line-of-sight propagation path present. In such a situation, random multipath components arriving at different angles are superimposed on a stationary dominant signal.

3.7.3 RAYLEIGH CHANNEL MODEL

The envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component in mobile radio channels. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. According to the central limit theorem, in the presence of sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components.

Rayleigh distributed occurs when there is no dominant component to the scatter. This process has zero mean and phase distributed evenly between 0 and 2π radians. This fading is the specialized model for stochastic fading when there is no line-of-sight signal present. The Rayleigh fading model is useful in highly developed city centers where there is no line of sight between the transmitter and the receiver.

CHAPTER 4

CHANNEL CODING

4.1 INTRODUCTION

Channel coding is an inherent part of any multicarrier system. This chapter discusses the performance of the OFDM with different coding techniques and a combination of coding techniques. Following this introduction, the chapter is organized as follows: Section 4.2 describes the different coding techniques and section 4.3 gives the simulation model and performance of channel coded OFDM system by evaluating the bit error rates for different values of SNR.

4.2 DIFFERENT CHANNEL CODES

Channel Coding is a technique used for controlling errors in data transmission over unreliable or noisy channels. Channel Coding provides provide protection from transmission errors. There are basically two types of Forward Error Correcting codes:

1: Block Codes

2: Convolutional Codes

Block codes work on fixed- size blocks (packets) of bits or symbols of predetermined size. Some of the commonly used block codes are Reed- Solomon codes, BCH codes, multidimensional parity codes, Hamming codes, etc. They are decoded by hard- decision algorithms as they are memoryless.

Convolutional codes work on bits or symbol streams of arbitrary length. They are most commonly decoded with the Viterbi algorithm, MAP or BJCR algorithms or other soft-decision algorithms. Convolutional codes are coding algorithms with memory.

Some of the commonly used channels coding schemes for multicarrier transmission are as follows:

4.2.1 Hamming Codes:

The binary Hamming codes have the property that

$(n , k) = (2^m – 1, 2^m – 1- m)$,

where m is any positive integer. For example, for m=3 we have a (7,4) Hamming codes. 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. The parity-check matrix of a Hamming code is constructed by listing all columns of length *r* that are non-zero. Hamming codes can only detect and correct errors when the error rate is low for example, in the case of computer memory (ECC memory), where bit errors are extremely rare. Hamming codes of parity check matrix of size [7, 4] were introduced in 1950. It encodes 4 bits of data into 7 bits of codeword by adding three parity bits. It can detect and correct single-bit errors only but with the addition of an overall parity bit, it can also detect double-bit errors also, but cannot correct them.

$$\mathbf{G} := \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix}_{4,7}$$

and

$$\mathbf{H} := \begin{pmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{pmatrix}_{3,7}.$$

4.2.2 Low Density Parity Check (LDPC) Codes

An LDPC code [5] *C(n, k)* is a type of linear block code. Its parity check matrix H[$n – k$, n] has mainly ‘0’s and only a limited number of ‘1’s, i.e. is sparse. Here, each k -bits block of information is encoded to a codeword of size n. Today, LDPC codes are widely used in many standards like WiMAX- IEEE 802.16e, DVB-S2 and IEEE 802.11n. Consider a LDPC code 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:

$$H = \begin{array}{c} \\ \\ \end{array} \begin{array}{cccccccc} n_1 & n_2 & n_3 & n_4 & .. & & .. & n_8 \end{array}$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 \end{bmatrix} \begin{array}{c} m_1 \\ m_2 \\ m_3 \\ m_4 \end{array}.$$

For a valid codeword, the modulo-2 sum of adjacent bits of every check node of the Parity check equations has to be zero. In other words, the vector x is a part of the codeword C only if it satisfies the condition:

$$\mathbf{HxT = 0} \qquad\qquad ,\forall\ \mathbf{x} \in \mathbf{C}.$$

The number of ‘1’s in each column of the parity check matrix ‘H’ is only 2, which makes it matrix sparse. The same code can be represented through a bipartite graph, called a ‘Tanner’ graph, illustrated in figure 4-2-1. This graph connects each check equation or node to its participating bits nodes.

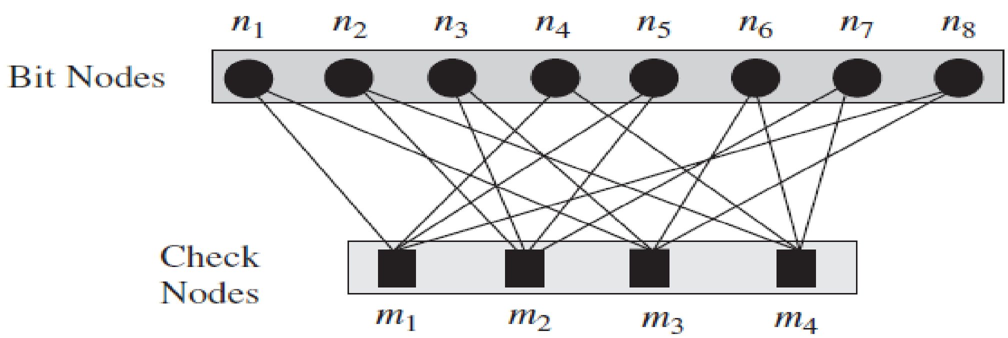


Figure 4-2-1 The Tanner graph representation of the LDPC code

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.

4.2.3 Convolutional Codes

Convolutional codes are used in Universal Mobile Telecommunications System and Global System for Mobile communications, digital cellular systems, dial-up modems, satellite communications, 802.11 wireless Local Area Networks (LANs), etc. The major reason for this popularity is the existence of efficient decoding algorithms such as Viterbi algorithms.

A convolutional encoder is a linear sequential circuit and therefore a Linear Time-Invariant or LTI system. An LTI system is completely characterized by its impulse response.

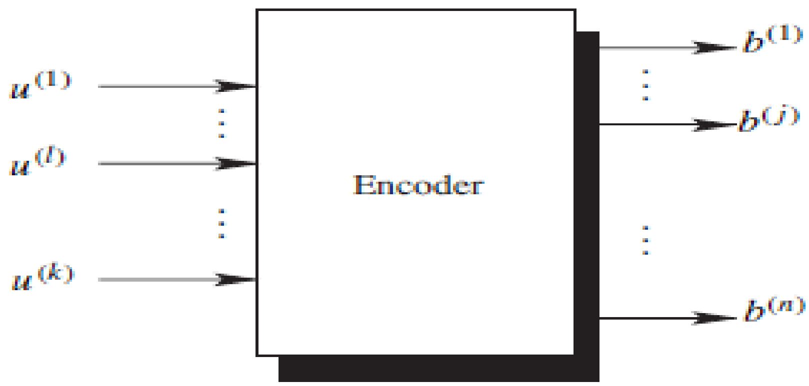


Figure 4-2-2 Convolutional Encoder

A Convolutional encoder with *k* input bits and *n* output bits is shown in figure 4-2-2. Here, k and n denote the number of encoder inputs and outputs respectively. Thus, the code rate is **R = K/N.**

The current n outputs are linear combinations of the present k input bits and the previous k × m input bits, where m is called the memory of the convolutional code. A binary convolutional code is often denoted by a three – tuple (n, k, m).

4.2.4 Turbo Codes

The turbo codes were first was introduced in 1993. They were based on convolutional coding. A turbo code is formed from the parallel concatenation of two codes separated by an interleaver. A general of turbo code encoder is shown in figure 4-2-3.

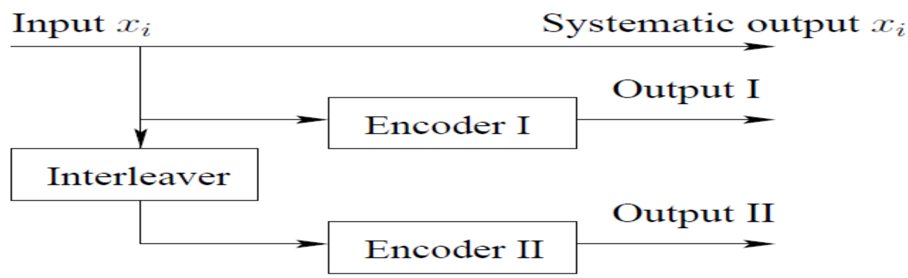


Figure 4-2-3 a generic turbo encoder

The two encoders used are identical and the code is in a systematic form, i.e. the input bits also occur in the output. The interleaver reads the bits in a pseudo-random order.

4.3 SYSTEM MODEL AND MATLAB SIMULATION

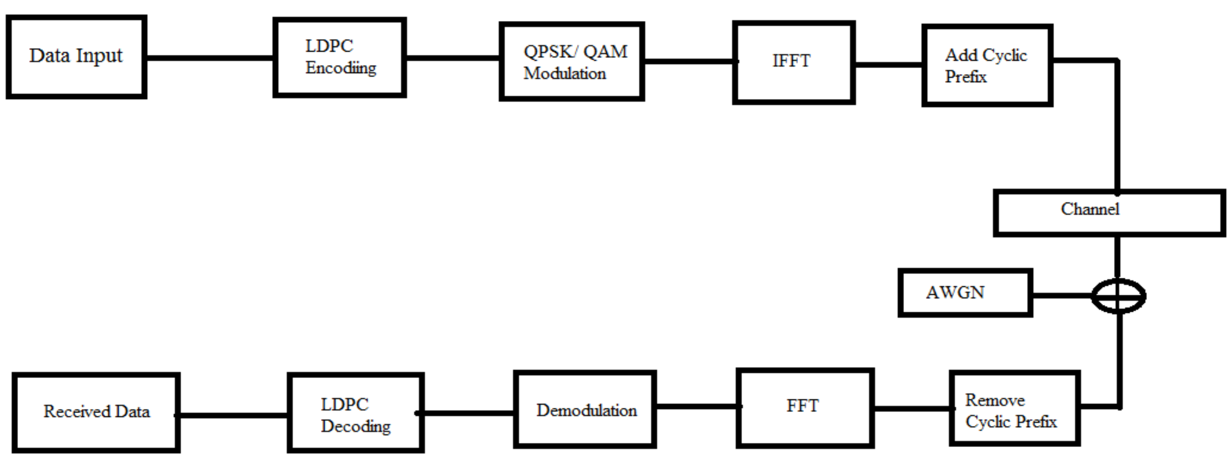


Figure 4-3-1 System model of LDPC coded OFDM

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. The length of cyclic prefix padded with each block should be longer than the channel response to mitigate the inter symbol interference. LDPC channel encoding helps resist the AWGN noise introduced in the channel. Let the signals be transmitted over an AWGN channel. The noise in the channel is a Gaussian random variable with zero mean and variance σ2. At the receiver side, the reverse operations are performed that is; removing cyclic prefix, FFT, demodulation and LDPC decoding of the received sequence. Finally, the numbers of erroneous bits are counted for performance analysis of the system.

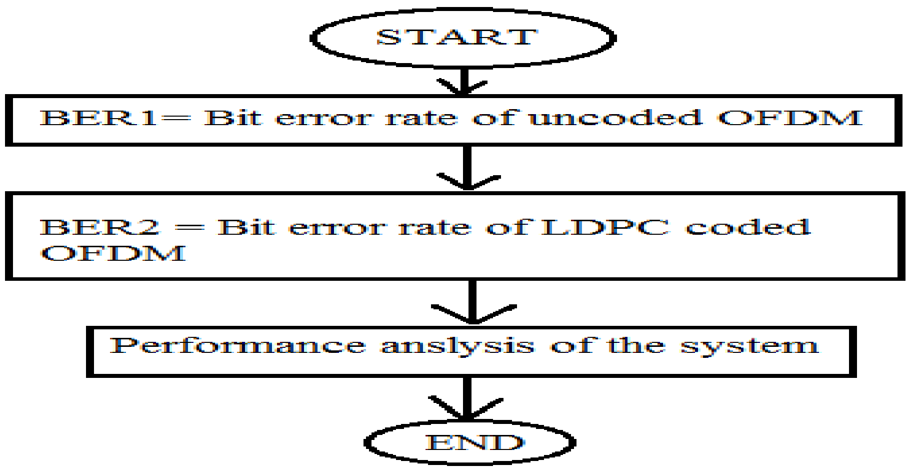


Figure 4-3-2 Flowchart of Simulation Procedure

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 4.3.1 Simulation Parameters

PARAMETER	**VALUE**
Digital Modulation	QPSK, 16-QAM
LDPC code rate	½
Channel Model	AWGN channel
CP Length	16 bits
FFT size	128

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.

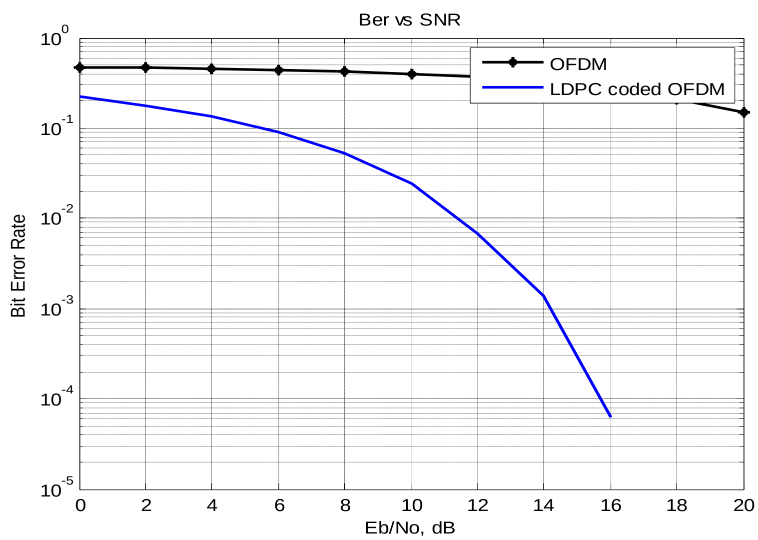


Figure 4-3-3 Performance Analysis of OFDM and LDPC coded OFDM with 64 FFT

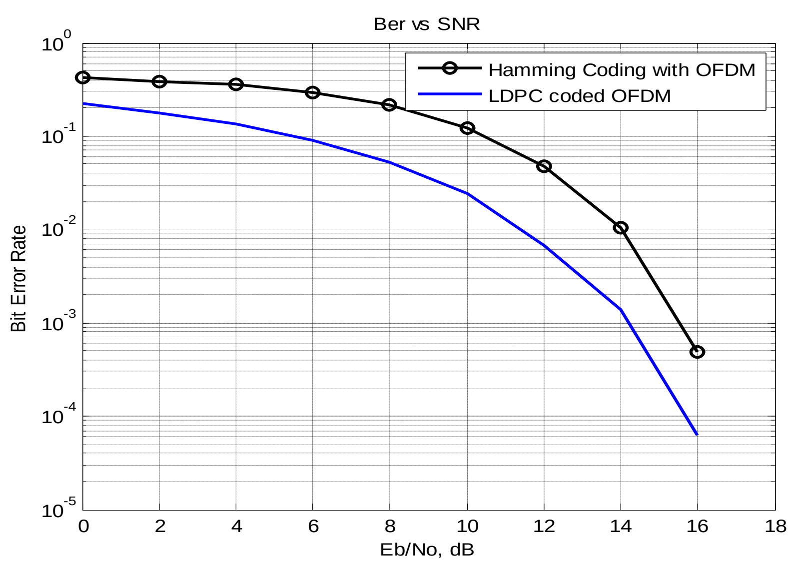


Figure 4-3-4 Performance Analysis of Hamming COFDM and LDPC coded OFDM with 64 FFT

