WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

OPTIMIZATION OF A MULTI-CARRIER CODE DIVISION MULTIPLE ACCESS (MC-CDMA)

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APPROVAL

This is to certify that the dissertation entitled “Optimization of multicarrier code division multiple access “has been carried out by the above group members for partial fulfillment of the award of degree of Bachelor of Science in electrical and computer engineering.

Specialized in communication stream

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DECELARATION

This work is submitted to Electrical and Computer Engineering Department in Partial Fulfillment of the Requirements for the Degree of Bachelor of science in Electrical and computer engineering (communication engineering specialization) for Wolkite University and we declare that the work entitled Optimization of multicarrier code division multiple access is our original work. We have not copied from any other students' work or from any other sources except where due reference or acknowledgement are made explicitly in the text, nor has any part been written for us by another person.

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ACRONYMS AND ABBRIVIATIONS

ACF	Auto-Correlation Function
A/D	Analog to Digital
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CCF	Cross-Correlation Function
CDMA	Code Division Multiple Access
CP	Cyclic Prefix
D/A	Digital to Analog
EN/NO	Energy of bit and Noise density
FDD	Frequency Division Duplexing
FEC	Forward Error Correction
FDMA	Frequency Division Multiplexing Access
FFT	Fast Fourier Transform
GSM	Global System for Mobile communication
HPA	Higher Power Amplifier
IC	Interference Cancellation
ISI	Inter-Symbol-Interference
ISP	Improved Sine Power

IFFT	Inverse Fast Fourier Transform
LTE	Long-Term Evolution
MAI	Multi-Access Interference
MC-CDMA	Multi-Carrier Code Division Multiple Access
MIMO	Multi-Input Multi-Output
MLSE	Maximum Likelihood Sequence Estimation
MMSE	Minimum Mean Square Error
MPI	Multi Path Interference
MS	Mobile Station
MUI	Multi User Interference
OFDM	Orthogonal Frequency Division Multiplex
PAPR	Peak to Average Power Ratio
P/S	Parallel to Serial
PTS	Partial Transmit Sequence
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RC	Raised Cosine
SLM	Selected Mapping
S/P	Serial to Parallel
STBC	Space Time Block Coding
TDD	Time Division Duplexing

TDMA	Time Division Multiple Access
WC	Walsh Code
W-H	Walsh Hadamard
WiFi	Wireless Fiderity
WiMax	Worldwide Interoperability for Microwave Access
ZCZ	Zero Correlation Zone
3GPP	Third Generation Partnership Project

ABSTRACT

MC-CDMA is one of the most promising techniques for future mobile communication since it offers high bit rate and high capacity transmission. It is the combination of two efficient techniques: Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Consequently, it combines the benefits and limitation of both CDMA as well as OFDM techniques. The project presents optimization of MC-CDMA in AWGN channel and Rayleigh channel using BPSK modulation technique. The result is shown through graph of performance of MC-CDMA using MATLAB software. Finally, the conclusion describes the system optimization by considering the optimum parameter such as power, BER, Code length, E_N/N_O and taking the point at which the system effectively performs.

CHAPTER ONE

1. Introduction

1.1. Background of study

Wireless communications is a type of data communication that is performed and delivered wirelessly. Wireless communications are an emerging field, which has seen enormous growth in the last several years. The spectacular growth of video, voice and data communication over the Internet, and the equally rapid pervasion of mobile telephony, justifies great expectations for mobile multimedia [9]. Due to this growth of multimedia communication, the users demanded high data rate communication systems in wireless environment where the spectral resource is scarce [10], [20].

Code Division Multiple Access (CDMA) is an up-to-date technology widely used in operational radar, navigation and wireless multimedia telecommunication systems and playing a dominant role in the philosophy of the next generation high data rate wireless systems. CDMA is a multiple access technique where different users share the same physical medium, that is, the same frequency band, at the same time. The main ingredient of CDMA is the spread spectrum technique, which uses high rate signature pulses to enhance the signal bandwidth far beyond what is necessary for a given data rate [19].

