Performance Enhancement of OFDM based Communication System using Haar Wavelet

DISSERTATION-II

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By

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Under the Guidance of

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LOVELY PROFESSIONAL UNIVERSITY

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1. Analysis of algorithm for OFDM systems using Rayleigh & Rician fading Channels
1. Distributed Wireless Communication Systems
1. Blind adaptive Channel estimation in OFDM Systems

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ABSTRACT

This work has been done on OFDM based communication system with the help of Haar wavelet. Orthogonal frequency-division multiplexing (OFDM) has great demand for its numerous advantages. In this work different modulation schemes – BPSK, QPSK, 16-QAM, 64-QAM along with various channel models such as AWGN, Rayleigh and Ricean have been used to analyze the performance of the proposed system. Certain parameters of the conventional system have been modified and the improvements in the performance of the OFDM system have been analyzed. The implemented system includes DWT which has given some improvements in the performance. MATLAB has been used for entire work. BER graphs have been plotted for the comparison of the proposed system with the conventional OFDM based communication system. Different channel noise models have been used in order to analyze the work. The results show that the proposed system has better performance as compared to the OFDM system with FFT. The BER for different modulation schemes with every channel model has been decreased as compared to the conventional OFDM system.

Contents

List of Figures

List of Tables

Abbreviations

OFDM	Orthogonal Frequency Division Multiplexing
DVB	Digital Video Broadcasting
FDM	Frequency Division Multiplexing
ISI	Inter Symbol Interference
FFT	Fast Fourier Transform
IFFT	Inverse Fast Fourier Transform
AWGN	Additive White Gaussian Noise
LAN	Local Area Network
PAPR	Peak to average Power Ratio
LOS	Line of Sight
PDF	Probability Distribution Function
CDF	Cummulative Distribution Function
DWT	Discrete Wavelet Transform
BPSK	Binary Phase Shift Key
QPSK	Quadrature Phase Shift Key
QAM	Quadrature Amplitude Modulation
MMSE	Minimum Mean Square Error
CP	Cyclic Prefix
BER	Bit Error Rate
SNR	Signal to Noise Ratio

CHAPTER 1

INTRODUCTION

To send or transmit message or information with the help of different methods then the field that is concerned with it is communications. In other way, for transmitting and receiving messages the technology that is used is communication. Also it can be defined as the method to transmit the message internally from one client to another [9]. A communication system is made up of devices that employ one or two communication methods (wireless or wired), different types of equipment (portable radios, mobile radios, base/fixed station radios, and repeaters), and various accessories (examples include speaker microphones, battery eliminators, and carrying cases) and/or enhancements (encryption, digital communications, security measures, and interoperability/networking) to meet the user needs [10]. In multicarrier modulation basically the most commonly used technique is orthogonal frequency division multiplexing (OFDM).So OFDM is an efficient and marvelous technique which is widely used in modern wireless communication due to its high spectrum efficiency. So OFDM is a method of encoding digital data based upon multiple carrier frequencies In other words, OFDM is multi path multiplexing technique where large number of Orthogonal, Overlapping, and narrow band sub carriers transmitted in parallel [9]. In OFDM system high data rate transmission is divided into lower data rate and that are transmitted simultaneously over number of subcarriers. Each of these signal are individually modulated and transmitted over the channel. The signal will be demodulated and recombined to get the original input signal at the receiver end. In OFDM System all sub carriers are arranged orthogonally. The biggest advantage of OFDM is the brilliant spectral efficiency. But, the main loophole or drawback of OFDM based transmission systems, is the high peak-to-average power ratio (PAPR) [2] of the transmitted signal, which may lead to in-band distortion across subcarriers and undesired spectral regrowth if the linear range of the high power amplifier (HPA) is not sufficient at the OFDM transmitter end. So PAPR is defined as the maximum power occurring in the OFDM transmission to the average power of the OFDM transmission [4].

1.1 Basic Theory of OFDM Systems:-

1.1.1Need of OFDM:-

When multicarrier system was not in fashion then Frequency division multiplexing and Time division multiplexing were popular. Now with the rapid growth of digital communication in recent years, the need for high-speed data transmission has increased. So it has been solved by OFDM. Although OFDM was first developed in the 1960s, only recently it has been recognized as an outstanding method for high-speed cellular data communication where its implementation relies on very high speed digital signal processing [2]. So now a days OFDM is widely used in (DVB-C) Digital Video Broadcasting-Cable, (DVB-T) Digital Video Broadcasting-Terrestrial, (Wi-MAX) Worldwide [4].

1.1.2 The Benefit of Using Multi-carrier Transmission.

The main benefit of multi carrier is that it is more bandwidth efficient process. Initially when FDM [12] system was in fashion then it was utilizing more bandwidth as compare to OFDM. In fig 1.4 it can be properly observe that OFDM is saving huge bandwidth as compare to FDM systems. Multichannel transmission has been used to solve this problem. The main idea is to increase the symbol duration and thus reduce the effect of ISI [3]. So reducing the effect of ISI yields an easier equalization, which in turn means simpler reception techniques.

In below Fig1.1 [11] there is spectrum of subcarrier which is like the spectrum of sinc function. It has maximum amplitude at the centre. Finally it has been arranged orthogonally.

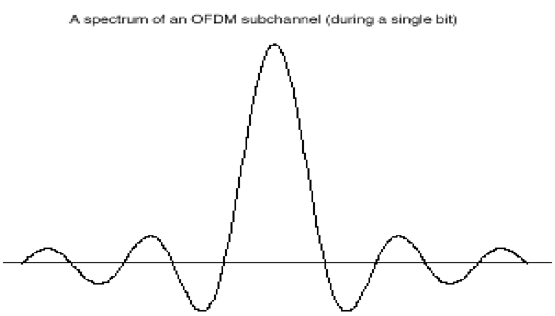


Fig 1.1 Single carrier spectrum

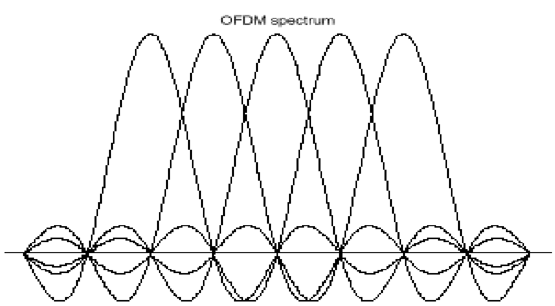


Fig 1.2 OFDM multiple subcarrier

In OFDM system it is known that it has high spectral efficiency. As the number of carrier signals are increasing then in conventional system there is wastage of bandwidth but Orthogonal FDM is properly utilizing the bandwidth of the systems. Ultimately Orthogonal FDM is more bandwidth efficient process. In Fig.1.3(a) [11] First we have signals which are occupying higher band-width ,since it is less band-width efficient process so due to orthogonality of signals in Fig.(b) [11] we are able to save the bandwidth up to B which is shown below.

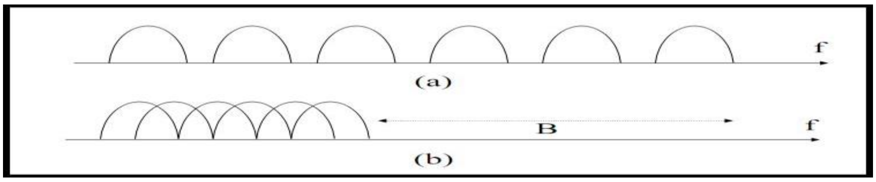


Fig 1.3(a) A typical FDM spectrum (b) A typical OFDM spectrum compared with FDM

1.1.3 Mathematical definition of OFDM signals:-

Generally any OFDM consists of multiple carriers. Here carrier can be represented as a complex Waveform like below [12]

$$S_c(t)=A_c(t)\, e^{j(\omega_c t + \phi_c t)}$$

Where $A_c(t)$ is the amplitude of signal and $\phi_c{}^t$ is the phase of the signal $S_c(t)$.The complex signal can be explained as

$$S_s(t)=\frac{1}{N}\sum_{n=0}^{N-1} An(t)\, e^{j(\omega_n t + \phi_n t)}$$

It is a continuous signal where each component of the signal over one symbol period can take fixed values of the variables likewise: $\phi n^t = \phi n$ and $A_n(t) = A_n$ where n=number of OFDM blocks and T is a time interval and the signal is sampled by 1/T then it can be represented as:

$$S_s(kT)=\frac{1}{N}\sum_{n=0}^{N-1} An\, e^{j((\omega_o t + \omega \Delta n)kT + \phi_n)}$$

Now consider $\omega_o = 0$ then the signal becomes

$$S_s(kT)= \frac{1}{N}\sum_{n=0}^{N-1} An\ e^{j((\omega\Delta n)kT + \phi n)}$$

Here $S_s(kT)$ is the time-frequency domain. Both are equivalent if

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{1}{NT} = \frac{1}{\tau}$$

where τ=Symbol duration period.

Since the OFDM signal can be defined by Fourier Transform. So the Fast Fourier Transform (FFT) can obtained frequency domain OFDM symbols and Inverse Fast Fourier Transform (IFFT) can obtain time domain symbols.

1.2 Principle and explanation of OFDM Systems:-

1.2.1 Principle of OFDM

Principal of OFDM system is to divide high data rate transmission into lower data rate and that are transmitted simultaneously over number of subcarriers. So, Each of these signals are individually modulated and transmitted over the channel. In the channel some of the noise due to channel is added up. These noises can occur due to different type of channel effects. In between transmitter and receiver there are a number of reflections, absorptions and scattering of the signals, which cause noise in the information signals. Finally at the Receiver end the signal will be demodulated and recombined to recover the original signal back.[9]

Being a multi-channel modulation system, OFDM employs Frequency Division Multiplexing (FDM). low bit-rate digital stream is modulated by each sub band carrier. It has N number of overlapping or orthogonal subcarriers. They are having a baud rate of 1/T. They are having a spacing of 1/T. These sub carriers are orthogonal to each other due to frequency spacing [11]. The demodulation of the symbol streams turns out to be proper so there is necessity of non overlapping spectra. The modulation of the orthogonal sub-carriers can also be represented as in Inverse Fourier Transform.

Being so effective against the multipath delay in mobile communication channels is the main advantage of OFDM. In order to get the proportional reduction of multipath spread delay ,the symbol rate is reduced by N times. If symbol rate is reduced by N time. In order to remove even small ISI, a guard time has to introduce for each OFDM symbol. Guard to be chosen should always be larger than the spread delay, such that there is no interference left. If the guard time is somehow left empty then Inter-carrier interference (ICI) might occur [4]. In order to avoid cross talks the OFDM in the guard time is cyclically extended.