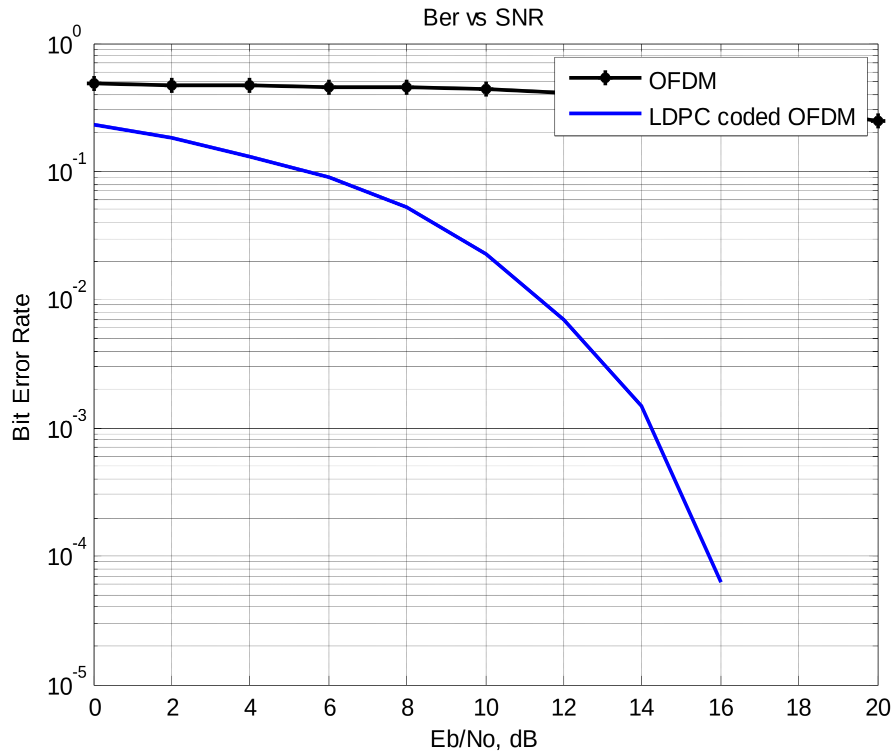


Figure 4-3-5 Performance Analysis of OFDM and LDPC coded OFDM with 128 FFT

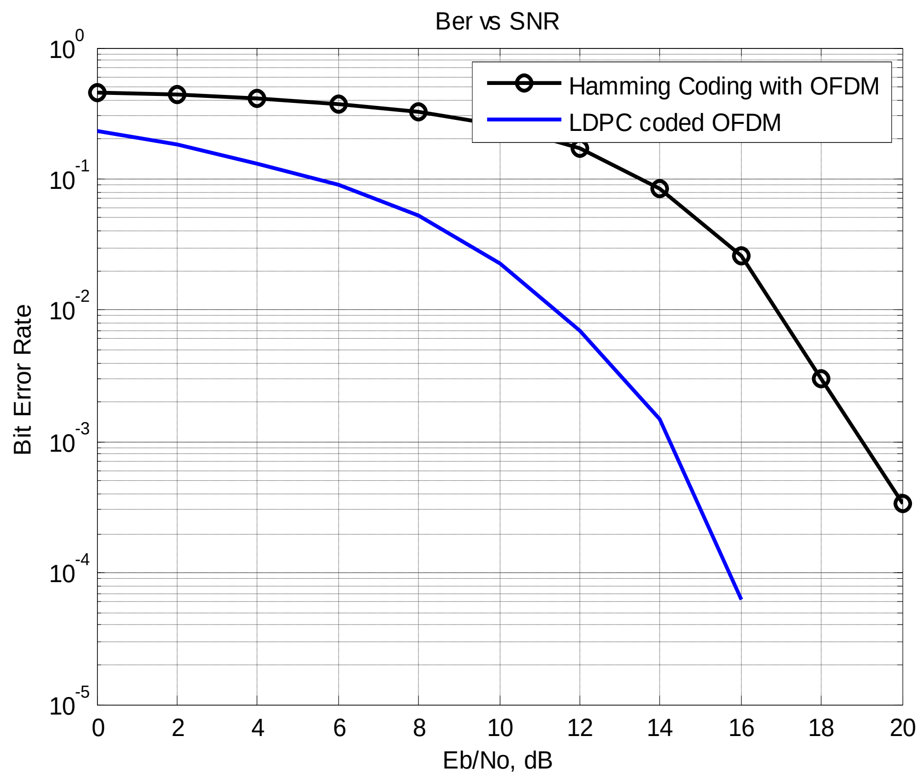


Figure 4-3-6 Performance Analysis of Hamming COFDM and LDPC coded OFDM with 128 FFT

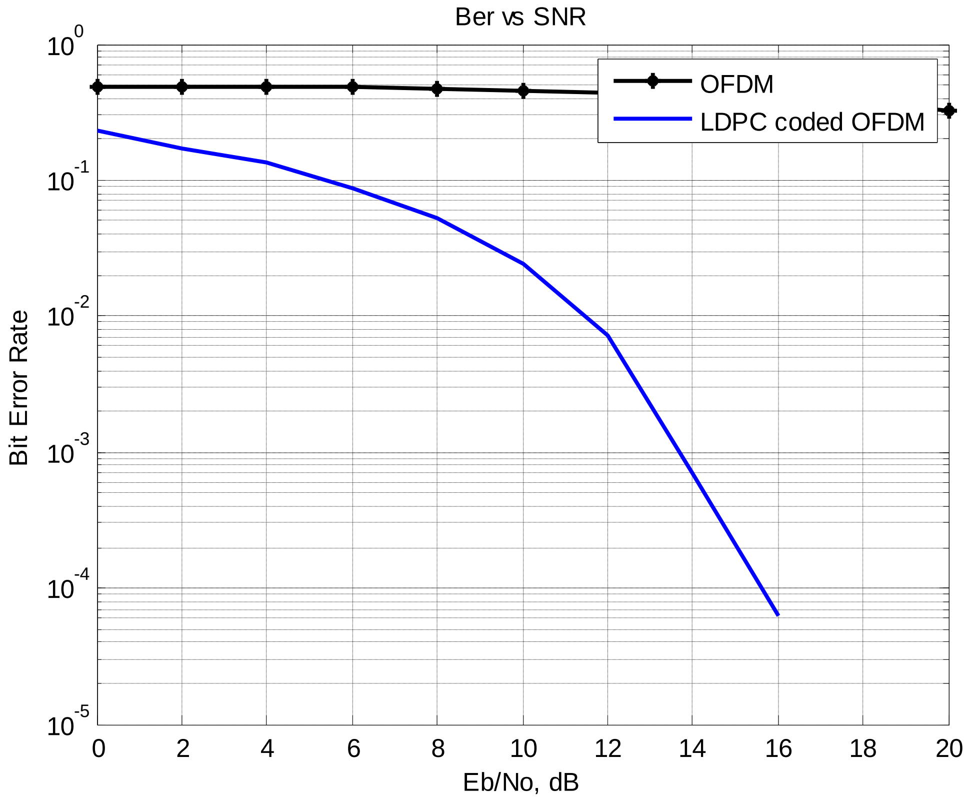


Figure 4-3-7 Performance Analysis of OFDM and LDPC coded OFDM with 256 FFT

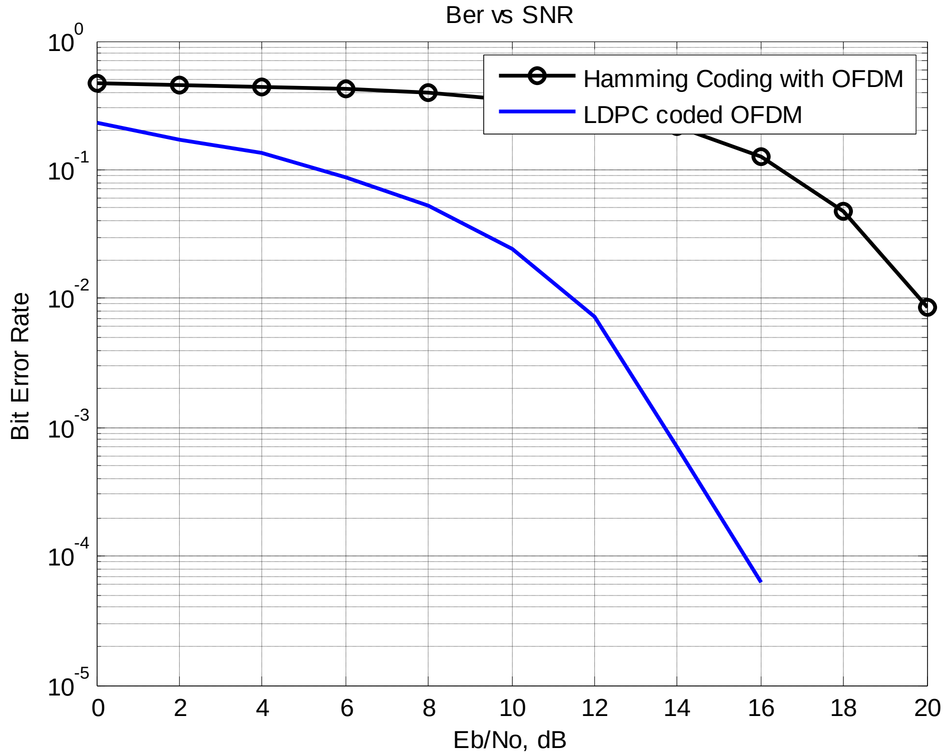


Figure 4-3-8 Performance Analysis of Hamming COFDM and LDPC coded OFDM with 256 FFT

The first two graph figure 3-3-3 and figure 3-3-4 give performance analysis of OFDM, Hamming coded OFDM and LDPC coded OFDM with FFT size of 64. Similarly figure 3-3-5 and figure 3-3-6 give performance for 128 FFT and figure 3-3-7 and figure 3-3-8 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 OFDM increase with forward error correction techniques.

CHAPTER 5

IMAGE FUSION AND COMPRESSION

5.1 INTRODUCTION

Image fusion is the process of combining two or more images by taking the relevant information from each of them. They may have different spatial and spectral characteristics. The main objective of the image fusion is to retain the most desirable characteristics of each image. Minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level is known as image compression. This reduction in file size allows more images to be stored in a given amount of disk or memory space, thus, reducing the time required for sending the images over the channel. In this chapter these two techniques for increasing the time efficiency of transmitted images are explained. In section 5.2, basics of image fusion is explained and in section 5.3 image compression technique is described. Later in section 5.3.1 SPIHT compression algorithm is described which is used in this work. Definitions of BER and PSNR are given in sections 5.4 and 5.5 respectively.

5.2 IMAGE FUSION

Image fusion is the process of combining two or more images by taking the relevant information from each of them. They may be acquired from same or different sensors. They may have different spatial and spectral characteristics. The main objective of the image fusion is to retain the most desirable characteristics of each image. The result of image fusion is a new image that retains the most desirable information and characteristics of each input image. Image fusion has been receiving increasing attention in the researches for a wide spectrum of applications due to the availability of multi – sensor data. Some of the examples of image fusion are shown below.