In a CDMA system, the different users can be identified and, hopefully, separated at the receiver by means of their characteristic individual signature pulses (sometimes called the signature waveforms), that is, by their individual codes.

The conventional code division multiple access technique used in third generation system faces serious limitations by channel dispersion, causing inter symbol interference (ISI), and it requires advanced signal processing algorithms to contain it. Multi carrier CDMA employing multiple stream of data channel can combat channel dispersion, hence ISI, thereby increasing system capability to accommodate a higher number of users and its data rate requirements [19].

Therefore, MC-CDMA is formed by combining orthogonal frequency division multiplexing (OFDM) with CDMA became a significant research topic. Consequently, MC-CDMA has the advantages of both CDMA and OFDM. The CDMA part increases spectrum utilization and the

OFDM part reduces multipath fading and Inter Symbol Interference (ISI). Thus, MC-CDMA is an efficient technique that reduces problems like, spectral limitation and distortion due to multipath channels. So, it is considered as a strong contender for future mobile communication to obtain high data rates at downlink.

The following are the basic techniques of multiple accesses:

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

1.1.1. Frequency Division Multiple Access (FDMA)

This was the initial multiple-access technique for cellular systems in which each individual user is assigned a pair of frequencies while making or receiving a call. One frequency is used for downlink and one pair for uplink. This is called frequency division duplexing (FDD). That allocated frequency pair is not used in the same cell or adjacent cells during the call so as to reduce the co channel interference. Even though the user may not be talking, the spectrum cannot be reassigned as long as a call is in place. Different users can use the same frequency in the same cell except that they must transmit at different times. The features of FDMA are as follows: the FDMA channel carries only one phone circuit at a time. If an FDMA channel is not in use, then it sits idle and it cannot be used by other users to increase share capacity. After the assignment of the voice channel the BS and the MS transmit simultaneously and continuously. The bandwidths of FDMA systems are generally narrow i.e. FDMA is usually implemented in a narrow band system. The symbol time is large compared to the average delay spread. The complexity of the FDMA mobile systems is lower than that of TDMA mobile systems. FDMA requires tight filtering to minimize the adjacent channel interference.

1.1.2. Time Division Multiple Access

In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time. In such cases, TDMA is a complimentary access technique to FDMA. Global Systems for Mobile communications (GSM) uses the TDMA technique. In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA and the users are allotted time slots during which they have the entire channel bandwidth at their disposal.

TDMA requires careful time synchronization since users share the bandwidth in the frequency domain. The number of channels are less, inter channel interference is almost negligible. TDMA uses different time slots for transmission and reception. This type of duplexing is referred to as Time division duplexing (TDD). The feature of TDMA includes the following: TDMA shares a single carrier frequency with several users where each user makes use of non-overlapping time slots.

1.1.3. Code Division Multiple Access (CDMA)

In code division multiple access (CDMA) system, the narrowband massage signal is multiplied by a very large bandwidth signal called the spreading signal. All CDMA users use the same carrier frequency and may transmit simultaneously. Each user has its own pseudorandom code word. The receiver performs a time correlation operation to detect only the specific desired code word. All other code word appears as noise. Each user operates independently with no knowledge of the other users.

In CDMA, the same bandwidth is occupied by all the users, however they are all assigned separate codes, which differentiates them from each other. CDMA utilize a spread spectrum technique in which a spreading signal (which is uncorrelated to the signal and has a large bandwidth) is used to spread the narrow band message signal.

1.2. Problem of statement

Today, wireless systems aim to reduce the ISI resulting from high data rate transmission and to utilize the finite bandwidth in an efficient way. To achieve this, a multiple access technique known as multi-carrier code division multiple access (MC-CDMA), which combines the benefits and drawbacks of both OFDM and CDMA techniques is preferable. CDMA system is interference limited. The OFDM part in an MC-CDMA structure will create peak to average power ratio (PAPR) that occurs in the system when several sub-channels add in phase at the output of the transmitter, which will reduce the power efficiency of the system. In this paper, we want to present optimization of MC-CDMA in AWGN channel and Rayleigh channel using BPSK modulation technique.