As we require to fit the input data rate in the OFDM symbols, so we have to make the perfect combination of modulation and coding techniques. Each channel to almost AWGN, that actually has made the choice of coding techniques and modulation easy up to an extent and also we need not to be worried about the effects of multi path spread delay. ICI and ISI have a considerable effect if the channel follows a multipath during the transmission. As long as the guard interval remains less than the delay spread of the channel, this effect will be significant.

The main reason for the ICI is the flat interval of FFT because of the interference of the multi-path components. The another reason stated for the ISI is the overlapping of the previous symbol with the current symbol in the interval of FFT. Delaying the window whose width equals to the guard time containing the maximum signal power can be observed as a solution to this problem [9]. Then the starting time of the desired FFT will be equal to the starting delay of the window. In addition, a delay is obtained between a matched filter output from a single pulse of OFDM.

One can implement the frequency diversity at the very best at its outcome in OFDM. Frequency diversity we generally see is inside the system and hence we can say that the availability of frequency diversity is free in MC-CDMA. It has some serious disadvantages too and discussed below in sections as following: Frequency Diversity can be best implemented in OFDM. In fact, in the MC-CDMA transmission which involves a combination technique a combination of CDMA and OFDM, frequency diversity is present inside the system or it can be said that its availability is free. High peak-to-average ratio is the most serious problem which is encountered by OFDM systems. Or we can say that the transmitted signal is suffered by extreme expedition of the amplitude. There are usually two types of cases – first, in which a comparatively large output is produced by adding signal components in the phase and in second case, we get the zero output by cancelling the components. This is the reason OFDM systems have large peak-to-average ratio (PAR). If we talk about the transmitter side, this problem of problem of Peak-To-Average Ratio gets bigger and serious [4]. A wide linear range is provided at the front end of the transmitter of the power-amplifier so that the clipping can be completely avoided and the peaks can be included. It will be very costly to make power amplifiers having the wide linear ranges. Further, this also results in high power consumption. In order to remove clipping a wide range must be given to the Analog to Digital (ADC'S) and the Digital to Analog (DAC's) converters.

1.2.2 Block diagram of OFDM Transmitter and Reciever

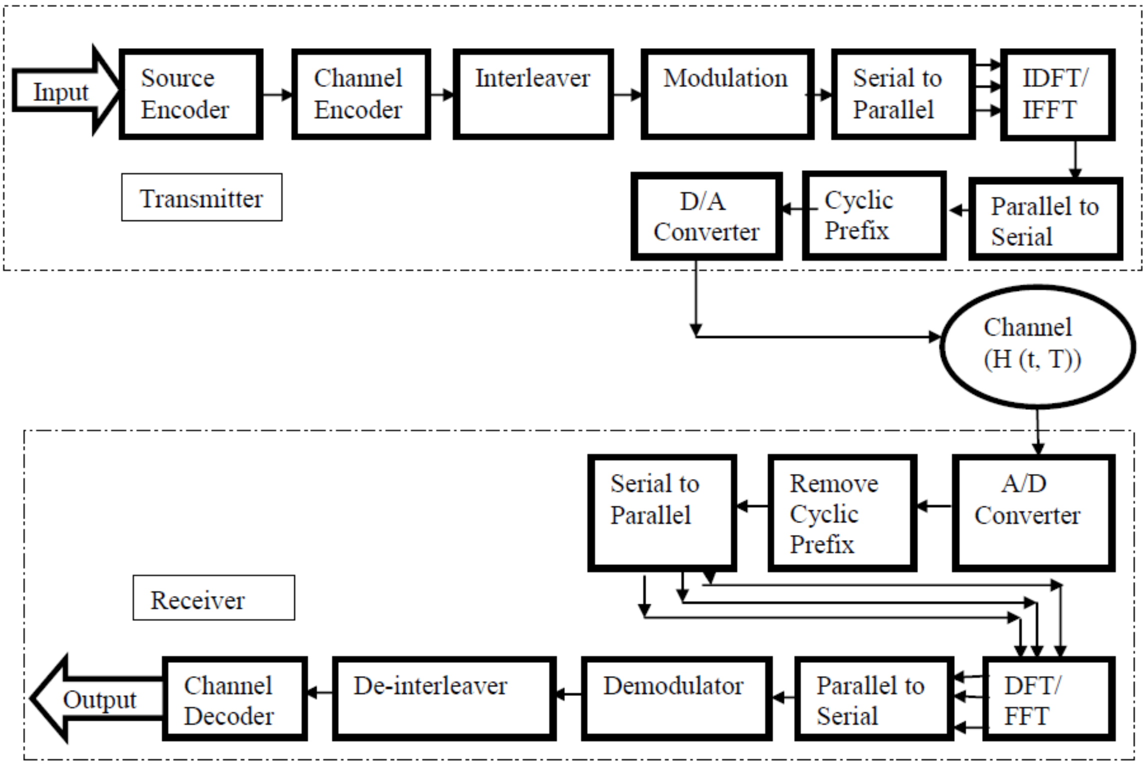


Fig. 1.4 OFDM block diagram

1.2.3 Working of OFDM Systems:-

- Input signal has been given which is in frequency domain and nature of the signal is digital.
- Then Source encoder has been used to decrease the repeatability of the signal. For Source encoding Huffman coding and Run length coding has been used. It decreases or compresses the data up to the desired bits. So encoded data is much smaller than its previous one.
- Then channel encoder has been used, which increases the repeatability of the Signal.
- After channel encoding if there is packet error or burst error in the encoded data than interleaver has been used, so that the burst error can be removed. Generally block interleaving technique is used to do the interleaving process. In block interleaving [12] , data is read as row wise and written as column wise and then it is transmitted.
- After Interleaving, modulation is done. Since data is required to send for very long distance so without modulation it is not possible. So for digital modulation ASK, FSK, PSK, and QAM technique can be used.
- Then the data is converted from serial to parallel. Because this is the basic requirement of the IDFT/IFFT process. So now when the data is converted in parallel form then IDFT/IFFT [11] operation can be done on the individual signals.
- Now at this stage IDFT/IFFT process is done. In this process Twiddle matrix is multiplied with input signals. So after IFFT process all the input signals become Orthogonal to each other. So due to this inter symbol interference is reduced. Due to this operation signals converted into time domain.
- So at the next stage, signal is converted from parallel to serial, so that cyclic prefix operation can be implemented. This parallel to serial conversion is required for cyclic prefix operation.

- Then Cyclic Prefix operation is performed in which additional guard band is inserted in between the data so that inter carrier interference effect can be reduced. So at this stage guard band as well as cyclic prefix can be used. If there is case of over lapping of symbols then guard band is inserted to mitigate the. problem. But in case of cyclic prefix last bit of the symbol is put at the first end, so if due to any uncertain reason if the channel the data of the one place is lost then again it can be recovered back.
- Then the next stage is digital to analog conversion. It is required to transmit the data symbol through the channel in the form of analog signals [11].
- Then data symbol is transmitted through channel. This channel may be of many types e.g. AGWN, Rayleigh, Rican, and Nakagami [9] etc. When any symbol passes through channel then its response is equal to the multiplication of symbols and its channel response.
- Now analog to digital converter is used so that the data can be converted in the digital form and the next stage can be performed properly.
- Then whatever the cyclic prefix has been added will be removed now.
- Then the data is required to convert from serial to parallel. Because this is the basic requirement of the DFT/FFT process. So further when the data is converted in parallel form then DFT/FFT operation can be done on the individual signals.
- At this stage DFT/FFT process is done. It is the reverse of IDFT/IFFT process. Due to this operation signals get converted from time domain to again frequency domain.
- In this stage, signal is converted from parallel to serial, so that demodulation can be performed.
- So after parallel to serial conversion demodulation is done, the reception of the OFDM symbols can be performed. Here same

technique will be used for demodulation, which has been used for modulation.

- After demodulation de-interleaving operation is performed. It is the inverse of the interleaving process. E.g. in block interleaving data is read as row wise and written as column wise and then transmitted.
- Now, channel decoder is used. For this viterbi decoding process can be used for decoding purpose.
- Output is taken, which is in the frequency domain and its nature of the signal is digital.

1.2.4 Condition for orthogonality:-

The two periodic signals can be orthogonal if the integral of their product over one period is equal to zero. So there are two possible cases – first for continuous time signal and second for discrete time signal [12].

Case 1 – Continuous time signal

$$\int_0^T \cos(2\pi nf1t)\ \cos(2\pi mf2t)dt = 0$$

Case 2- Dicrete time signal

$$\sum_0^{N-1} \cos(2\pi kn\,/N)\ \cos(2\pi km/N)dt = 0$$

Where $m \neq n$ in both the cases.

1.3 Applications of OFDM System:-

Generally OFDM is used as the transmission technique in digital audio broadcasting , television broadcasting applications.and in (Wi-MAX) applications. In this section the main application of the OFDM will be explained.

1.3.1 Digital Video Broadcasting (DVB)

One of the standard for broadcasting digital television over satellites, cables is Digital video .Some important parameters are listed as :It has two different modes of operation i.e. the mode with 6817 sub carriers with 8k modes and the mode with 1705 sub carriers with 2k . It also uses 64 QAM sub carrier modulation, QPSK and 16 QAM. It uses (RS) which is Reed-Solomon outer code i.e. (204,188, t=8) and also has an inner convolution code (177,133 octal) for error-control. For obtaining coherent demodulation and reference amplitudes, we use pilot sub carriers. Pilot sub carriers are also used to perform the two dimensional channel estimation.

1.3.2 Wireless LANs

One of the most important application if we have to look upon is wireless LANs [15] in OFDM. The reason for employing OFDM for Wireless LANs is that very small of spread delay encounters more often. The spread delay is very less if we consider the case for indoor environments and also the in such environments the efficiency of OFDM is very high. However in outdoor environments, we employ same guard interval in order to reduce the effect of spread delay.

1.4 Advantages of OFDM Systems:-

- High spectral efficiency.
- Flexible spectral adaption can be realized.
- Different modulation scheme can be used on individual sub-carriers.
- Very simple realization by using FFT/DFT

1.5 Disadvantages of OFDM Systems:-

- Phase Noise
- Image Rejection
- PAPR
- It requires time and frequency synchronization.

1.6 Channels in communication system

1.6.1 Rayleigh Fading Channel

Rayleigh fading [9], actually, is caused by the multipath reception that leads to a significant effect on an incoming signal of a propagation environment. Rayleigh fading is the model that is to be followed for the propagation of signal of different layers of earth. Rayleigh fading occurs only when there is no LOS (line of sight) is present between the transmitter and receiver. Rayleigh fading is nothing but the fading that takes place in an environment where there is a large number of reflections present. Actually what happens that the basic model of Rayleigh fading assumes a received multipath signal to consist of a large number of reflected waves. If we talk about no LOS path between the transmitter and receiver than it is the best model in terms of propagation of channel. In such type of scenario the signal may be considered to be scattered between the transmitter and receiver. And the approach that is required for the analysis of the nature of the signal is statistical.