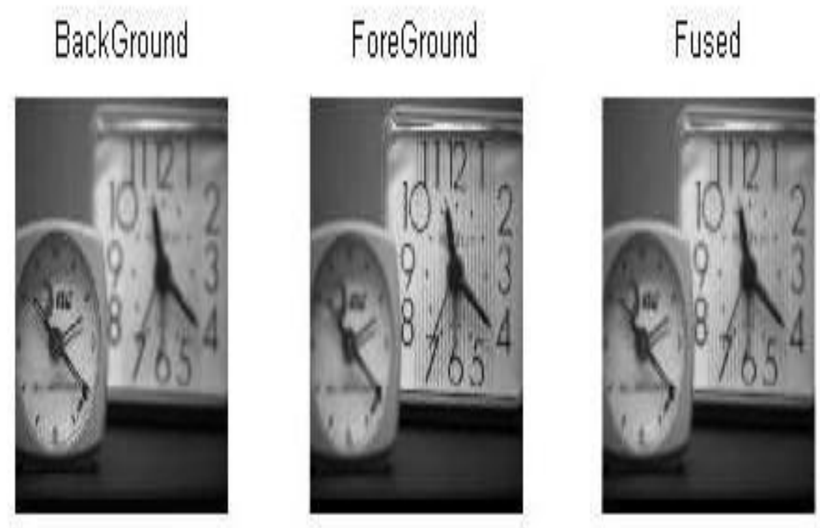


Fig. 5.2.1 Example of Image Fusion

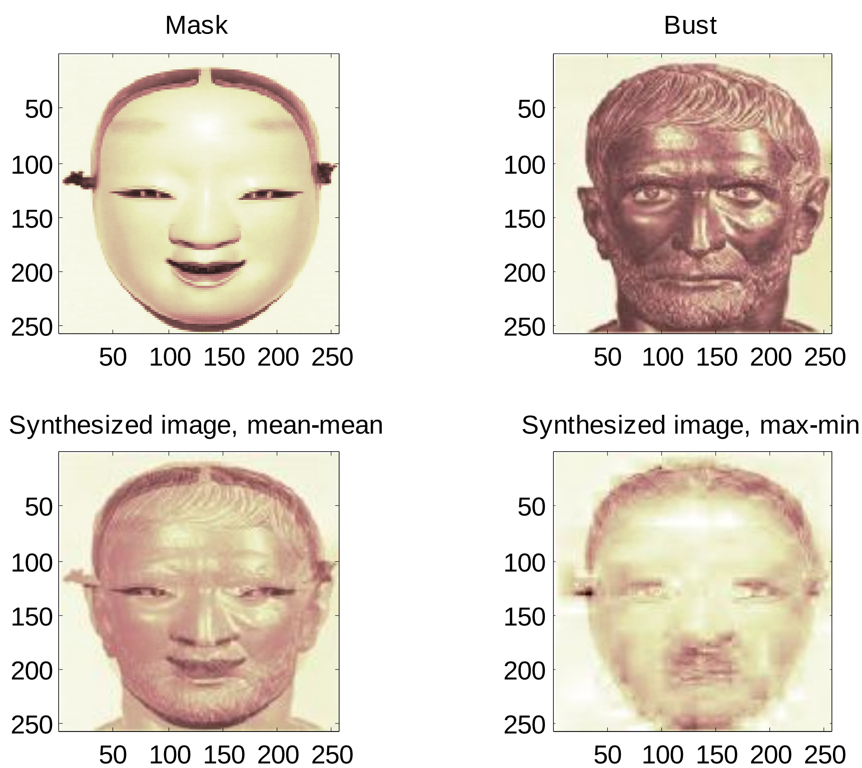


Figure 5-2-2 Example of Image Fusion

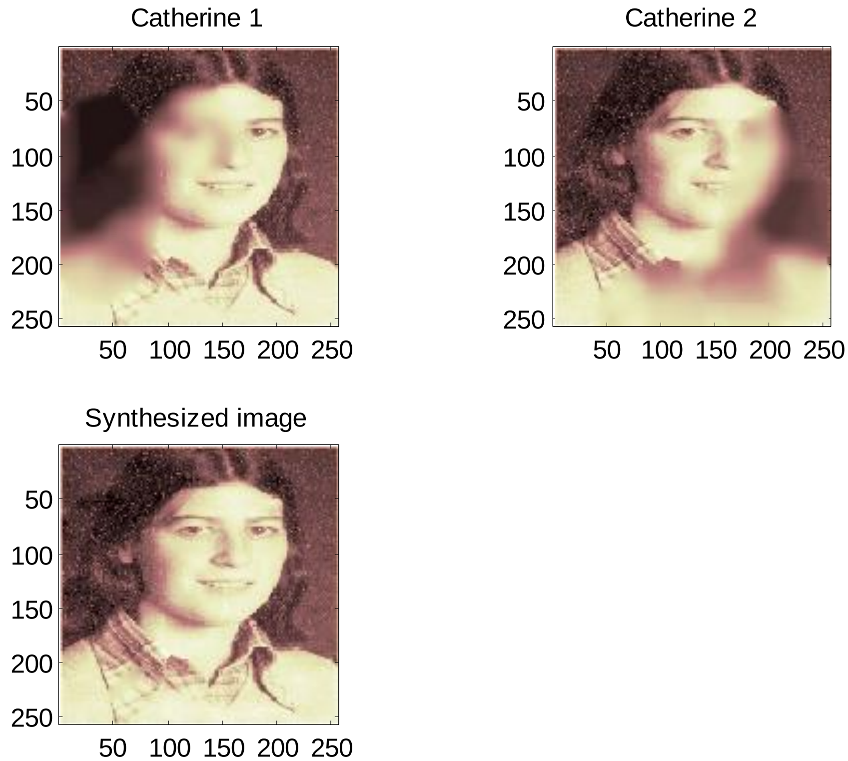


Figure 5-2-3 Restoration by fusion of fuzzy images 'Catherine'

5.3 IMAGE COMPRESSION

Image compression is the process of minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. This reduction in file size allows more images to be stored in a given amount of disk or memory space, thus, reducing the time required for sending the images over the channel. There are several different ways to compress an image file. The most commonly used compressed graphic image formats are the JPEG format and the GIF format. The JPEG or Joint Photographic Experts Group method is more often used for photographs. The GIF method is commonly used for line art and other images in which geometric shapes are relatively simple. Image compression may be either lossless or lossy. Lossy methods are especially suitable for natural images such as photographs in applications where minor loss of fidelity is acceptable to achieve a substantial reduction in bit rate. Lossless compression is preferred for archival purposes and is used for medical imaging purposes, technical drawings or comics and clip arts.

An encoder and a decoder can be used for the compression process. The encoder converts the received image into a series of binary data or bit- stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. If the total data quantity of the original image is greater than the total data quantity of the decoded image, then the decoded image is known as compressed.

The compression ratio is defined as follows:

$$CR = R1/R2$$

Where R1 is the data rate of original image and R2 is that of the encoded bit-stream. In this thesis, SPIHT compression has been used which is described in section 4.3.1.

5.3.1 SPIHT ALGORITHM

Set Partitioning in Hierarchical Trees is an image compression algorithm that defines and partitions sets in the wavelet decomposed image using a special data structure called a ‘spatial orientation tree’. This tree comprises of a group of wavelet coefficients arranged in a tree rooted in the lowest frequency subband with offspring in the same spatial orientation for higher frequency subbands. The main idea of SPIHT algorithm is to sort the wavelet coefficients in the following three stages:

- List of Insignificant Sets (LISs)
- List of Insignificant Pixels (LIPs)
- List of Significant Pixels (LSPs)

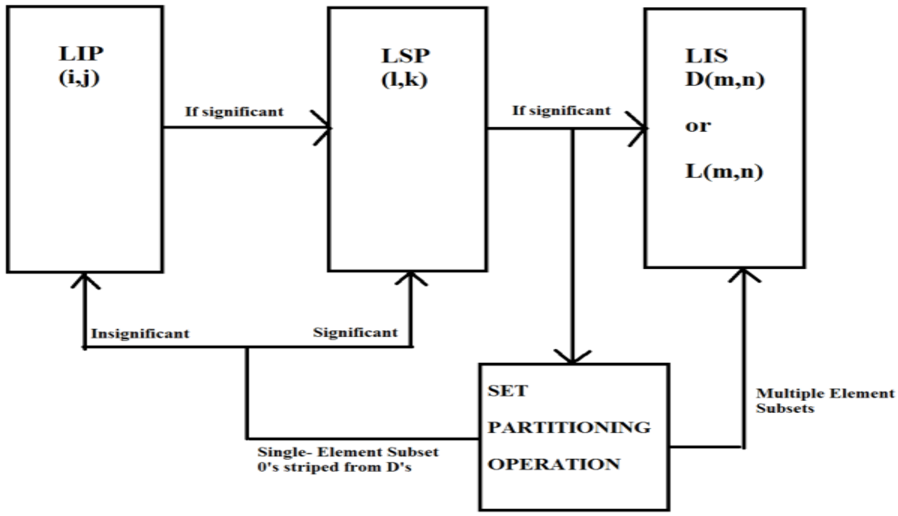


Figure 5-3-1 SPIHT Sorting Process

There are three stages in SPIHT algorithm:

1: Initialization - First of all, a threshold value is defined based on maximum value in the wavelet pyramid. The set of LSPs is then formed in the form of an empty stack. It puts the coordinates of all coefficients in the coarsest level, that is; the lowest frequency band of the wavelet pyramid into the LIP. It also puts the coordinates of coefficients which have descendants into the LIS.

2: Sorting – In the sorting process, the elements of the LIP and the sets that have roots in the LIS are firstly sorted. For each pixel in the LIP, a significance test is carried against the current threshold and the test results are obtained as an output bit stream. The results are then encoded in a binary format as either 0 or 1. This process of sorting and partitioning is continued until all significant coefficients are obtained and stored in the LSP.

3: Refinement - The sorting process of the SPIHT is followed by a refinement process. It is done for all entries in the LSP with a determined threshold value, except the entries moved to the LSP during the last sorting phase. The sorting process and refinement stage is continued until a required bit rate is achieved. Also, the threshold value is divided by 2.

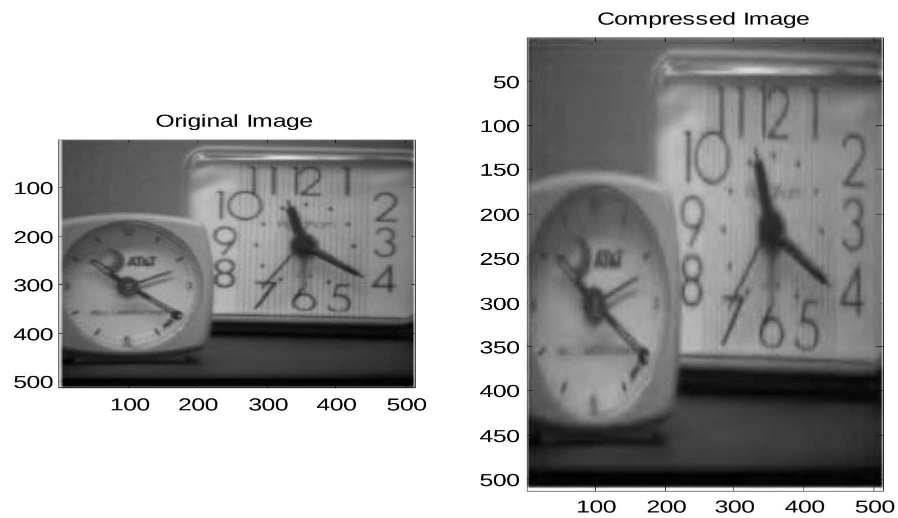


Figure 5-3-2. Example of SPIHT Compression

SPIHT method represents an important advancement in the field of image compression. It is not a simple extension of traditional methods for image compression. The method deserves special attention because it provides the following:

- Good image quality and high PSNR, especially for color images;
- Produces a fully embedded coded file;
- It is optimized for progressive image transmission;
- Simple quantization algorithm;
- Fast coding/decoding (nearly symmetric);
- Can be used for lossless compression.
- Has wide applications, completely adaptive;
- Can code to exact bit rate or distortion;
- Efficient combination with error protection.

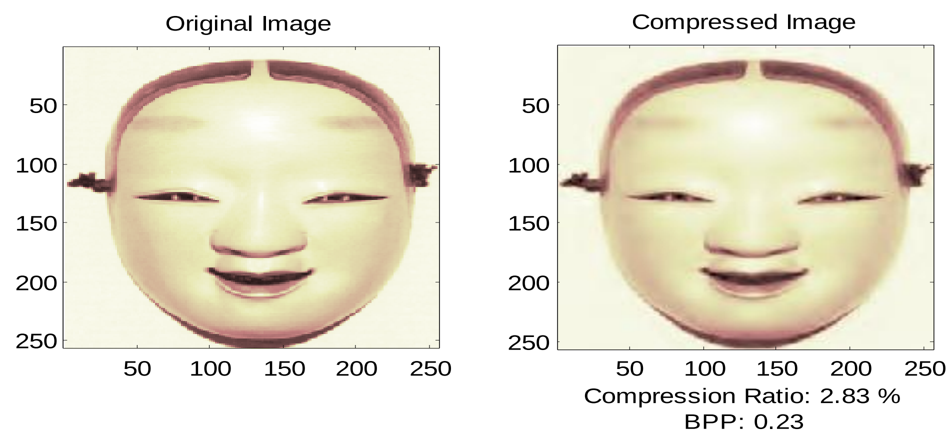


Figure 5-3-3 Example of SPIHT Compression

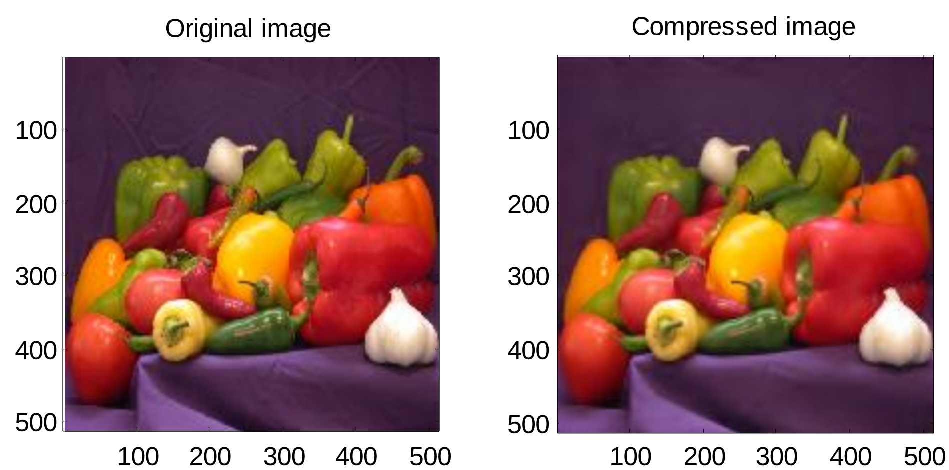


Figure 5-3-3 Example of SPIHT Compression with CR=1.65 and (bits per pixel) bpp=0.39

Different compression methods were developed specifically to achieve at least one of these objectives but what makes SPIHT really outstanding is that it yields all these qualities simultaneously.

5.4 BIT ERROR RATE

Bit error rate or BER is one of the main parameters used for analyzing the performance of the systems that transmit digital data from one location to another. Bit error rate (BER) assesses the full end to end performance of a transmitter, receiver and the medium between them. Therefore, BER evaluated the actual performance of a system in operation. A bit error rate is defined as the rate at which errors occur in a transmission system or in other words it is the ratio of number of erroneous bits to the total number of bits transmitted. BER can be affected by a number of factors.

- Interference.
- Increase transmitter power
- Lower order modulation
- Reduce bandwidth

5.5 PEAK SIGNAL TO NOISE RATIO

Peak signal-to-noise ratio, also called PSNR, is the ratio maximum possible power of signal and the power of corrupting noise that affects the signal. PSNR is usually expressed in terms of the logarithmic decibel scale. PSNR is mostly used to measure the performance of the reconstructed image and is defined by Mean Square Error (MSE) as:

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

where m x n give the dimensions of image. PSNR can be obtained using this mean square value by the formulas below:

$$
\begin{aligned}
PSNR &= 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \\
&= 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \\
&= 20 \cdot \log_{10}\left(MAX_I\right) - 10 \cdot \log_{10}\left(MSE\right)
\end{aligned}
$$

where MAX denotes the maximum possible pixel value of an image.

CHAPTER 6

PROPOSED SYSTEM

6.1 RESEARCH METHODOLOGY

OFDM technique in multimedia transmission is the basis of this thesis. OFDM as a multicarrier transmission technique is a subject of high interest in wireless communications. The use of OFDM has increased greatly due to its numerous advantages: high data rate transmission, the quality of the reception and its ability to combat Inter-symbol Interference (ISI) especially in fading channels. The purpose of this project is to analyze the performance of OFDM technique over different channels with different channel coding schemes under specific assumption. Two RGB images fused together and compressed using SPIHT method are the transmission data in this thesis. Transmitting multiple images take double time than transmitting one single fused image. Also there will be overall more errors when multiple images are transmitted over a noisy channel. An error correcting code can be used for resolving this. The different channels exhibit different effects on the performance of image transmission using OFDM technique. Results from the simulation analysis will be viewed in comparison with theoretical results.

Figure 6-1-1 shows the steps in the implementation of this thesis. As in the review of literature images transmission over LDPC coded OFDM system will be implemented and bit error rate will be evaluated. Parameters of this system will be compared with LDPC coded OFDM systems with FFT and DWT. Also, wavelet based image fusion algorithm is used for combining images to be transmitted and SPIHT compression technique is used for reducing image size.