1.3. Objective of the project

1.2.1. General objective

The main objective of this project is to solve the problem of frequency selective fading and interference to improve the performance of communication channel system BER in MC-CDMA.

1.3.2. Specific objectives

- To simulate the performance evaluation of MC-CDMA using MAT LAB
- To determine the optimum system parameters at a given system BER
- To improve the limitations of CDMA such us bandwidth, fading and noise
- To compare the performance of MC-CDMA and CDMA

1.4. Scope of project

MC-CDMA combines the benefits of CDMA with the natural robustness to frequency selectivity offered by OFDM. It can be interpreted as CDMA with the spreading taking place in the frequency rather than temporal domain. In MC-CDMA, the processing and signature spreading occurs in the frequency domain. This work includes optimization of MC CDMA system by considering the optimum parameter such as power, BER, Code length, E_N/N_O and taking the point at which the system effectively performs.

CHAPTER TWO

2. LITERATURE REVIEW

Literature review has been done on research works carried out in the area of MC-CDMA. Some of the important results obtained by the researches are:

As MC-CDMA is based on OFDM, in this paper, the performance of OFDM system is studied as a prerequisite to analyzing MC-CDMA system. Then the Bit Error Rate (BER) performance of the MC-CDMA system is observed for different modulation techniques using MATLAB. The observations are carried out over Rayleigh fading channel with Additive White Gaussian Noise (AWGN). Walsh-Hadamard (W-H) code is used for spreading, as it reduces the Multiple Access Interference (MAI). It is seen that BPSK and QPSK show better performance in terms of BER. Finally, it is observed that, due to Multi User Interference (MUI) and Multipath Interference (MPI), the performance of MC-CDMA degrades when the number of users in a channel is increased [4].

To realize a power-efficient MC-CDMA system, it is important to understand the damage to the property of the spreading sequence due to the nonlinearity of the high power amplifier (HPA). However, the effects are not well investigated. In this study, the authors investigated the degradation of communication quality due to nonlinear characteristics when performing Forward Error Correction (FEC) coding. From the results, it became clear that MC-CDMA outperforms OFDMA as a multiple access scheme, but is more sensitive to the nonlinearity, especially in the higher mode modulation [5].

MC-CDMA is a multiuser and various get to framework which is shaped by the mix of Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA). The main work of the research is multiple input multiple output (MIMO) Multi Carrier Code Division Multiple Access (MC-CDMA) framework by utilizing equalization techniques and different modulation systems that profoundly decreases the Bit Error Rate(BER). The MC-CDMA framework with transfer gives higher information rates. Be that as it may, Inter Symbol Interference (ISI) influences the general execution of these frameworks. To enhance the execution of the framework it is proposed to break down the framework with various modulation techniques, for example, Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM) and with equalizers, for example, Minimum Mean Square Error (MMSE) and Maximum Likelihood Sequence Estimation (MLSE). At last the reproduction is completed utilizing MATLAB and the execution of the performance of the system is evaluated [3].

It has a great significance to quantitative analysis of the new sequence generated by the improved Chebyshev mapping, and it can adapt the spread spectrum communication well in MC-CDMA system. Select m sequence, Gold sequence and improved Chebyshev chaotic sequence as the spread spectrum sequence through the BPSK modulation mode in the MC-CDMA downlink to simulation experiment. It can be proved that the error performance of the improved Chebyshev sequence is better than the other two sequences, and reveal the variation of the system error rate of the signal to noise ratio based on performed and analysis [2].

Moreover, with space time block coding (STBC) technique, MC-CDMA systems can have an added merit of transmit diversity. In this paper, we have developed an STBC MC-CDMA system and evaluated it for Multiple access interference (MAI) based on different spreading codes. We have employed three spreading codes namely orthogonal Gold code, Walsh Hadamard code and orthogonal complementary sequence. We have compared the performance of these codes in both 64 and 128 subcarrier systems and find that the orthogonal complementary sequence performs better than the other two in both the scenarios [1].