EXAMPLE- Consider a busy, packed or narrow street where the base station is hidden behind a building few blocks away and the incoming signal encounters many obstructions and scattering objects in the local area.

At such a situation, Rayleigh fading is a model that comes handy and is very reliable because it describes the form of fading that occurs when multipath propagation exists i.e. when the signals reach the receiver , the overall signal is a summation of all the signals that have reached the receiver via different paths that are useable.

1.6.2 PDF of Rayleigh Fading Channel

$$P(r) = \begin{cases} \frac{r}{\sigma^2} \, exp^{\left(\frac{-R^2}{2\sigma^2}\right)} & , \ (0 \leq r \leq \infty) \\ 0, & (r < 0) \end{cases}$$

Where ,

r = rms value of the received voltage signal before envelope detection.

$\boldsymbol{\sigma}^2$ = ac power in the signal envelope, it also gives the mean value of the Rayleigh

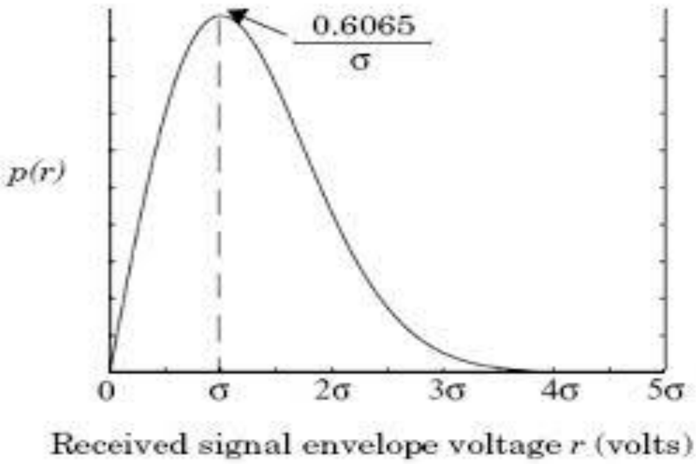


Fig 1.5 PDF of Rayleigh Fading Channel [10]

1.6.3 CDF of Rayleigh Fading Model

$$P(R) = P_r\,(r \le R) = \int_0^R p(r)\,dr = 1 - exp^{\left(\frac{-R^2}{2\sigma^2}\right)}$$

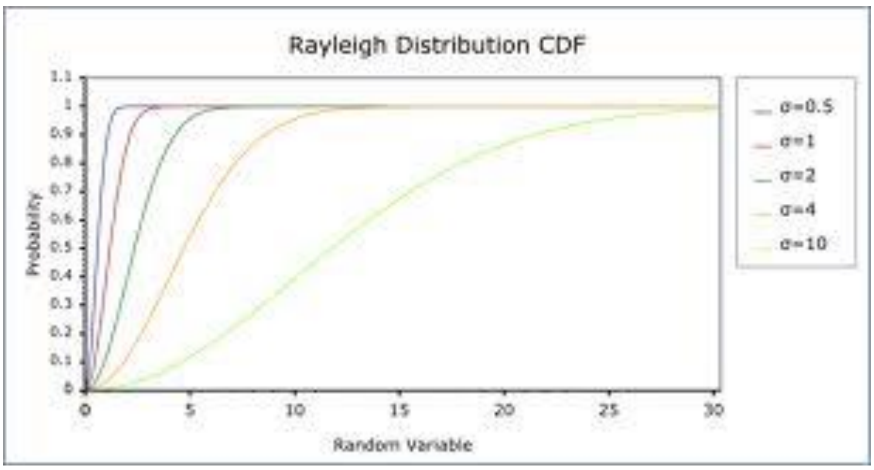


Fig 1.6 CDF of Rayleigh Fading Channel [10]

1.6.4 Rician Fading Channel

The Rician fading [11] model is analogus to the Rayleigh fading model, the only difference is that in Rician fading, a strong dominant LOS component is present. This dominant component is a stationary (non fading) signal and is commonly known as the LOS (Line of Sight Component). This fading takes place when one of the paths, typically a line of sight signal, is much stronger than the others. When there is a dominant stationary (non-fading) signal component is present like the line -of -sight propagation path, the small scale fading is Rician. The dominant wave can be a phasor sum of two or more dominant signals e.g. the line of sight and a ground reflection. This combined or resultant signal is then mostly treated as a deterministic or fully predictable process.

Example: Rician fading is best suitable for rural environments,where the multipath profile includes a few reflected paths combined with a strong line of sight path and the spectral power follows a Ricean distribution (Rayleigh fails here).

1.6.5 Degeneration of Rayleigh from Ricean

The effect of a dominant signal that arrive with many weaker multipath signals leads to Ricean distribution. What happens here that the dominant signal becomes weaker and the composite signal resembles a noise signal which has an envelope that is Rayleigh, thus Ricean distribution degenerates to a Rayleigh distribution when the dominant component fades away.

1.6.6 PDF of Rician Fading Model

$$P(r) = \begin{cases} \frac{r}{\sigma^2}\, exp^{\left(\frac{-R^2+A^2}{2\sigma^2}\right)} .Io\left(\frac{Ar}{2\sigma^2}\right), & (A \geq 0, r \geq 0) \\ 0, & (r < 0) \end{cases}$$

Where,

A = peak amplitude of the dominant signal

Io = modified Bessel function of the first kind and zero-order

The Ricean distribution is often described in terms of a parameter K, which is defined as the ratio between the deterministic signal power and the variance of the multipath . It is given by

K = $\frac{A^2}{2\sigma^2}$ or in terms of dB

$$K(dB) = 10 \log \left(\frac{A^2}{2\sigma^2}\right) dB$$

K is known as Ricean factor and completely specifies the Rician distribution . As A→0 , K→ -∞ and as the dominant path decreases in amplitude , the Rician distribution degenerates to a Rayleigh Distribution.

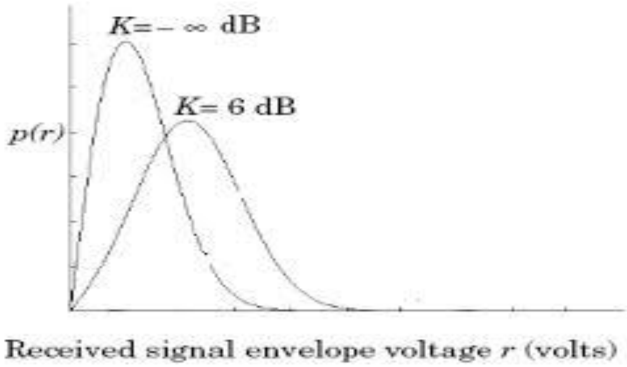


Fig 1.7 PDF of Rician Fading Channel [10]

1.6.7 CDF of Ricean Fading Model

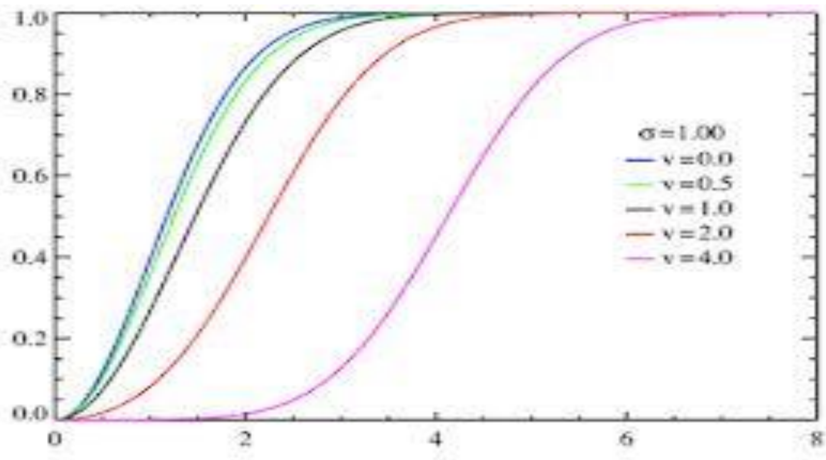


Fig 1.8 CDF of Rician Fading Channel [10]

1.6.7 Additive White Gaussian Noise (AWGN)

AWGN [12] is the most basic noise model where fading effect and interference is 0. We all know, practically it is not possible so it is a virtual or theoretical model used as a comparable model as it sets benchmark for maximum performance for other channels."Additive" because it is added to any noise that might be intrinsic to the information system. 'White' refers to idea that it has uniform power across the frequency band for the information system. The spectrum of the noise if flat for all frequencies. 'Gaussian' because it has a normal distribution in the time domain with an average time domain value of zero. **The values of the noise h(n) follows the Gaussian probability distribution function,**

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}}\, exp^{\frac{-(x-\mu)^2}{2\sigma^2}}.$$

we will consider standard normal distribution or unit normal distribution i.e μ=0 and σ = 1. p(x) = $\frac{1}{\sqrt{2\pi}}\, exp^{\frac{-x^2}{2}}$.The factor $1/\sqrt{2\pi}$ in this expression ensures that the total area under the curve is equal to one and The ½ in the exponent ensures that the distribution has unit variance General expression for additive noise is given by

y(n) = x(n) + h(n).

1.7 Wavelets and Wavelets transforms

The Wavelet transform is a way or method to decompose a signal of interest into a set of basis waveforms, called wavelets, which thus provide a way to analyze the signal by examining the coefficients (or weights) of wavelets. This method is used in various applications and is becoming very popular among technologists, engineers and mathematicians alike. In most of the applications, the power of the transform comes from the fact that the basis functions of the transform are localized in time (or space) and frequency, and have different resolutions in these domains. Different resolutions often correspond to the natural behavior of the process one wants to analyze, hence the power of the transform. These properties make wavelets and wavelet transform natural choices in fields as diverse as image synthesis, data compression, computer graphics and animation, human vision, radar, optics, astronomy, acoustics, seismology, nuclear engineering, biomedical engineering, magnetic resonance imaging, music, fractals, turbulence, and pure mathematics. The word wavelet derives from the French researcher, Jean Morlet, who used the French word ondelette – meaning a “small wave”.

A little later it was transformed into English by translating “onde” into “wave” to thus arrive at the name wavelets. As the name suggests, wavelets are small waveforms with a set oscillatory structure that is non-zero for a limited period of time (or space) with additional mathematical properties. The wavelet transform is a multi-resolution analysis mechanism where an input signal is decomposed into different frequency components, and then each component is studied with resolutions matched to its scales. The Fourier transform also decomposes signals into elementary waveforms, but these basis functions are sines and cosines. Thus, when one wants to analyze the local properties of the input signal, such as edges or transients, the Fourier transform is not an efficient analysis tool. By contrast the wavelet transforms which use irregularly shaped wavelets offer better tools to represent sharp changes and local features. The wavelet transform gives good time resolution and poor frequency resolution at high frequencies and a good frequency resolution and poor time resolution at low frequencies. This approach is logical when the signal on hand has high frequency components for short durations and low frequency components for long durations. Fortunately, the signals that are encountered in most engineering applications are often of this type.