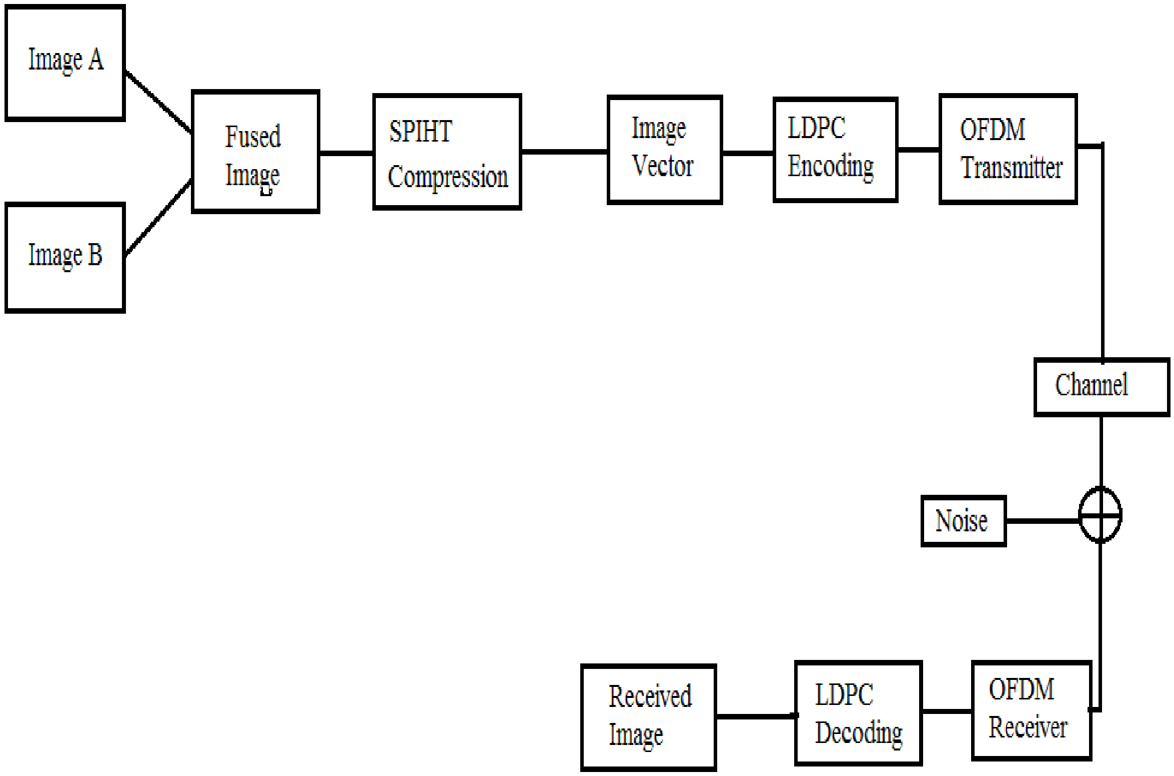


Figure 6-1-1 Research Model

6.2 SIMULATION PROCEDURE

Two images are taken as input and fused together using wavelet image fusion technique. They are then compressed using SPIHT compression and transmitted on different channel models with LDPC coded FFT-OFDM and LDPC coded DWT-OFDM. The images are fused with alpha factor 0.5 that is both images are mixed equally. An LDPC code has been employed with rate R=1/2 and parity check matrix of dimensions 32400x64800. The number of useful subcarriers if 52 and cyclic prefix is 16.

Table 6.2.1 Simulation Parameters of the LDPC coded OFDM system

PARAMETER	VALUE
Digital Modulation	QPSK, 16-QAM

LDPC code rate	½
Channel Model	AWGN channel
CP Length	16 bits
FFT size	128
Alpha Factor	0.5
Compression Ratio	1.5204
Bits per pixel	0.3649

The flowchart for the simulation of the proposed methodology is as follows:

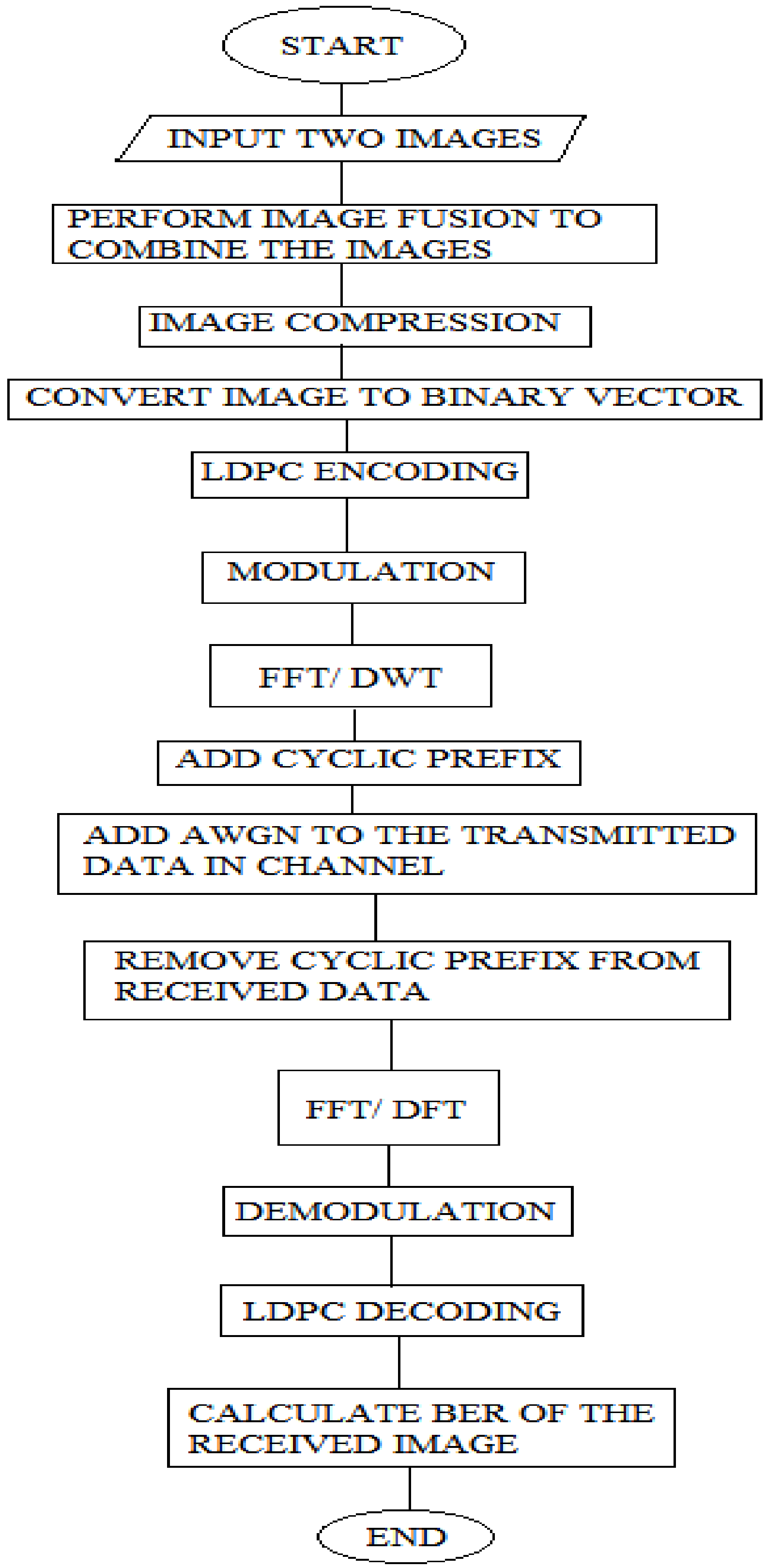

START
INPUT TWO IMAGES
PERFORM IMAGE FUSION TO COMBINE THE IMAGES
IMAGE COMPRESSION
CONVERT IMAGE TO BINARY VECTOR
LDPC ENCODING
MODULATION
FFT/ DWT
ADD CYCLIC PREFIX
ADD AWGN TO THE TRANSMITTED DATA IN CHANNEL
REMOVE CYCLIC PREFIX FROM RECEIVED DATA
FFT/ DFT
DEMODULATION
LDPC DECODING
CALCULATE BER OF THE RECEIVED IMAGE
END

Figure 6-2-1 Flowchart for simulation of proposed technique

6.3 RESULTS

The whole procedure was followed with and without LDPC encoding. It was observed that the performance of the system was much better when LDPC channel codes were employed before OFDM modulation transmitter. Analysis has been done in the presence of AWGN. Simulations have been done on Rayleigh and Rician channel models. Also, BER and PSNR have been evaluated of the reconstructed image for both the systems.

1: For AWGN

Table 6.3.1 Comparison of BER probability for OFDM and LDPC coded OFDM

SNR (dB)	BER with OFDM	BER with LDPC coded OFDM
0	.268	.217
2	.215	.171
4	.166	.123
6	.119	.077
8	.075	.042
10	.039	.016
12	.015	.003
14	.003	.0006
16	.0004	.000
18	.000	.000
20	.000	.000

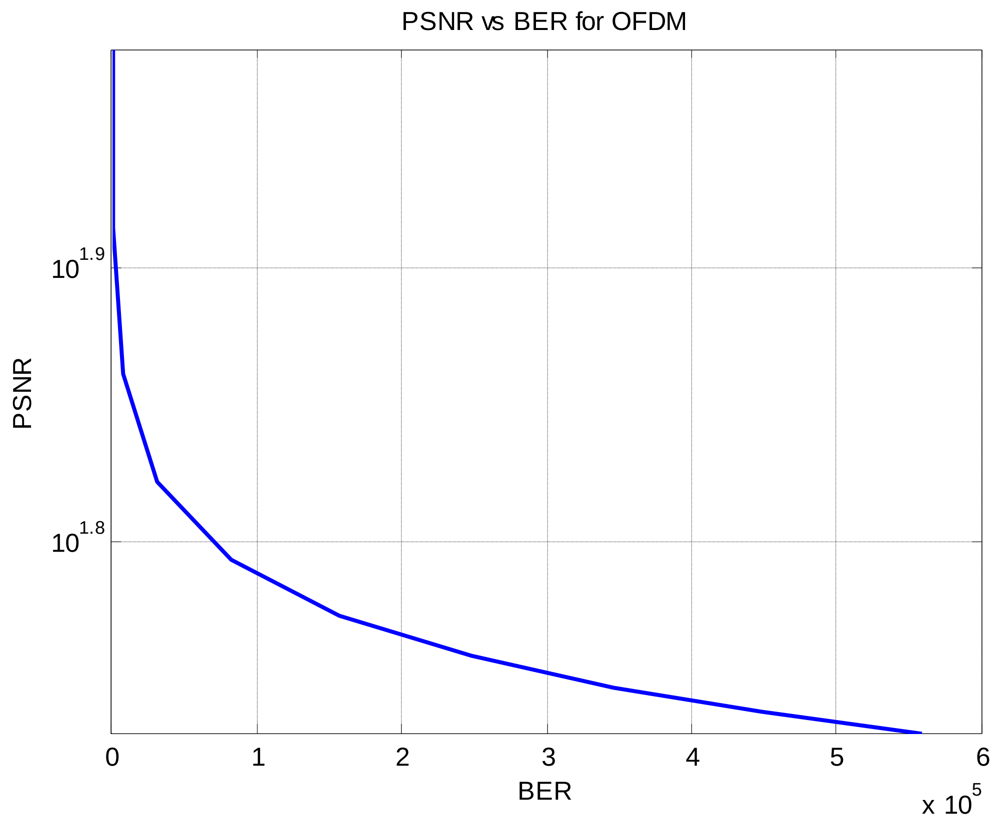


Figure 6-3-1 PSNR vs BER plot for transmitted and reconstructed image with OFDM

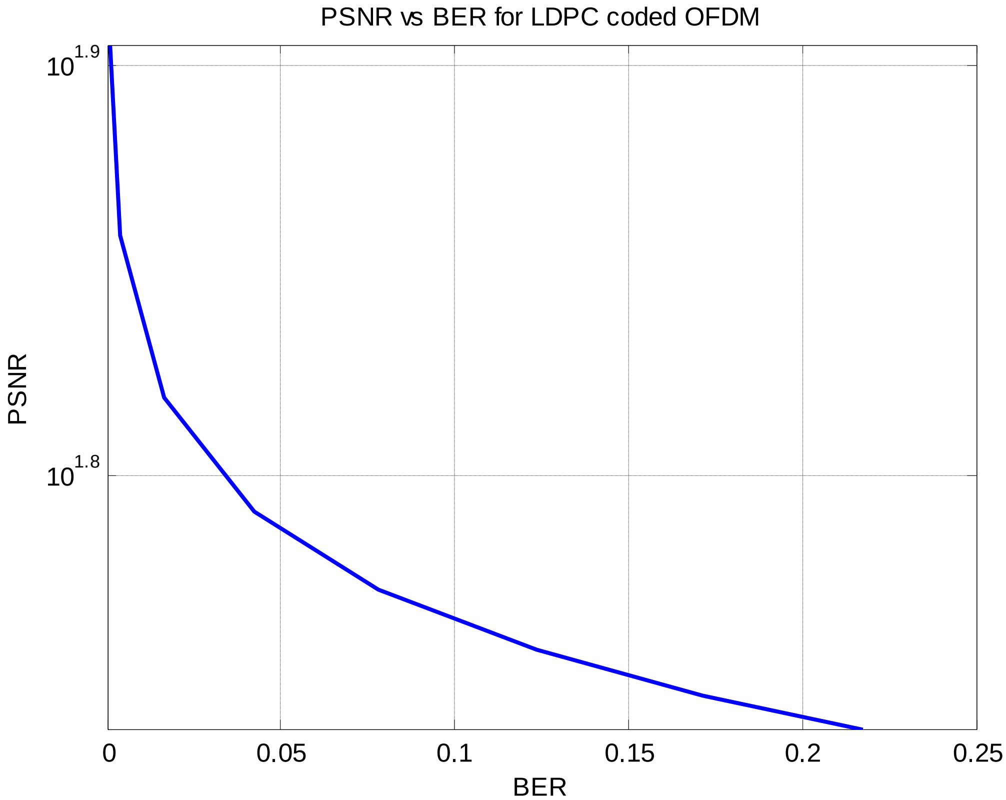


Figure 6-3-2 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded OFDM

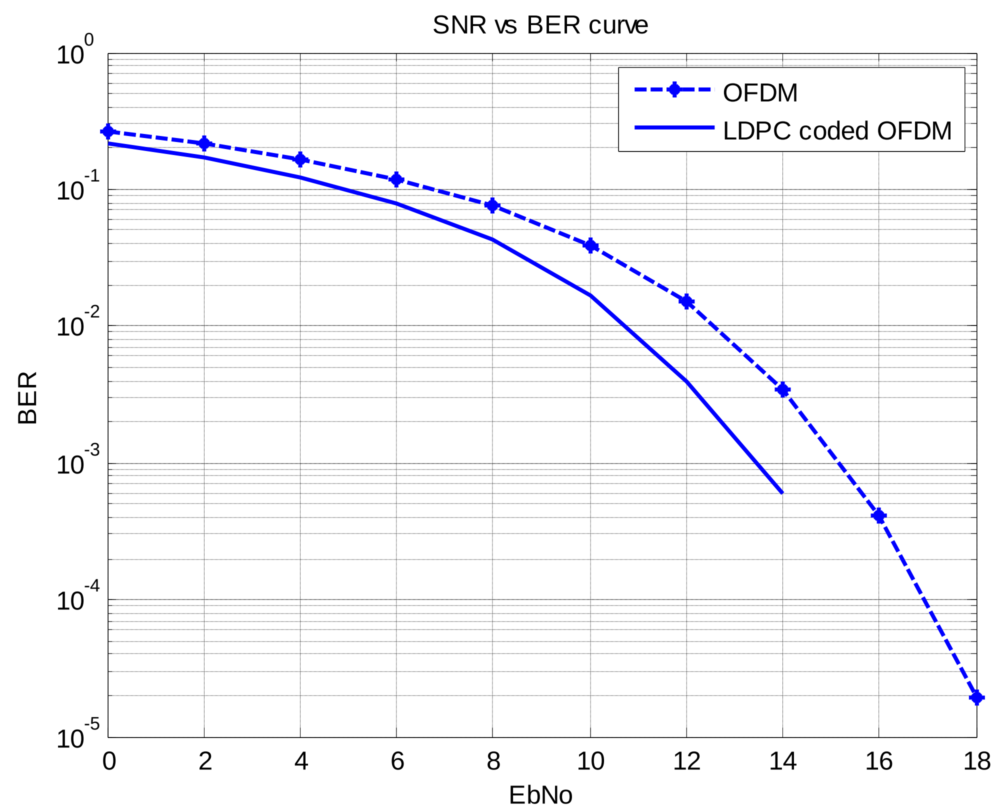


Figure 6-3-3 SNR vs BER plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system