One of the main fundamental drawbacks of MC CDMA systems is its high peak-to-average-power ratio (PAPR). This paper presents a PAPR Reduction method for MC CDMA system with various Pulse Shaping Functions. The pulse shapes like Raised cosine pulse (RC) and Improved sine power pulse (ISP) are used for pulse shaping the MC CDMA system. The results like bit error rate (BER) performance and PAPR of the MC CDMA system with and without pulse shaping indicates that the MC CDMA system with pulse shaping is better than the normal MC CDMA system and the pulse shaping with ISP is better compared to raised cosine pulse [17].

The wireless communication channel suffers from much impairment such as AWGN, the path loss, the shadowing and the fading. This work considered fading as is a major problem and in order to reduce it, diversity is being used. Finally, it was considered that thus in diversity technique, multiple copies of the same data are transmitted to the receiver via multiple paths or channels and the final decision is made by the receiver without knowing to the transmitter [20].

Multicarrier OFDM arrangements with MIMO systems having numerous benefits, which are detailed in this thesis. This work highlighted the limitations of conventional detection and channel estimation techniques designed for multiuser MIMO-OFDM systems in the so-called rank-deficient scenarios, where the number of users supported or the number of transmit antennas employed exceeds the number of receiver antennas. This is often encountered in practice; unless the number of users granted access are limited in the base station's or radio port's coverage area [13].

Interference was the limiting factor in wireless communication systems. This work explained the downlink of the Third Generation Partnership Project (3GPP) Long-Term Evolution (LTE) based on OFDM. It has the potential for enhanced interference reduction compared to previous systems based on CDMA. This OFDM spectrum user is simultaneously desired wherein the signal was very strong and the interference was weak. This result confirms that there is a significantly higher benefit of multiple antennas in a wireless system, if the mobile terminals are aware of the frequency-selective interference and sharing of resources among the multiple users in a cell is enabled [18].

A mathematical analysis for the performance of OFDM signals over multipath Nakagami-m fading channels. In contrast to the previous research, this work focused on the effects of the non-uniform phase distribution on the error rate performance. It has obtained a unified expression derived for the MGF of the frequency-domain channel gained on Nakagami-m channels with non-uniform phase distributions. This work was employed to obtain accurate error rate expressions for different modulation and diversity formats [15].

A dynamic fractional frequency reuse framework for multicellular OFDM network. This dynamic feature is characterized by the capability of redistributing the spectral resource according to the varying cell load. This dynamic scheme is shown to yield better cell throughput and service rate performance, especially in unequal cell-load scenarios. This method is simple yet effective and can be used in next-generation cellular systems [14].

However, this work, MC-CDMA optimization is differing from the others by verifying to select a preferable optimum power from the power range [-10,10] dB and what the interference will when the user is increase in number. As well as comparing the performance of CDMA and MC-CDMA by considering a bit error rate.

CHAPTER THREE

3. METHODOLOGY

3.1. Multiple Access Techniques

Mobile communications are rapidly becoming more and more necessary for everyday activities. With so many more users to accommodate, more efficient use of bandwidth is a priority among cellular phone system operators. Equally important is the security and reliability of these calls.

Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner. As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users. And this must be done in a way such that the quality of service doesn't degrade within the existing users [16].