1.8 Haar Wavelet

A sequence of rescaled "square-shaped" functions which together form a wavelet family or basis is Haar wavelet [14]. Wavelet analysis and Fourier analysis is analogus - it allows a target function over an interval to be represented in terms of an orthonormal function basis. The simplest possible known wavelet is Haar [3]. Although it has many advantages but being not continuous and not differentiable are its drawbacks . This property can, however, be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines [1].

The Haar wavelet's mother wavelet function $\psi(t)$ can be described as:-

$$\psi(t) = \begin{cases} 1 & 0 \leq t < 1/2, \\ -1 & 1/2 \leq t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

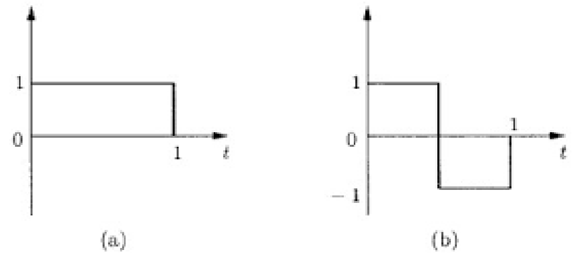


Fig 1.9 (a) Haar wavelet scaling function (b) The Haar Wavelet

Its scaling function ϕ(t) can be described as:-

$$\phi(t) = \begin{cases} 1 & 0 \leq t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

CHAPTER 2

LITERATURE REVIEW

In [1] a novel BPSK OFDM system based on Haar wavelet transformation is proposed. The technique that has gained or currently gaining a lot of attention is Orthogonal frequency-division multiplexing (OFDM) and hence regarded as a strong candidate for many next-generation wireless communication systems. However, OFDM has certain drawbacks like high effects due to the high peak-to-average power ratio (PAPR) owned by the transmitted signals and no robustness to spectral null channels. The Haar wavelet transformation operates decomposition over the data symbol sequence after binary-to-complex mapping shows that half of the data symbols are zeros and the rest are either $\sqrt{2}$ or $-\sqrt{2}$.Then, the PAPR is reduced by $10 \log10 2 \approx 3$ dB at most, compared with the conventional OFDM system. A novel decoding algorithm for the OFDM system to show robustness to spectral null channels, and derive the bit error rate (BER) performance in theory from unbalanced QPSK modulation is also proposed. Finally, the BER performance of the proposed OFDM is compared and analysed with the conventional OFDM over different channels and it was found that the proposed OFDM system shows excellent performance.

In [2] using wavelet transform an efficient and robust technique is proposed for the OFDM system. As the wireless digital communications is rapidly expanding, demand is increasing for wireless systems that are reliable and have a high spectral efficiency. Orthogonal Frequency Division Multiplexing (OFDM) achieves high data rates therefore it has been regarded for its brilliant performance. Fast Fourier Transforms (FFT) has been used to produce the orthogonal sub-carriers. Due to the drawbacks of OFDM-FFT based system which are the high peak-to-average ratio (PAR) and the synchronization, many works have replaced the Fourier transform part by wavelet transform and an efficient technique for the OFDM system using wavelet transform is proposed. This system shows a superior performance when compared with traditional OFDM-FFT systems through an Additive White Gaussian Noise (AWGN) channel. The system performance is described in Bit Error Rate (BER) as a function of Signal to Noise Ratio (SNR) and the peak-to-average ratio (PAR). Furthermore, the proposed system gives nearly a perfect reconstruction for the input signal in the presence of Gaussian noise.

In [3] to increase the data rate of wireless medium with high performance, orthogonal frequency division multiplexing (OFDM) is used which is a powerful technique that uses an Inverse Fast Fourier Transform (IFFT) at the transmitter to modulate a high bit-rate signal onto a number of carriers. The problem with this technique is that it is inherently inflexible and requires a more complex IFFT core. This paper provides an analysis of a technique for both designing wavelets and to measures respective performances, called Orthogonal Wavelet Division Multiplex (OWDM), an alternative to OFDM, which uses a Discrete Wavelet Transform (DWT) instead of using the IFFT to generate the output and has a lower computational complexity and increases flexibility. The three of the more common wavelet families are investigated with increasing order to ascertain which wavelet transform is the most suited for use in an AWGN channel and measures the performance in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) for AWGN channel in comparison with OFDM and illustrates the next level analysis of new system comparing different wavelets. It is also able to increases the spectral efficiency and decreases the bit error rate as compare with OFDM. Performance of BER, evaluation of SNR and the design of OWDM are synthesized through computer simulations using MATLAB.

In [4] Tone Reservation technique has been used for the reduction of PAPR. It includes no of set of reservation of tones. So by using this technique reserved tones can be used to minimize the PAPR. Actually tone reservation technique for multicarrier transmission and also shows the reserving tones to reduce the PAPR. Tone reservation, technique is depend on amount of complexity when there is number of tones is small reduction in PAPR may represent non negligible samples of available band width. So finally it can be observe that the main advantage of this tone reservation is very positive that no process is needed at receiver end. At the same time need not to transmit the side information along with the transmitted signal. Basically in this technique no of loop is used .and the signal will pass from each loop. Finally depending on the no of iterates the output PAPR value will be displayed

In [5] channel estimation - the technology which is receiving popularity and consideration in Orthogonal Frequency Division Multiplexing (OFDM) systems is considered. over a frequency-selective fading channel modified Minimum Mean Square Error (MMSE) is suggested and simulation is done by MATLAB . The algorithm used here has the benefit of low complexity when compared with MMSE. The drawback is a minimal attenuation of Mean Square Error (MSE) and Bit Error Rate (BER) performances occurs in the final simulation results. For practical applications it can be considered.

In [6] blind adaptive algorithms are suggested to identify the impulse response of the channels having multipath by the estimation of the blind channel zero padding OFDM systems. In particular, there are two schemes - RLS and LMS which are obtained when the orthogonal iteration method is properly modified. A very fast convergence combined with low computational complexity is shown by these two schemes. Also the numerical stability is developed to a greater extent. In the numerical analysis for the calculation of singular vectors the above schemes play a vital role. The acceptable performance of the adaptive schemes is demonstrated after certain simulation experiments under various signaling conditions. Pilot signal estimation and channel interpolation have different algorithms which are based on comb type pilots . Plot signal estimation can be formed by the MMSE or LS criteria.

In [7] a fresh outlook of the LSF principle is suggested here Till now, algorithms for data detection and channel estimation types have been put forward for orthogonal frequency division multiplexing (OFDM) system. Some algorithms are based on linear minimum mean-square error (LMMSE) estimation, while some are based on least-squares-fitting (LSF). LSF principle follows a non-statistical approach while a statistical approach is followed by LMMSE. Certain parameters such as signal-to-noise ratio (SNR) and correlation matrices need to be apprehended. The basic approach which is followed here is that by approximation of eigenvector the non-statistical LSF principle can be derived with the help of the statistical LMME principle. Both these principles are connected by link. The terms which are found to be same in the MSEE expressions of these two principles during analysis further encourages the established link.

In [8] a wide review of wavelets is presented. The areas where wavelets have been favorably applied are - almost all aspects of digital wireless communication systems that include data compression, source and channel coding, signal denoising, channel modeling and design of transceivers. The chief and primary property of wavelets in these applications is in their flexibility and ability to characterize signals accurately. In this paper recent trends and developments in the use of wavelets in wireless communications are reviewed. Major applications of wavelets in wireless channel modeling, interference mitigation, denoising, OFDM modulation, multiple access, Ultra Wideband communications, cognitive radio and wireless networks are surveyed. The concourse of information and communication technologies and the possibility of omnipresent connectivity have posed a challenge to developing technologies and architectures capable of handling large volumes of data under severe resource constraints such as power and bandwidth. Wavelets are uniquely qualified to address this challenge. The flexibility and adaptation provided by wavelets have made wavelet technology a strong candidate for future wireless communication.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Problem Formulation

As wireless digital communications is expanding at a very past pace, demand for the same systems with greater reliability and spectral efficiency has increased too. Orthogonal Frequency Division Multiplexing (OFDM) has been recognized for its good performance to achieve high data rates. Fast Fourier Transforms (FFT) has been used to produce the orthogonal sub-carriers. Due to the drawbacks of OFDM-FFT based system which are the high peak-to-average ratio (PAR) and the synchronization, many works have replaced the Fourier transform part by wavelet transform. In this paper, an efficient technique for the OFDM system using wavelet transform is proposed. When compared with traditional OFDM-FFT systems through an Additive White Gaussian Noise (AWGN) channel the performance of the system is superior. The system performance is described in Bit Error Rate (BER) as a function of Signal to Noise Ratio (SNR). Furthermore, the nearly a perfect reconstruction for the input signal in the presence of Gaussian noise is obtained by the proposed system.