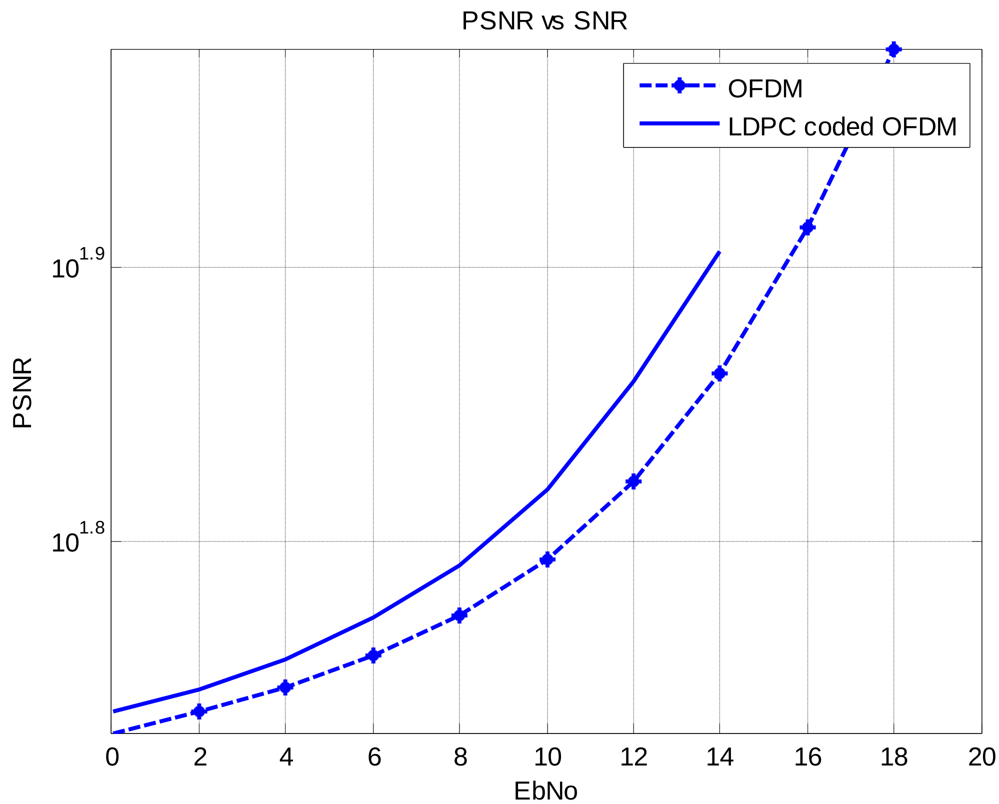


Figure 6-3-4 SNR vs PSNR plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system

2: For Rician Channel model

Table 6.3.2 Comparison of BER probability for OFDM and LDPC coded OFDM

SNR (dB)	BER with OFDM	BER with LDPC coded OFDM
0	.5375	.5638
2	.4592	.4440
4	.4569	.4428
6	.4559	.4408
8	.4552	.4415
10	.4551	.4402
12	.4544	.4401
14	.4544	.4392
16	.4543	.4408

18	.4539	.4407

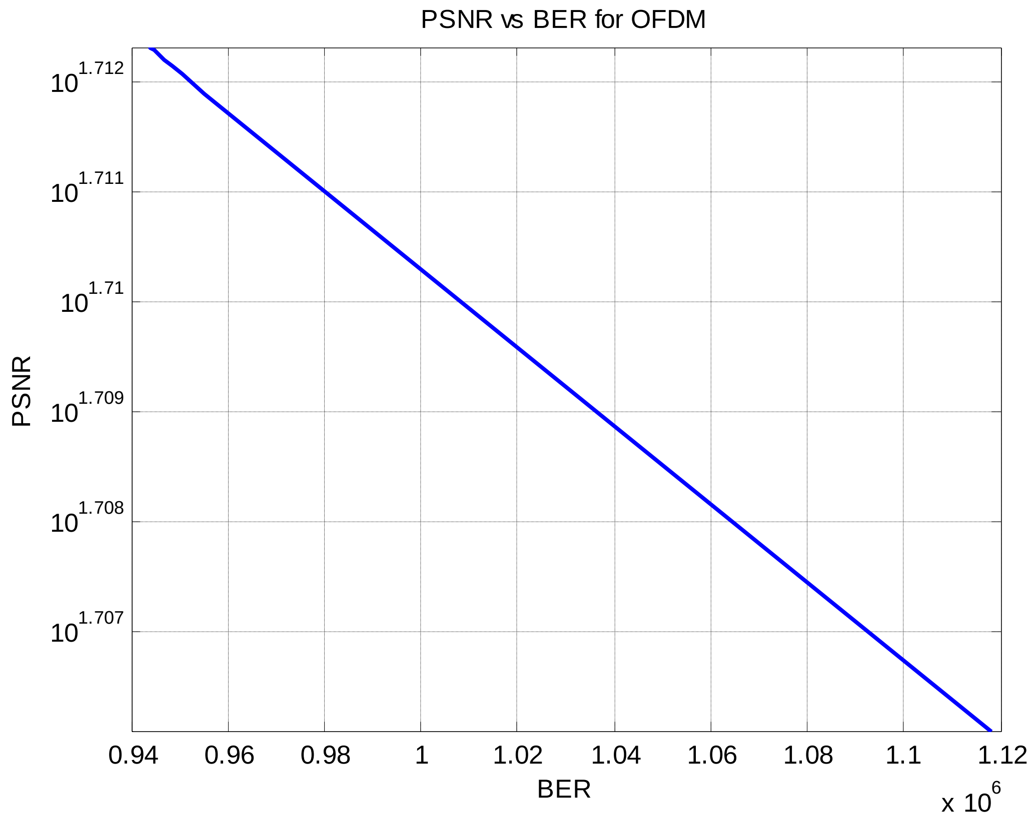


Figure 6-3-5 PSNR vs BER plot for transmitted and reconstructed image with OFDM

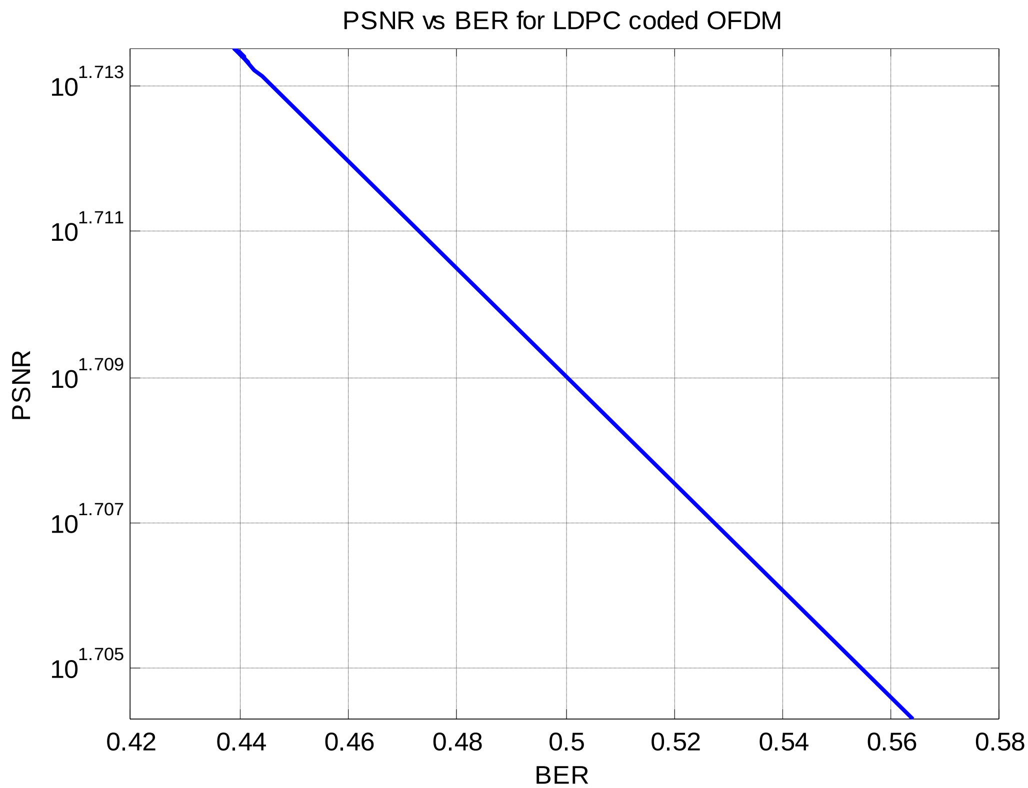


Figure 6-3-6 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded OFDM

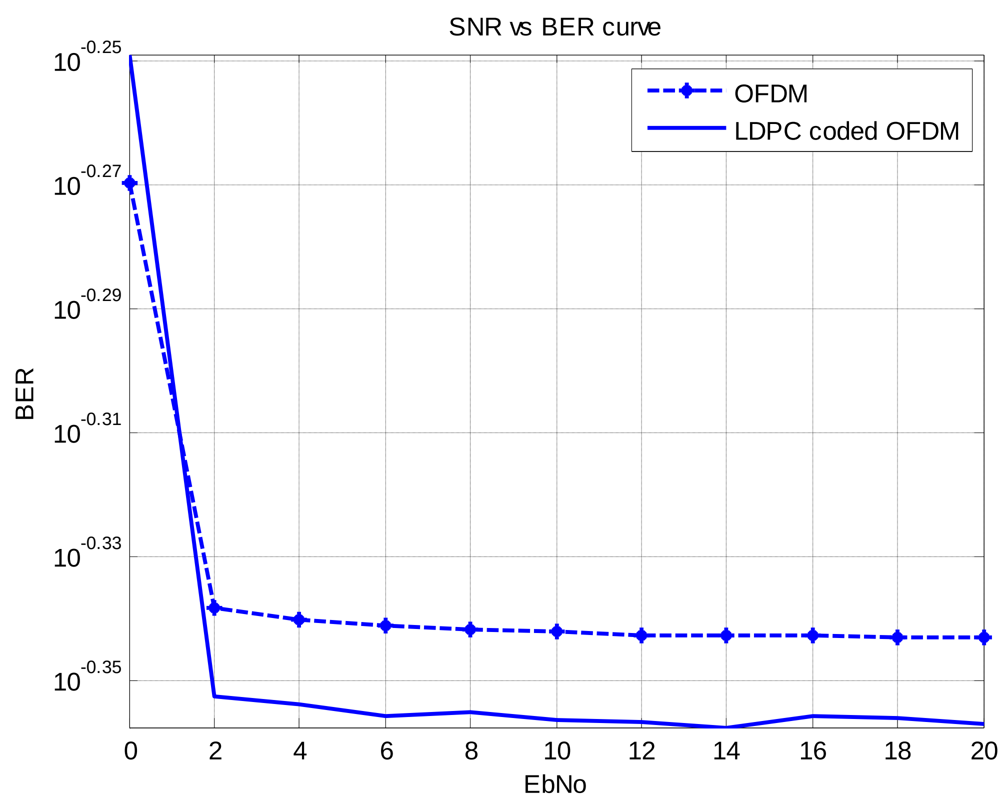


Figure 6-3-7 SNR vs BER plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system

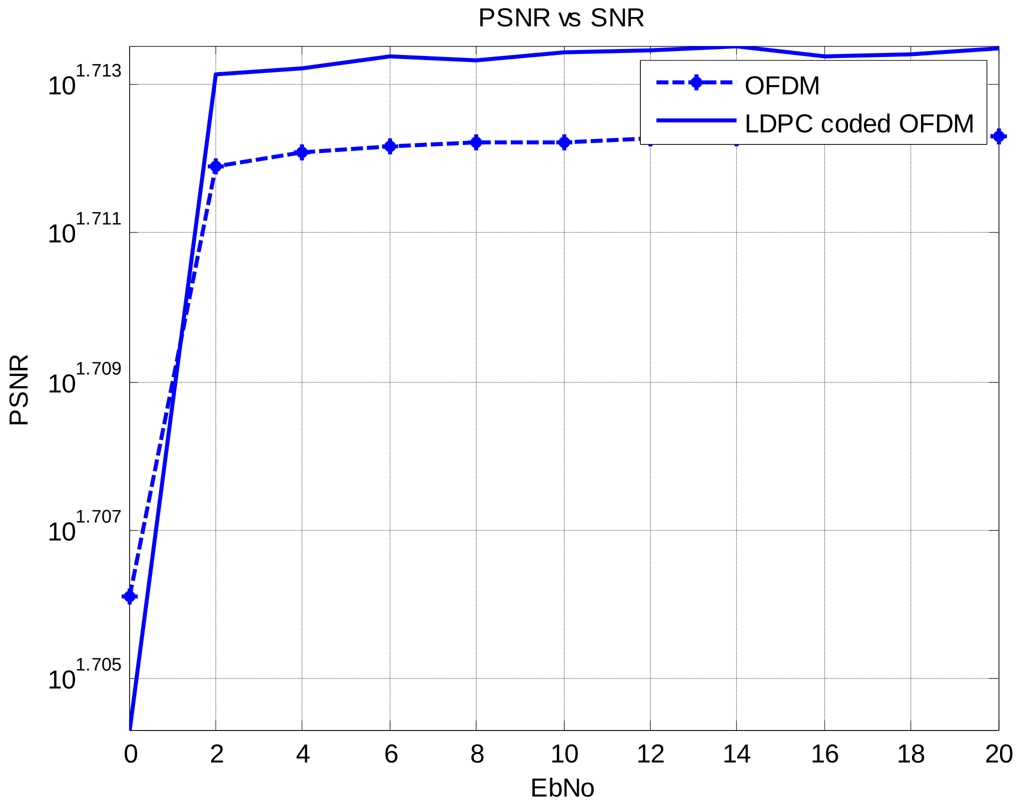


Figure 6-3-8 SNR vs PSNR plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system

3: For Rayleigh Channel model

Table 6.3.3 Comparison of BER probability for OFDM and LDPC coded OFDM

SNR (dB)	BER with OFDM	BER with LDPC coded OFDM
0	.4581	.4663
2	.4607	.4589
4	.4602	.4615
6	.4612	.4555
8	.4608	.4479
10	.4603	.4487
12	.4599	.4517
14	.4601	.4531
16	.4602	.4491

18	.4598	.4475
20	.4605	.4493

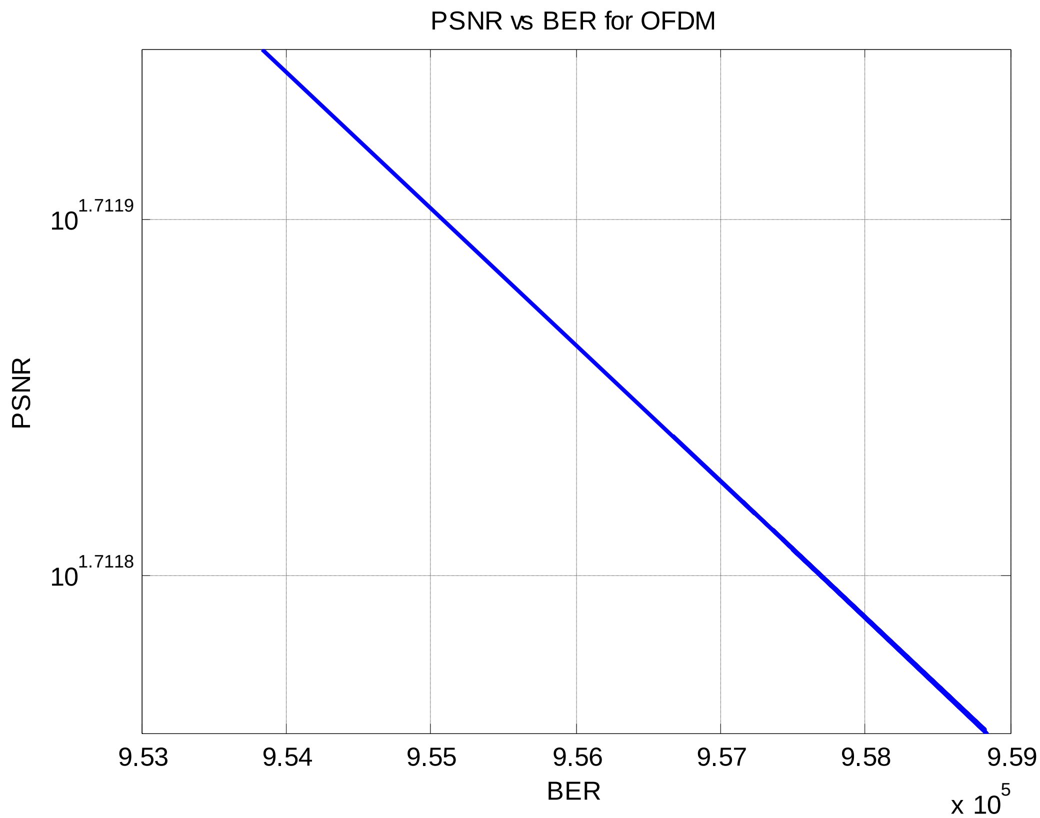


Figure 6-3-9 PSNR vs BER plot for transmitted and reconstructed image with OFDM

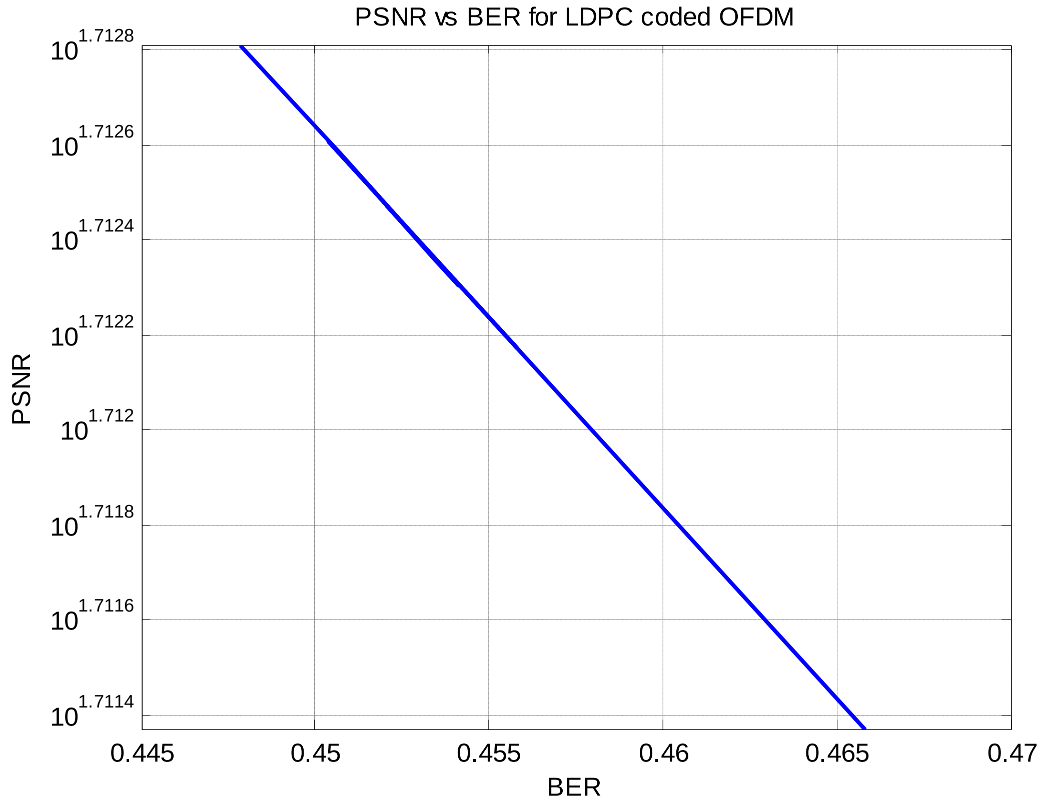


Figure 6-3-10 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded OFDM

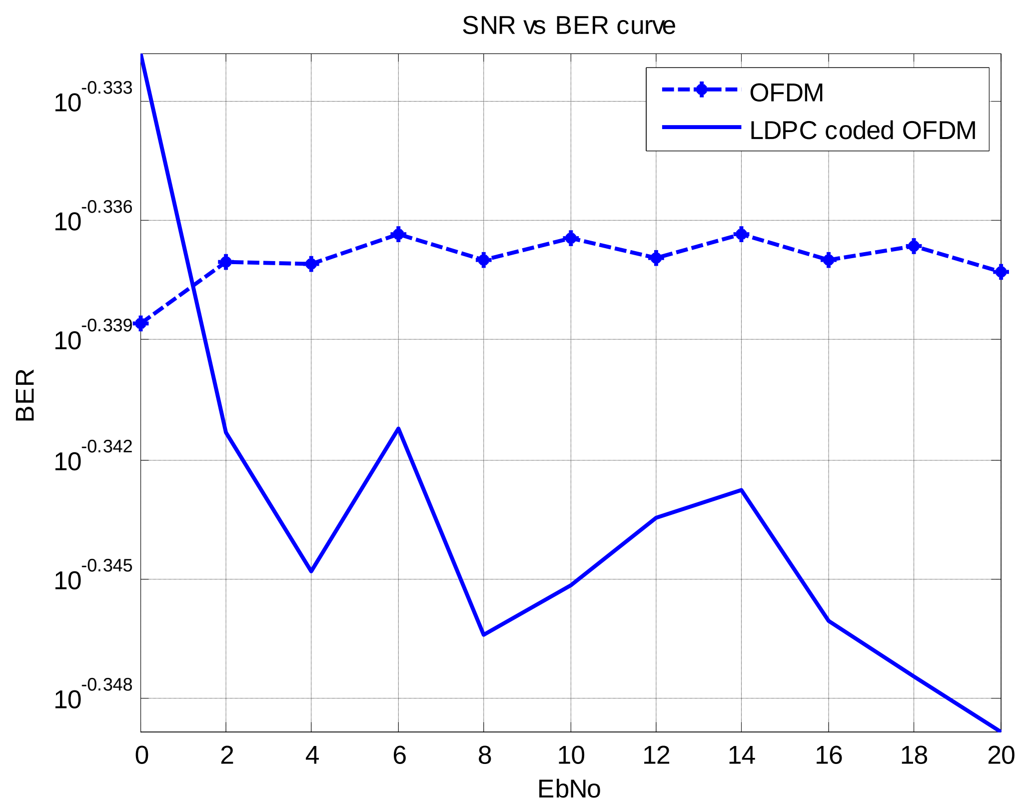


Figure 6-3-11 SNR vs BER plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system**

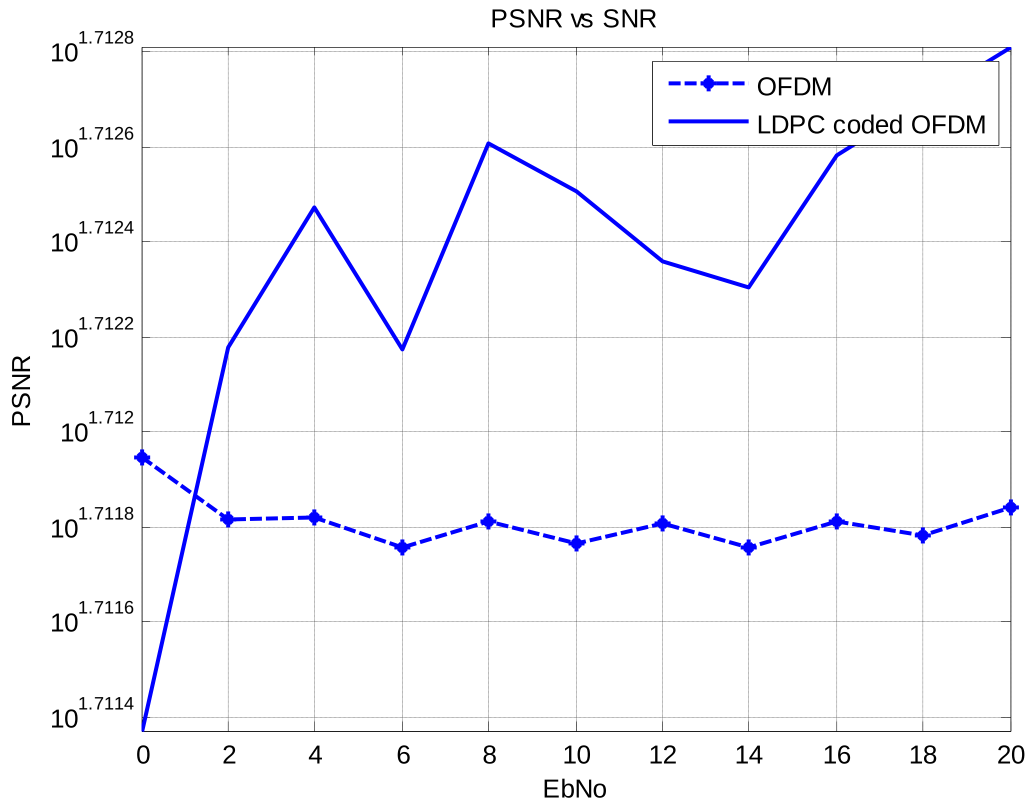


Figure 6-3-12 SNR vs PSNR plot for fused and compressed image transmitted with OFDM system and LDPC coded OFDM system

- Time to transmit two different images separately = 46.9560 seconds
- Time to transmit a single fused image = 32.4555 seconds

It was observed that the time required to transmit a single fused and compressed image was much lower than the time taken by two different images.

Similarly, analysis has been done for LDPC coded FFT- OFDM and LDPC coded DWT-OFDM.

1: For AWGN channel

Table 6.3.4 Comparison of BER probability for LDPC code FFT-OFDM and LDPC coded DWT-OFDM

SNR (dB)	BER with LDPC coded FFT- OFDM	BER with LDPC coded DWT-OFDM
0	.2589	.1049
2	.2542	.0690
4	.2519	.0389
6	.2483	.0180
8	.2402	.0066
10	.2299	.0033
12	.2190	.0020
14	.2023	.0011
16	.1867	.0005
18	.1598	.0003
20	.1297	.0002