3.2 Objectives

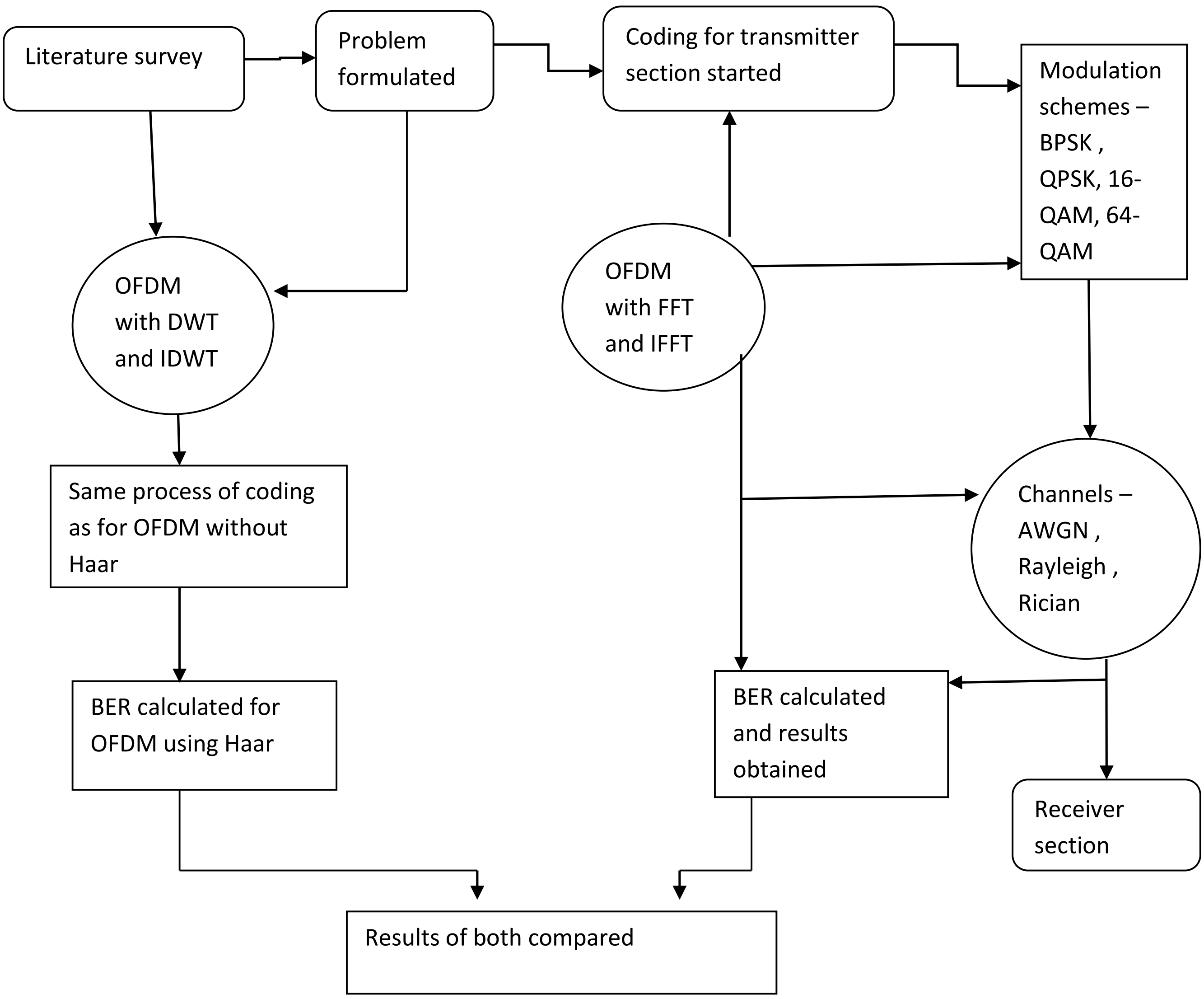
- To study and implement OFDM based communication system.
- Analysis of the implemented system for various modulation schemes with different channel models
- To improve the performance of the system with the combination of Haar wavelet

3.3 Approach

After reading a lot of papers, journals, articles about communication system – OFDM communication as an area of research is selected and problem is formulated on the basis of it. After a deep literature survey Discrete Haar Wavelet Transform is used to enhance the performance of the system. Firstly, the coding for the conventional OFDM with FFT and

IFFT is done and BER for various modulation schemes i.e BPSK , QPSK , 16-QAM , 64-QAM is calculated and results are obtained. After this, the coding for the proposed OFDM system using DWT and IDWT is done and BER for various modulation schemes i.e BPSK , QPSK , 16-QAM , 64-QAM is calculated and results are obtained. The results of the proposed system are compared with the conventional system. The software used for coding is MATLAB.

3.4 METHODOLOGY FLOW CHART



3.5 MATLAB

MATLAB is basically a numerical computing environment and fourth-generation programming language which is developed by Math Works. MATLAB allows matrix manipulations, plotting of functions, data implementation of algorithms and creation of interfaces. It also allows interfacing with programs written in other languages, including C, C++, and Java. It is known that MATLAB is an interactive system whose basic data element is an array which does not require any type of dimensioning. It allows us to solve many technical computing problems, especially those with matrix and vector formulations. There are some windows in matlab they are Command window, Figure window and Editor window. All the windows are used for different cases. They are:-

(1)The Command Window

The Command Window is the main window in which we communicate with MATLAB. If the MATLAB interpreter displays a prompt (>>) indicating that it is ready to accept commands from us.

(2)Editor

There is another important kind of window called "Editor" where we do programming and check its result using run button, if there is error in the program suddenly we check and run it.

(3)The Figure Window

The MATLAB directs graphics output to a window that is separate from the Command Window is known as a figure window. When, graphics functions are given or after the command automatically a new figure windows is created, if there is no current window. If a figure window already exists, MATLAB uses that window. If multiple figure windows exist, one is designated as the current figure and is used by MATLAB (it is generally the last figure used or the last figure we clicked the mouse in).

(4)Dis-advantages of MATLAB.

Matlab generally, uses a large amount of memory and if the computers are slow then it is very hard to use. It sits “on top” of Windows, getting as much CPU time as Windows allows it to have. This makes real-time applications very complicated.

(5)Advantages of MATLAB.

MATLAB has the basic data element is the matrix. Here, simple integer is considered an matrix of one row and one column. Several mathematical operations that work on arrays or matrices are built-in to the Matlab environment easily. For example, cross-products, dot-products, determinants, inverse matrices etc. It is not only a programming language, but a programming environment as well. It allow us to test algorithms immediately without recompilation. we can type something at the command line or execute a section in the editor and immediately see the results.We can perform operations from the command line, as a sophisticated calculator easily.In Matlab the graphical output is optimized for interaction. We can plot our data very easily, and then change its sizes and colours.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Simulations

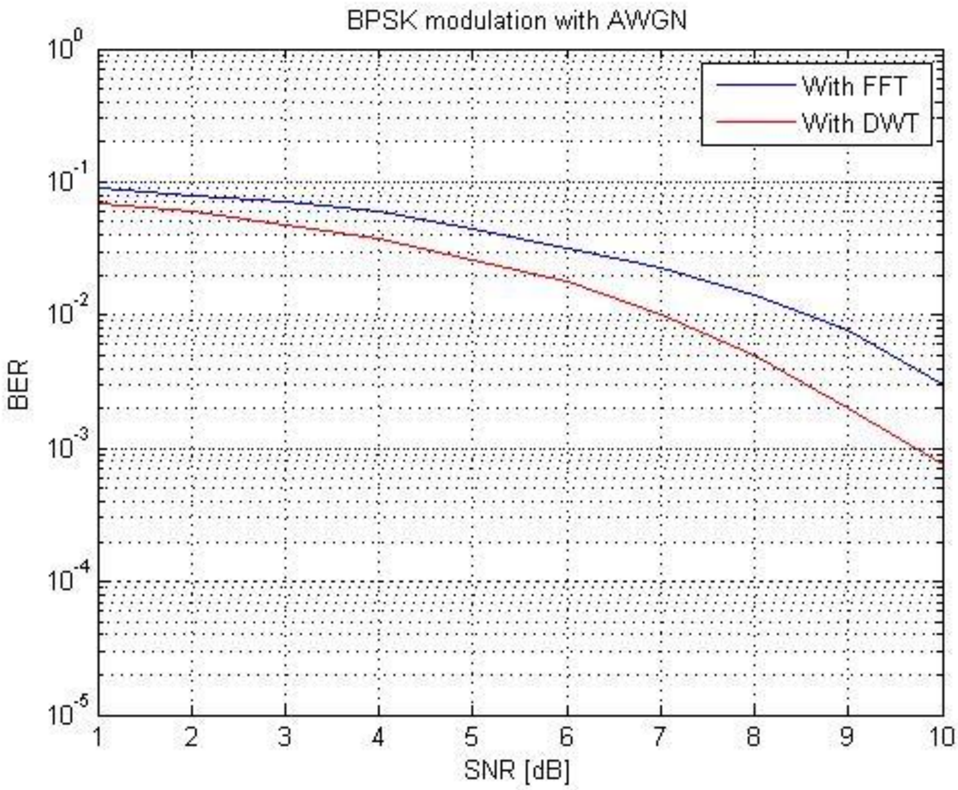


Fig. 4.1 BER vs SNR for BPSK with AWGN

SNR (dB)	BER probability with FFT	BER probability with DWT
1	.09	.07
2	.08	.06
3	.07	.048
4	.06	.038
5	.045	.026
6	.032	.018
7	.0226	.01
8	.014	.005
9	.0078	.002
10	.003	.00075

Table 4.1 Comparison of BER probability for BPSK with AWGN

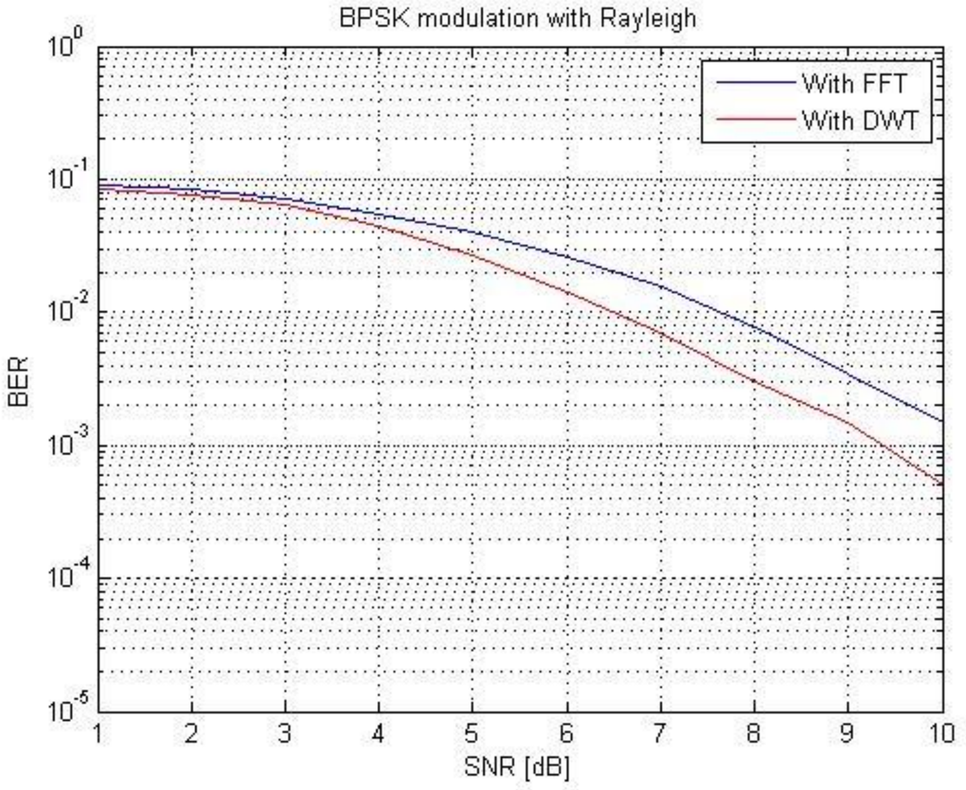


Fig. 4.2 BER vs SNR for BPSK with Rayleigh

SNR (dB)	BER probability with FFT	BER probability with DWT
1	.09	.084
2	.085	.0756
3	.07	.06435
4	.0645	.04455
5	.0398	.02677
6	.0256	.01933
7	.0169	.006986
8	.0077	.0029873
9	.00345	.001485
10	.0015	.00049875

Table 4.2 Comparison of BER probability for BPSK with Rayleigh

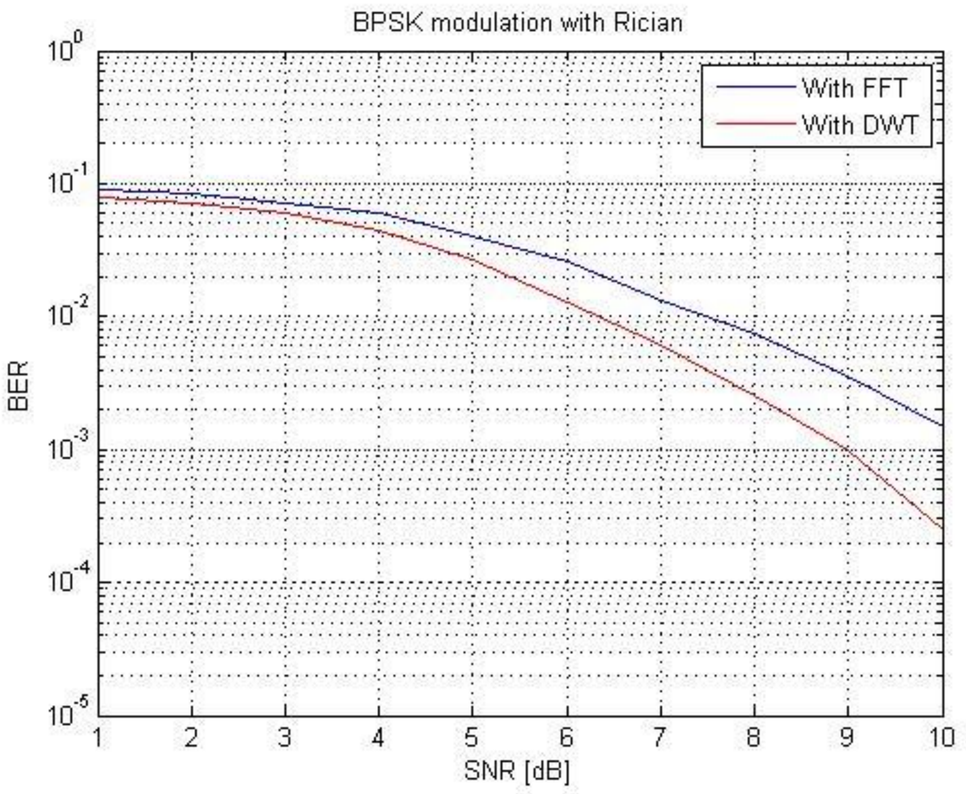


Fig. 4.3 BER vs SNR for BPSK modulation with Rician

SNR (dB)	BER probability with FFT	BER probability with DWT
1	.09	.08
2	.085	.07
3	.07	.06
4	.06	.045
5	.04	.027
6	.026	.013
7	.0134	.006
8	.0075	.0025
9	.00315	.0011
10	.0015	.00025

Table 4.3 Comparison of BER probability for BPSK with Rician

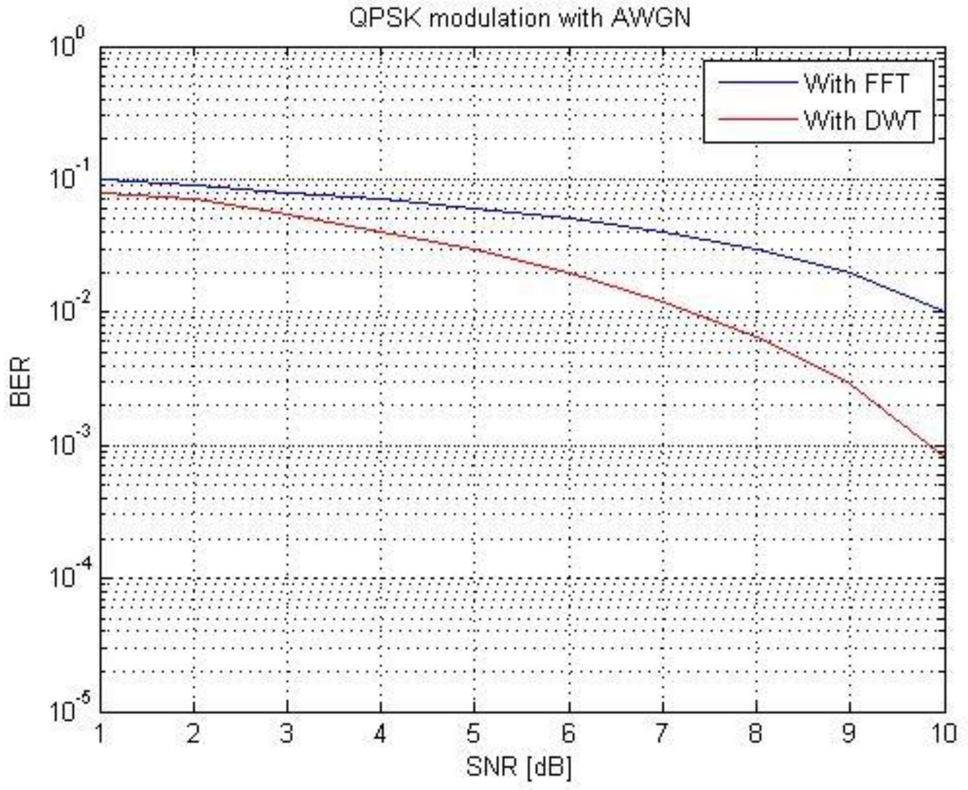


Fig. 4.4 BER vs SNR for QPSK modulation with AWGN

SNR (dB)	BER probability with FFT	BER probability with DWT
1	.09	.08
2	.08	.07
3	.07	.055
4	.06	.04
5	.045	.03
6	.032	.02
7	.0226	.012
8	.014	.0065
9	.0078	.0029
10	.003	.0008

Table 4.4 Comparison of BER probability for QPSK with AWGN

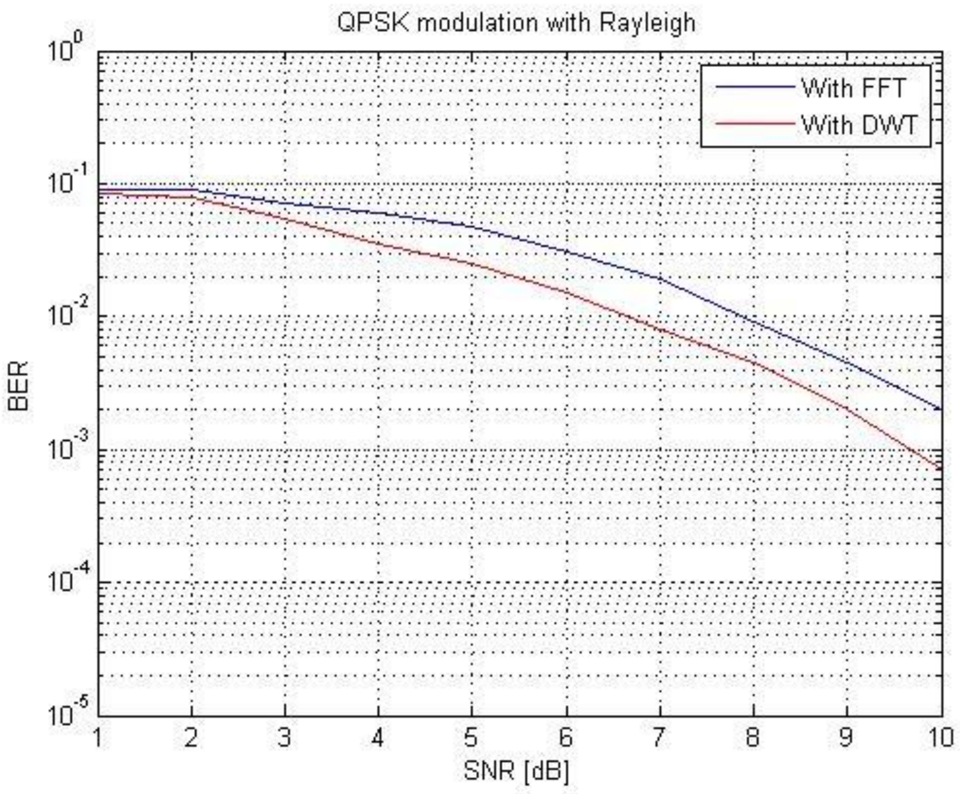


Fig. 4.5 BER vs SNR for QPSK modulation with Rayleigh

SNR (dB)	**BER probability with FFT**	**BER probability with DWT**
1	.09	.083
2	.089	.08
3	.07	.055
4	.06	.035
5	.048	.025
6	.031	.015
7	.019	.008
8	.009	.0045
9	.0045	.002
10	.002	.0007

Table 4.5 Comparison of BER probability for QPSK with Rayleigh

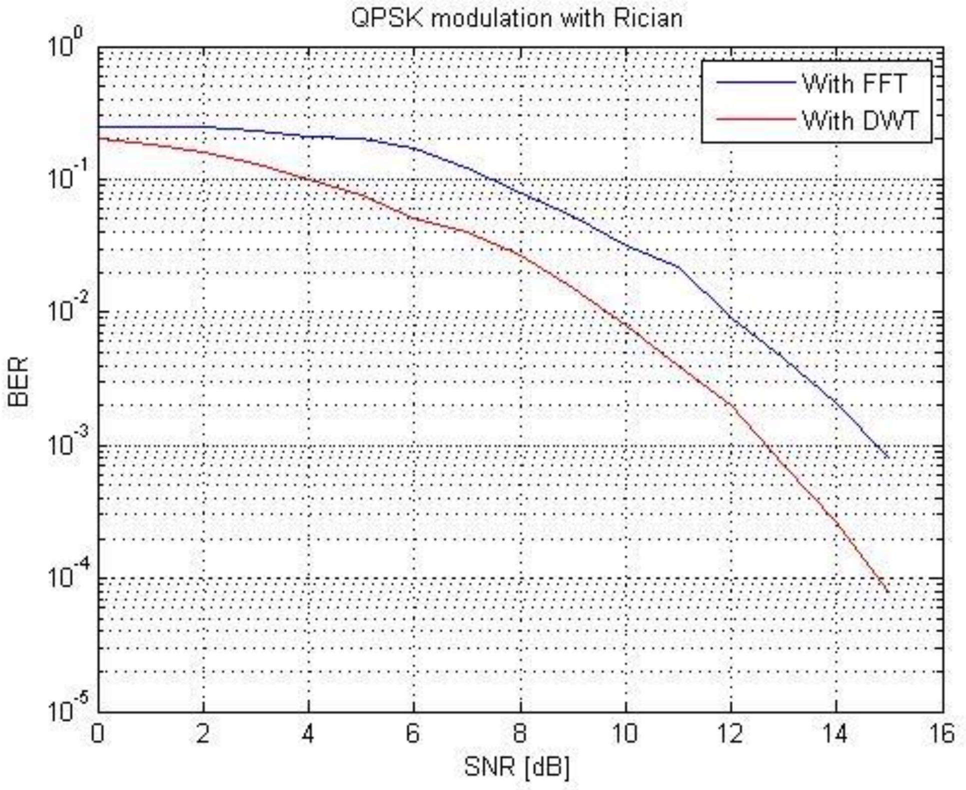


Fig. 4.6 BER vs SNR for QPSK modulation with Rician

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.25	.2
1	.245	.18
2	.24	.16
3	.23	.13
4	.21	.1
5	.2	.075
6	.17	.05
7	.12	.04
8	.08	.027
9	.052	.015
10	.032	.008
11	.022	.004
12	.009	.002
13	.0045	.0007
14	.0021	.00027