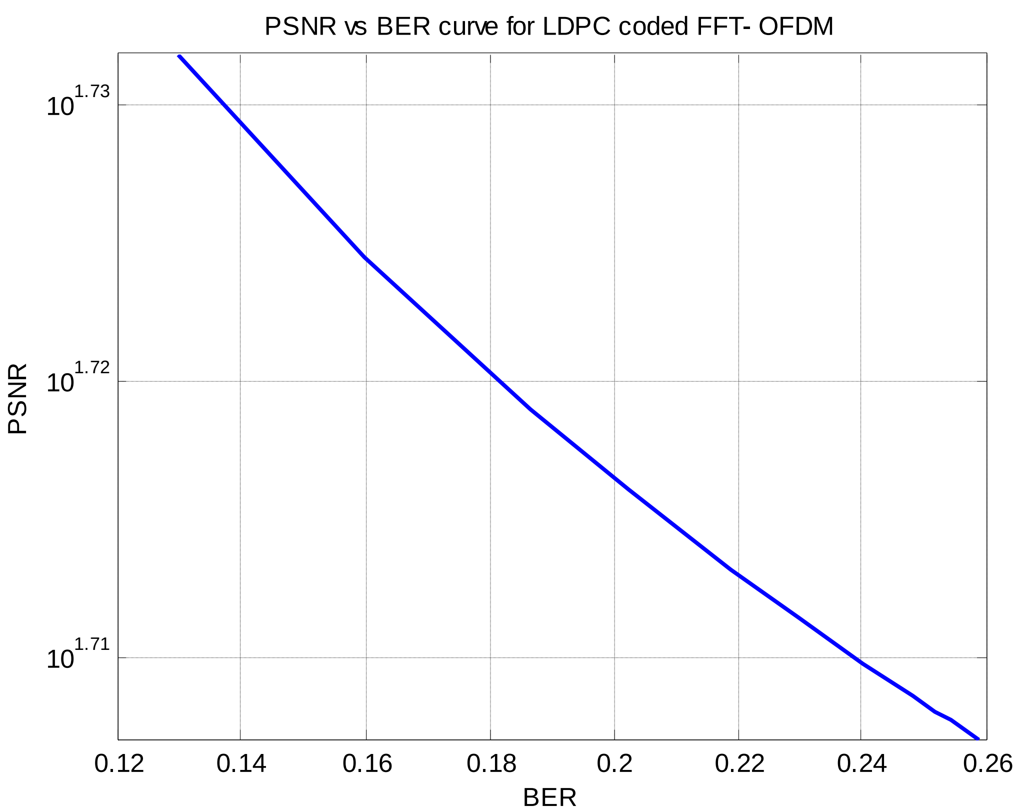


Figure 6-3-13 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded FFT-OFDM

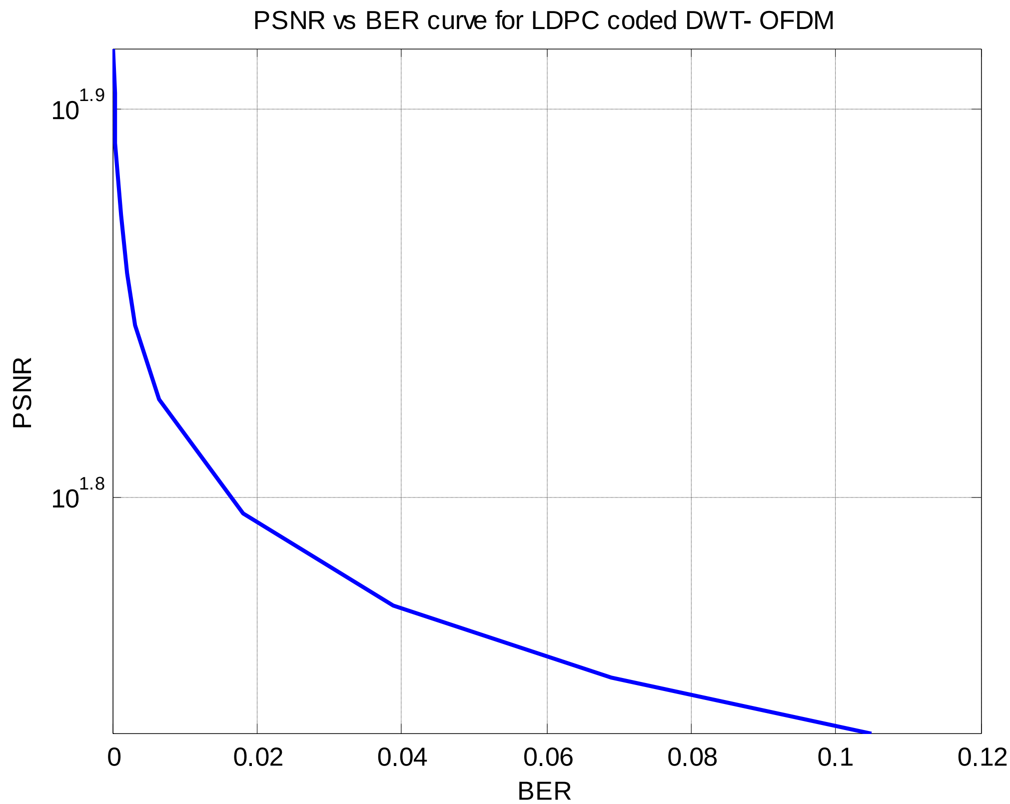


Figure 6-3-14 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded DWT-OFDM

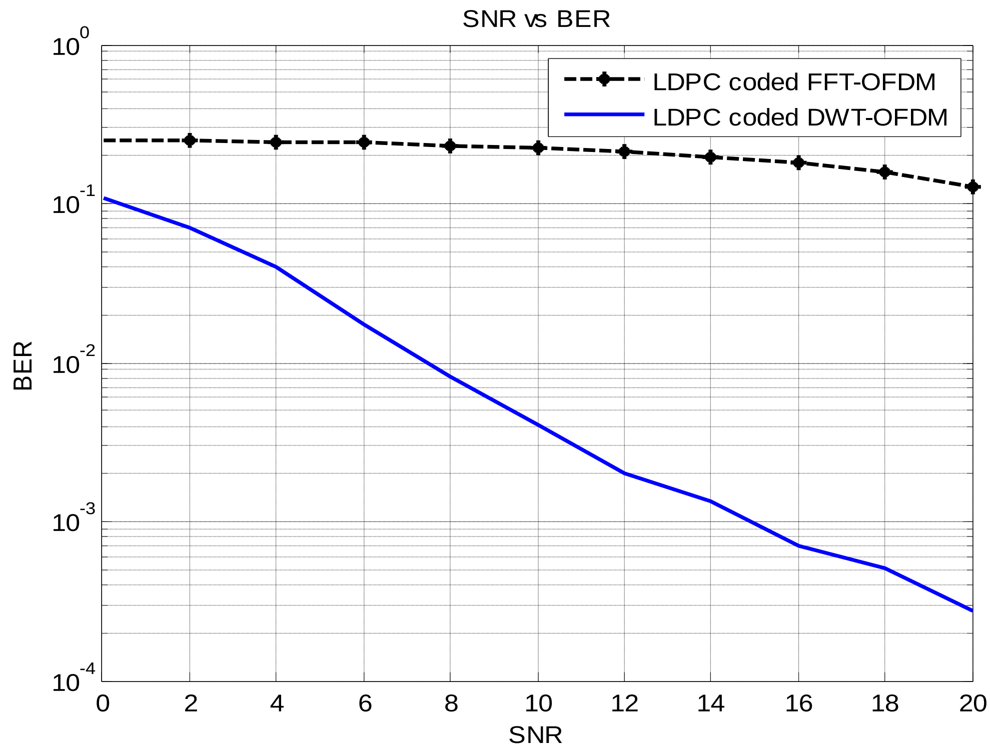


Figure 6-3-15 SNR vs BER plot for fused and compressed image transmitted with LDPC coded FFT-OFDM system and LDPC coded DWT-OFDM system

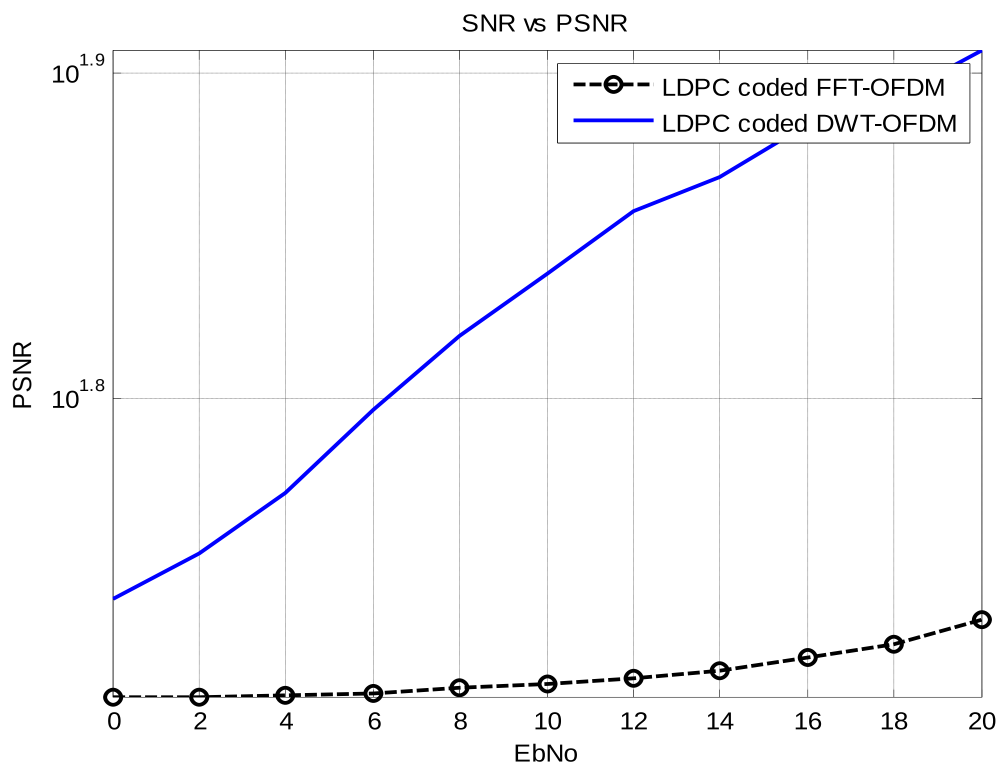


Figure 6-3-16 SNR vs PSNR plot for fused and compressed image transmitted with LDPC coded

FFT-OFDM system and LDPC coded DWT-OFDM system

2: For Rician channel model

Table 6.3.5 Comparison of BER probability for LDPC code FFT-OFDM and LDPC coded DWT-OFDM

SNR (dB)	BER with LDPC coded FFT- OFDM	BER with LDPC coded DWT-OFDM
0	.2011	.2011
2	.2243	.0017
4	.2238	.0013
6	.2236	.0016
8	.2237	.0014
10	.2235	.0016
12	.2238	.0014
14	.2242	.0015
16	.2239	.0017
18	.2243	.0015
20	.2239	.0018

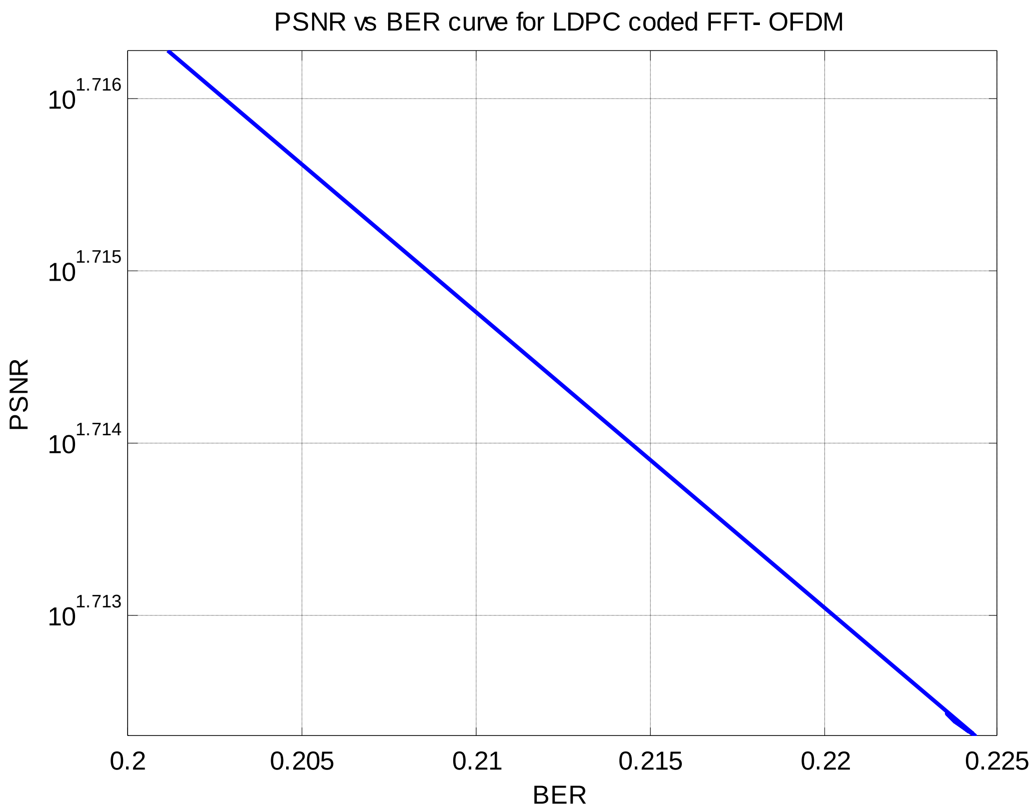


Figure 6-3-17 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded FFT-OFDM

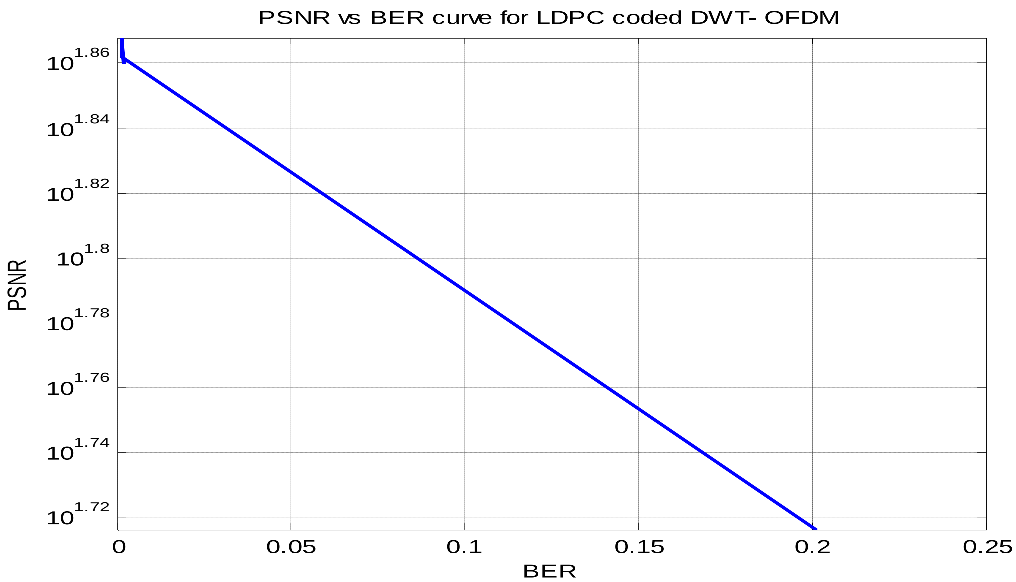


Figure 6-3-18 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded DWT-OFDM

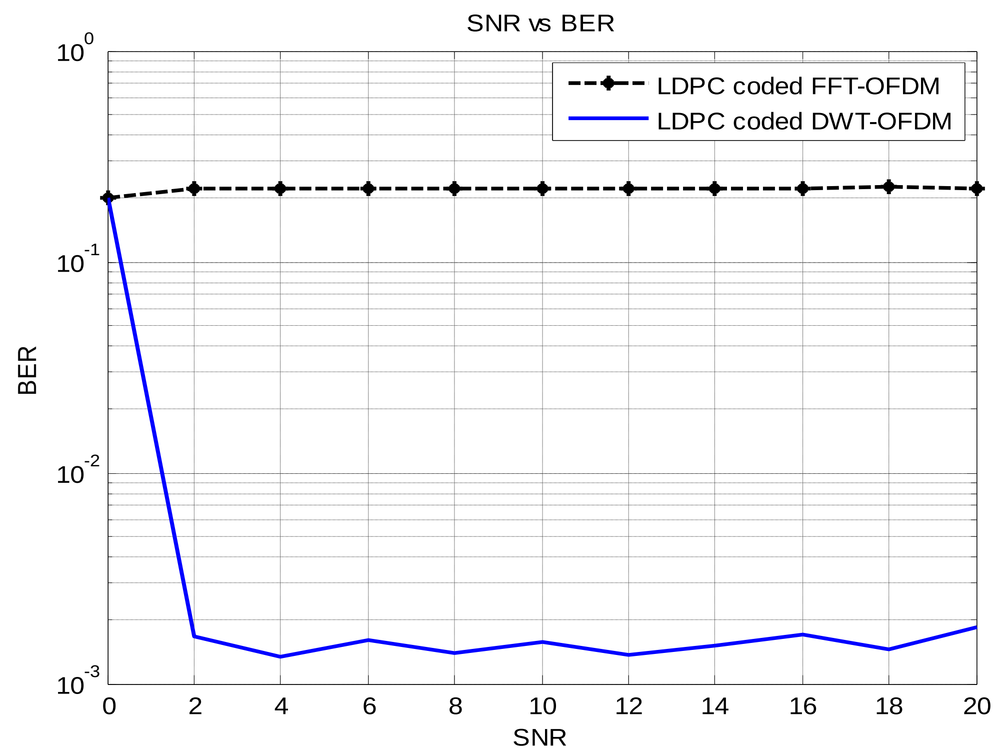


Figure 6-3-19 SNR vs BER plot for fused and compressed image transmitted with LDPC coded FFT-OFDM system and LDPC coded DWT-OFDM system