Table 4.6 Comparison of BER probability for QPSK with Rician

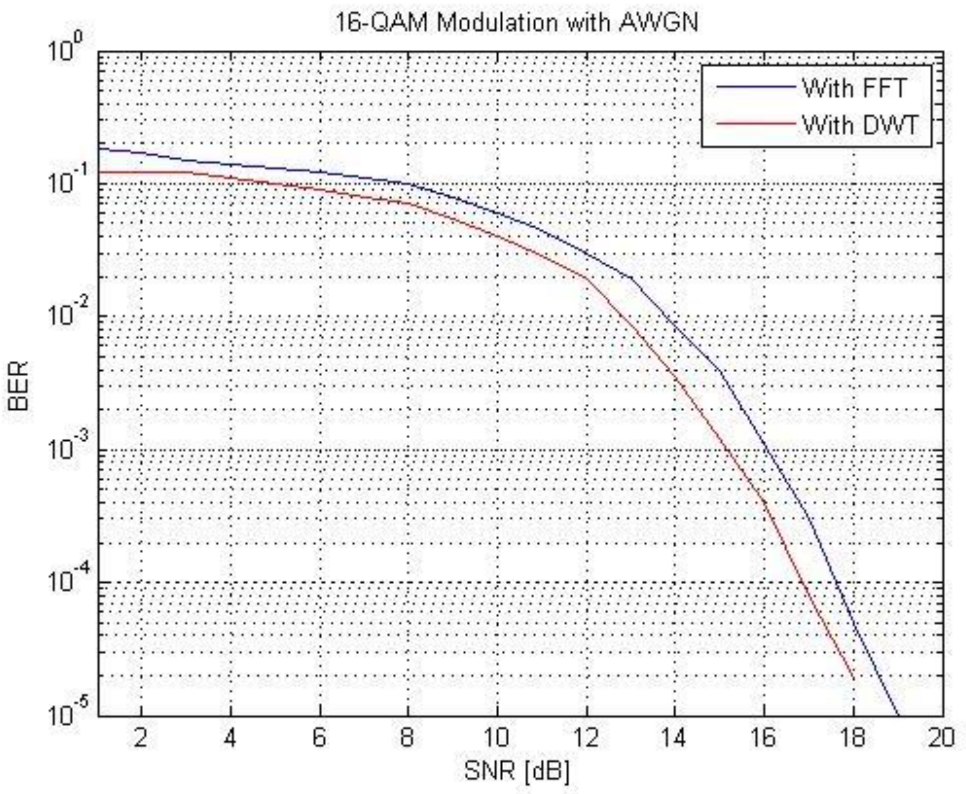


Fig. 4.7 BER vs SNR for 16-QAM modulation with AWGN

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.18	.124
1	.17	.122
2	.15	.12
3	.14	.11
4	.13	.1
5	.12	.09
6	.11	.08
7	.1	.07
8	.08	.055
9	.06	.04
10	.045	.029
11	.03	.019
12	.019	.0085
13	.0085	.0035
14	.0039	.0012

Table 4.7 Comparison of BER probability for 16-QAM with AWGN

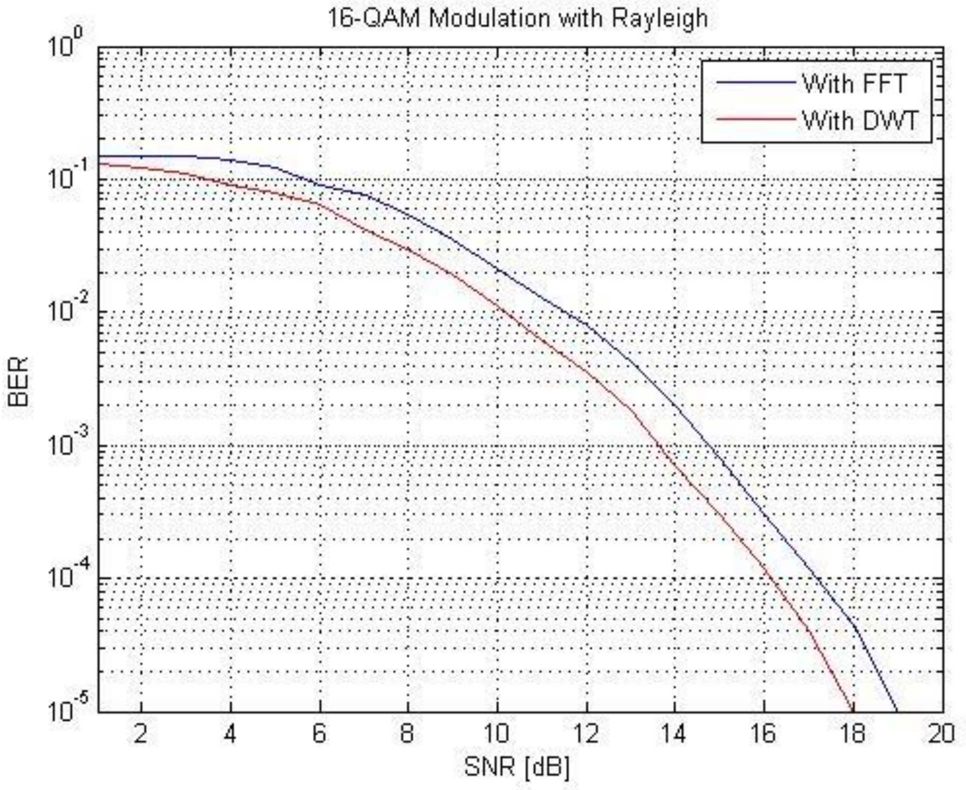


Fig. 4.8 BER vs SNR for 16-QAM modulation with Rayleigh

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.15	.13
1	.144	.12
2	.142	.11
3	.14	.09
4	.12	.08
5	.09	.065
6	.075	.042
7	.055	.03
8	.035	.019
9	.021	.011
10	.013	.006
11	.008	.0035
12	.0042	.0018
13	.002	.0007
14	.0008	.0003

Table 4.8 Comparison of BER probability for 16-QAM with Rayleigh

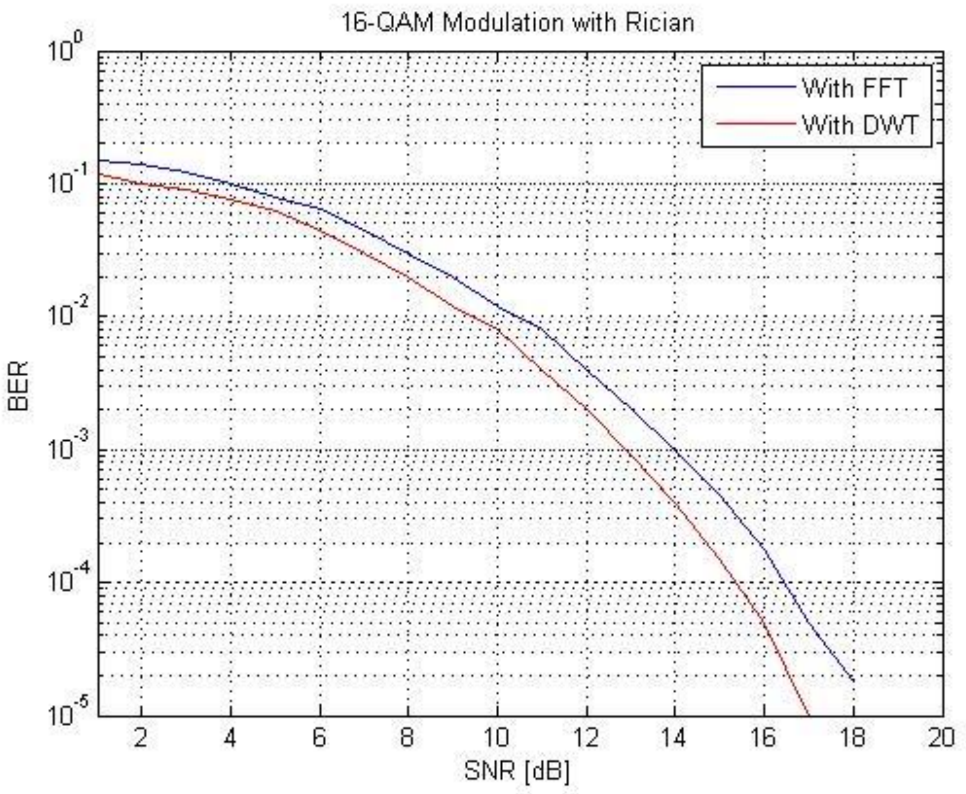


Fig. 4.9 BER vs SNR for 16-QAM modulation with Rician

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.15	.12
1	.14	.1
2	.12	.09
3	.1	.075
4	.08	.062
5	.065	.045
6	.045	.03
7	.03	.02
8	.02	.012
9	.012	.008
10	.008	.004
11	.004	.002
12	.002	.0009
13	.001	.0004
14	.0045	.00015