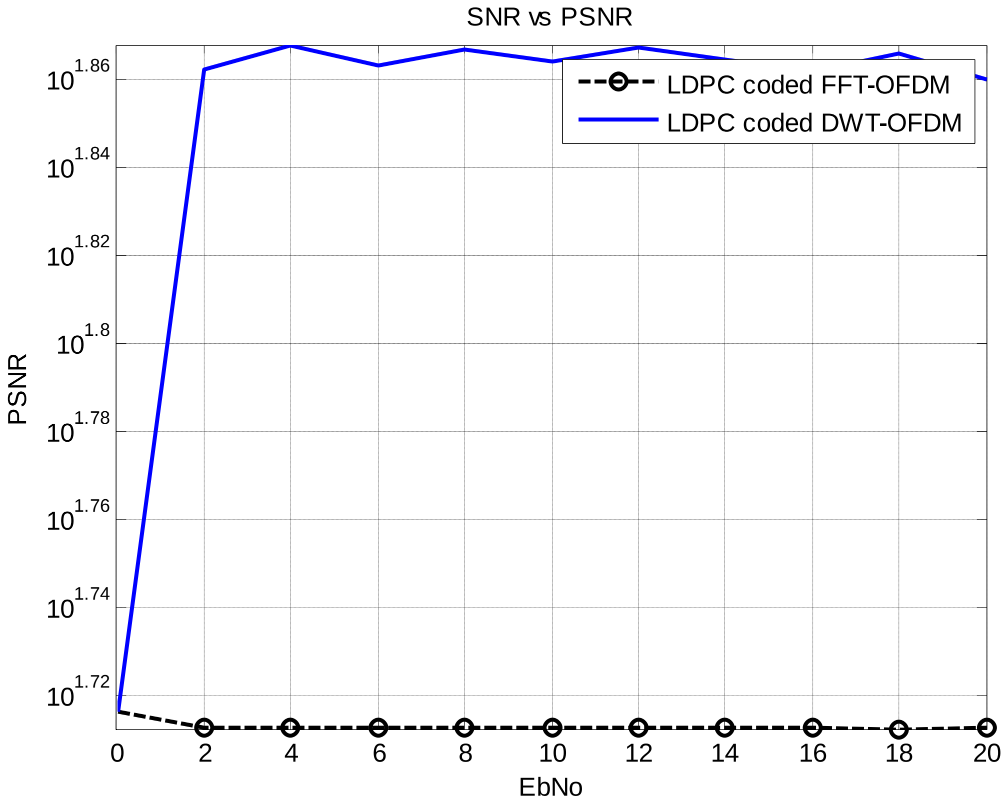


Figure 6-3-20 SNR vs PSNR plot for fused and compressed image transmitted with LDPC coded FFT-OFDM system and LDPC coded DWT-OFDM system

3: For Rayleigh channel model

Table 6.3.6 Comparison of BER probability for LDPC code FFT-OFDM and LDPC coded DWT-OFDM

SNR (dB)	BER with LDPC coded FFT- OFDM	BER with LDPC coded DWT-OFDM
0	.2709	.2688
2	.2640	.0775
4	.2647	.0263
6	.2634	.0137
8	.2620	.0095
10	.2631	.0079
12	.2624	.0077
14	.2616	.0069
16	.2582	.0060
18	.2572	.0065

20	.2614	.0054

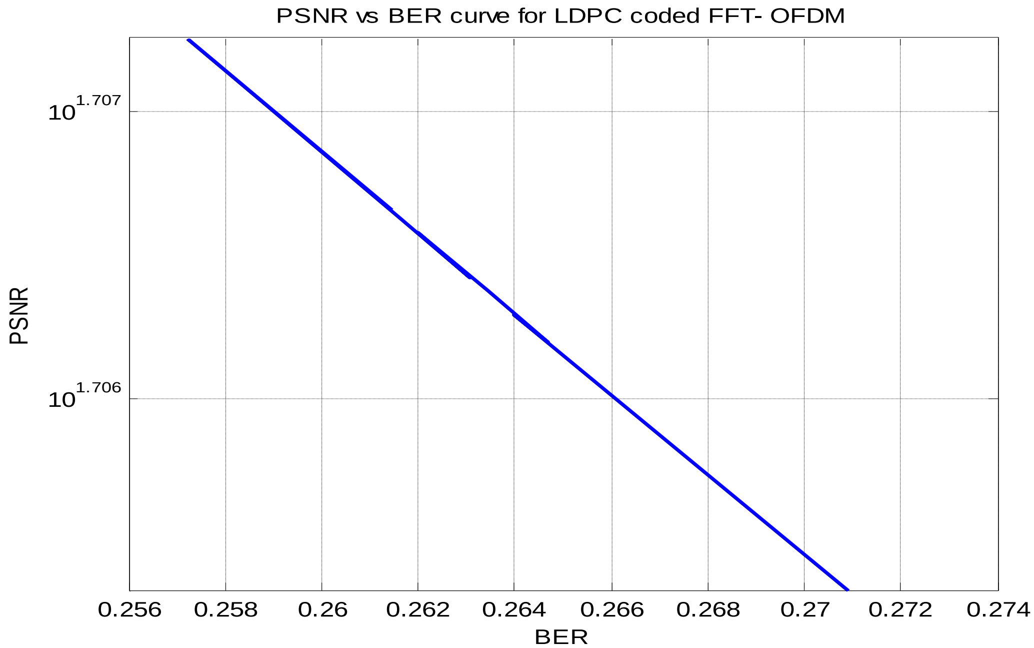


Figure 6-3-21 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded FFT-OFDM

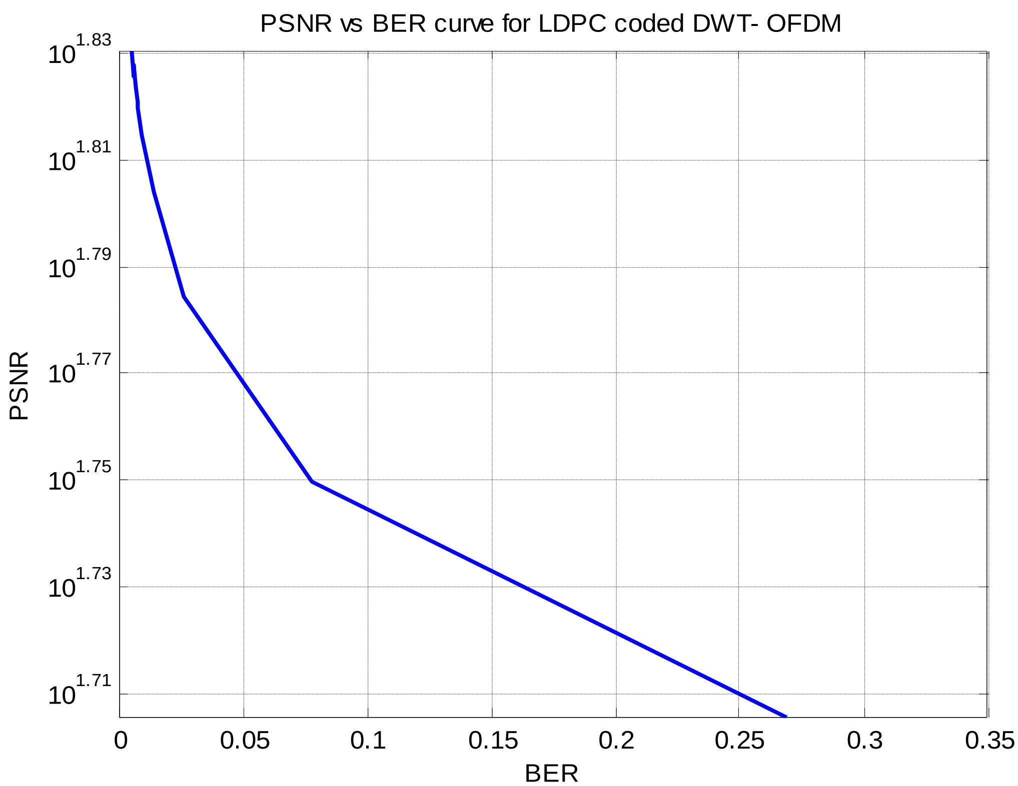


Figure 6-3-22 PSNR vs BER plot for transmitted and reconstructed image with LDPC coded DWT-OFDM

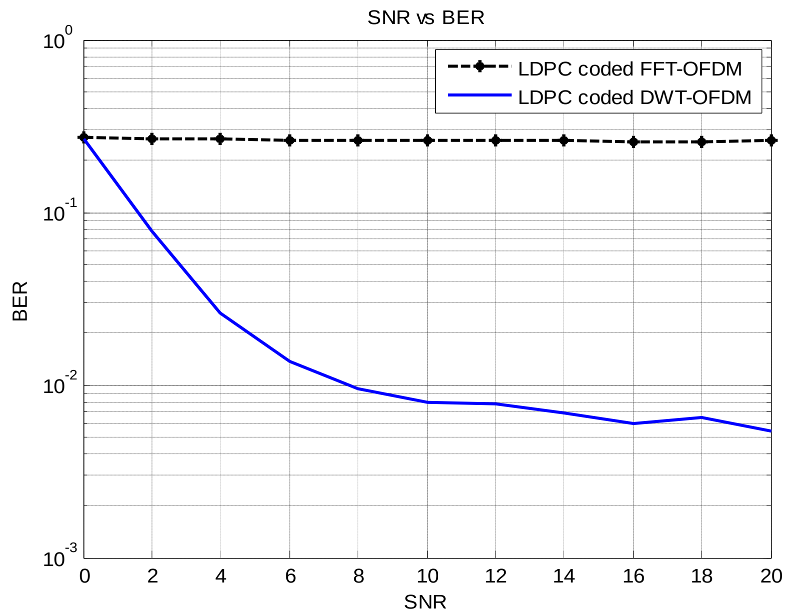


Figure 6-3-23 SNR vs BER plot for fused and compressed image transmitted with LDPC coded FFT-OFDM system and LDPC coded DWT-OFDM system

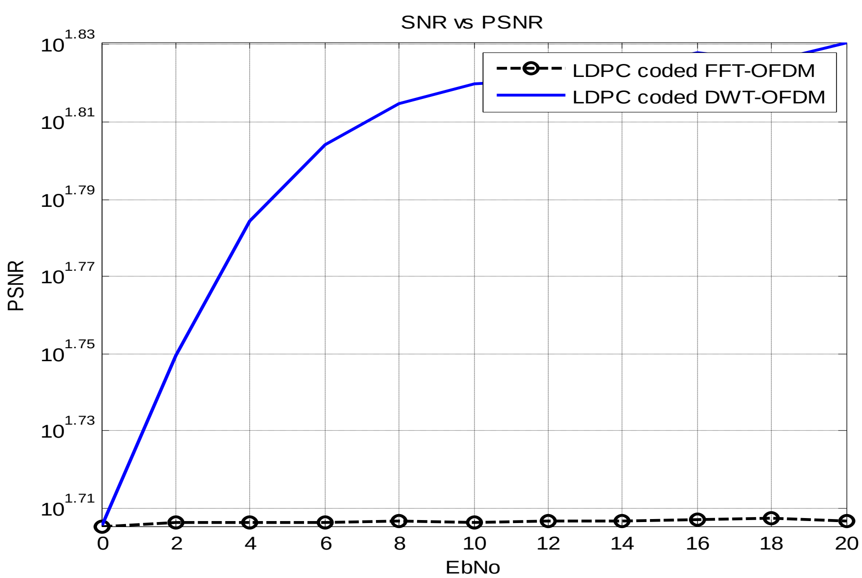


Figure 6-3-24 SNR vs PSNR plot for fused and compressed image transmitted with LDPC coded FFT-OFDM system and LDPC coded DWT-OFDM system

6.4 SUMMARY

The need for efficient transmission of data is of primary concern with growth in technology. Different types of data such as image transmission require larger bandwidth as well as redundancy from noise. Encryption of data from noise is an important aspect and this can be obtained by channel coding. The main requirement in wireless communication is efficiency of the received image which can be observed by bit error rate and other similar parameters such as PSNR, MSE, etc. The principle of multicarrier transmission is to convert a serial high rate input stream into multiple parallel streams of slow rate. The carrier signal is also divided into subcarriers and the sub-streams are then modulated over different sub- carriers. OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique based on frequency division multiplexing. In OFDM, 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 are fed to a de-multiplexer and demodulated and recombined to obtain the original signal at the receiver. OFDM reduces Inter-symbol Interference as well as Inter-channel Interference This report gives an overview of OFDM systems, different types of forward error correction techniques, image fusion and compression concepts and fading parameters. Further, the proposed system is to transmit fused and compressed image over LDPC coded OFDM systems for increasing spectral efficiency without the need of additional power and bandwidth. Second objective is to improve PSNR and reduce BER via different channel coding techniques. Finally, BER will be evaluated and compared for robust image transmission over LDPC coded OFDM system and un-coded OFDM system.

6.5 CONCLUSION

It is concluded that a more efficient image transmission system with better error resistance can be obtained by combining OFDM systems with different channel codes and comparing them. Also, less bit error rate and simulation time is observed when instead of transmitting multiple images; a single fused image is transmitted. In OFDM, 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. Hence, OFDM reduces Inter-symbol

Interference. Also since a cyclic bit guard bit is added to OFDM symbol, there is a huge reduction in Inter-channel Interference. The whole procedure was followed with and without LDPC encoding. It was observed that the performance of the system was much better when LDPC channel codes were employed before OFDM modulation transmitter. Also, because of image fusion and compression there is a remarkable decrease in total simulation time. Further addition of DWT (Discrete Wavelet Transform) added more increase in efficiency of the system. Based on the observations of the MATLAB simulation results, it was concluded that:

1: Performance of LDPC coded OFDM system is better than uncoded OFDM system.

2: Performance of DWT- OFDM system is better than FFT- OFDM system.

3: Simulation time to transmit single fused and compressed image is much less than transmitting multiple images.

4: Finally, performance of fused and compressed image transmission with LDPC coded DWT-OFDM system is better than with LDPC coded FFT-OFDM.

6.6 FUTURE SCOPE

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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