Table 4.9 Comparison of BER probability for 16-QAM with Rician

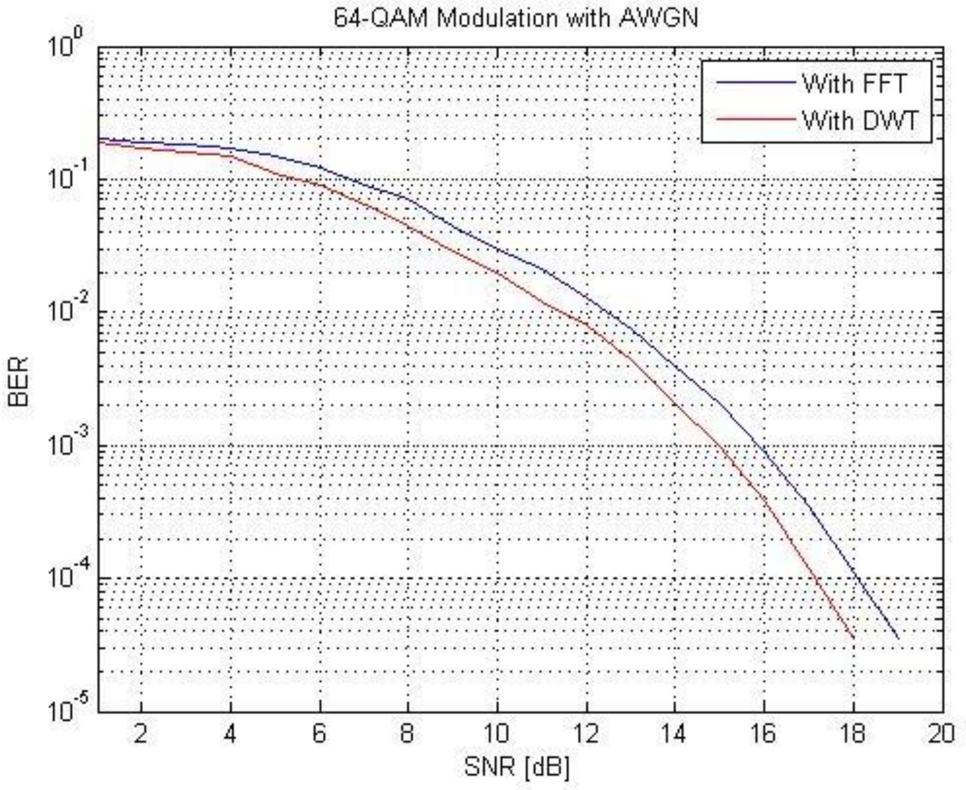


Fig. 4.10 BER vs SNR for 64-QAM modulation with AWGN

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.2	.19
1	.19	.17
2	.18	.16
3	.17	.15
4	.15	.11
5	.12	.09
6	.09	.065
7	.07	.045
8	.045	.029
9	.03	.02
10	.021	.012
11	.013	.008
12	.0075	.0044
13	.004	.0021
14	.0021	.0010

Table 4.10 Comparison of BER probability for 64-QAM with AWGN

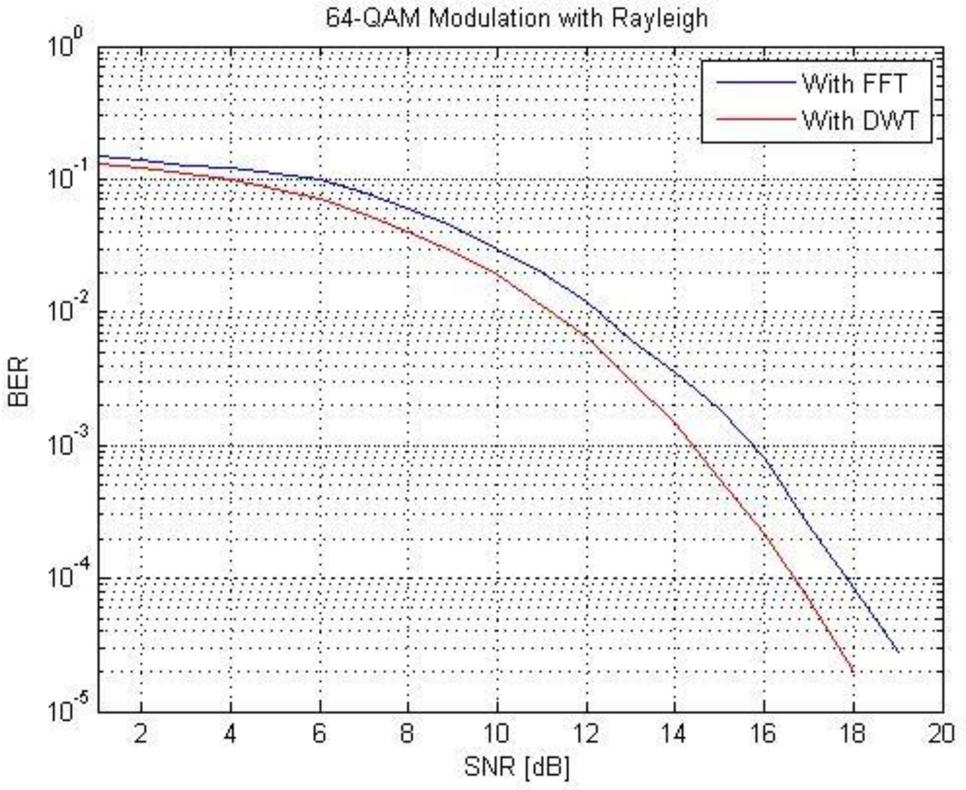


Fig. 4.11 BER vs SNR for 64-QAM modulation with Rayleigh

SNR (dB)	BER probability with FFT	BER probability with DWT
0	.15	.13
1	.14	.12
2	.125	.11
3	.121	.1
4	.11	.83
5	.1	.07
6	.08	.055
7	.06	.04
8	.045	.029
9	.03	.019
10	.02	.011
11	.012	.0065
12	.006	.003
13	.0035	.0015
14	.0019	.00055

Table 4.11 Comparison of BER probability for 64-QAM with Rayleigh

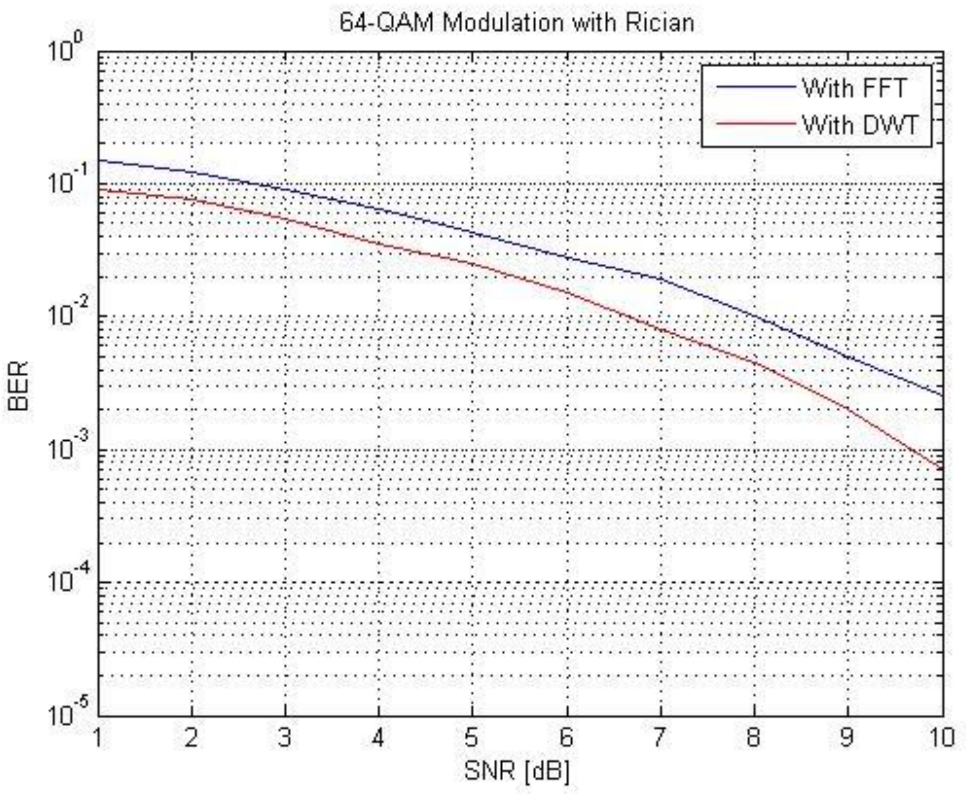


Fig. 4.12 BER vs SNR for 64-QAM modulation with Rician

SNR (dB)	BER probability with FFT	BER probability with DWT
1	.15	.079
2	.12	.055
3	.089	.035
4	.065	.025
5	.043	.013
6	.028	.015
7	.019	.008
8	.01	.0045
9	.005	.002
10	.0025	.0007

Table 4.12 Comparison of BER probability for 64-QAM with Rician

4.2 Analysis

In this section, the theoretical and simulation results of the BER versus SNR for (1) the conventional OFDM system and (2) the proposed Haar wavelet-based OFDM System are provided and step-by-step different modulations are used i.e.

- BPSK
- QPSK
- 16-QAM
- 64-QAM.

The following three channels are selected –

- AWGN
- Rayleigh
- Rician

For simplicity, the minimum mean square error estimation method (MMSE) is used at the receiver. Hence, the proposed OFDM system shows robustness as compared with the conventional OFDM system, which is very preferable in practical applications. Also, the OFDM-DWT system behavior is studied through MATLAB simulink. In addition, comparisons between the OFDM-FFT systems and the proposed OFDM-DWT are done in terms of BER and SNR. The comparisons module between the OFDM-FFT and the proposed OFDM-DWT are shown in figures above . The more SNR, the less BER for the system due to the reduction of the noise effect. Also, the BER probability for every modulation scheme shows that there is a considerable amount of improvement in every place,

The proposed system based on DWT shows better performance than the other traditional systems. This is because of the use of IDWT instead of IFFT. The effect of the CP to remove the inter symbol interference is expounded when multi-path propagation is tested. It can be seen all the modulation schemes with different channels shows greater performance with higher SNR above 5 dB. The output from the proposed OFDM-DWT system gives nearly a perfect reconstruction for the input signal.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE OF THE STUDY

An efficient OFDM-DWT system is proposed with different modulation schemes using different channels.. .In this work different modulation schemes – BPSK, QPSK, 16-QAM, 64-QAM along with various channel models such as AWGN, Rayleigh and Ricean have been used to analyze the performance of the proposed system. Extensive simulation programs were performed to investigate the efficiency of the proposed system compared with traditional OFDM systems based on FFT. The proposed system showed a superior performance. In addition, it had less BER performance as a function of SNR than traditional systems. Moreover, it donated a perfect reconstruction for the input signal.

From the above results, it is suggested that the Haar wavelet is the most suited for OFDM because of the higher resilience to noise in a channel followed by the Daubechies and Haar wavelet achieved the best BER performance. Analysis also show that the proposed OFDM system does not increase too much computational complexity at the transmitter.

Further research can be done to reduce PAPR using these modulation schemes and Symlet wavelet [1] can be used to study the BER performance.

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