3.2. Block Diagram of MC-CDMA System

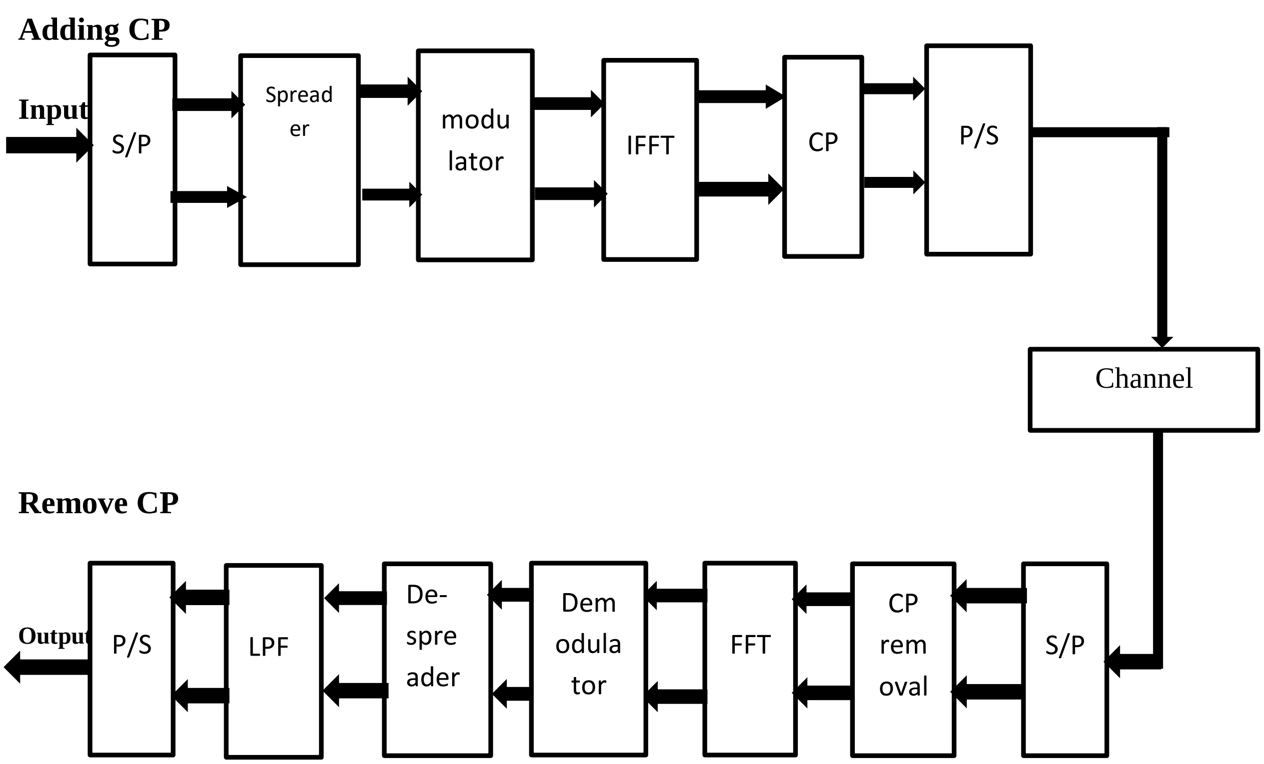

Figure 3.1 MC-CDMA Block diagram.

3.2.1. Block diagram description

S/P (serial to parallel): Converts the serial stream of data in to parallel streams of data.

Spreader: is the device used to spread the code.

Modulator: Generate a modulated signal suited to the characteristics of the transmission channel.

IFFT: Convert the data from frequency domain in to time domain.

CP (Cyclic Prefix): used to reduces the interference between successive symbols.

P/S (parallel to serial): Converts the parallel stream of data in to serial stream of data.

Channel: Is the electronic medium that bridges the distance from source to destination.

FFT: Converts the data from time domain in to frequency domain.

Demodulator: Demodulates the signal to be suited for the receiver to receive.

De-spreader: is used to de-spread the code that can spread at the receiver side.

LPF (Low Pass Filter): Rejects the high frequency portion of data signals.

3.2.2. Working Principle of MC-CDMA

Original data serial streams are converted to parallel streams and then MC-CDMA transmitter spreads the original data stream over different sub- carriers using a given spreading code in the frequency domain. In other words, a fraction of the symbol corresponding to a chip of the spreading code is transmitted through a different sub-carrier. But it is phase shifted (typically 0 or `180 degrees) according to the orthogonal code values. The code values differ per sub carrier. The sub-carrier is transformed in time domain and then modulated with each of the data stream. CP is a cyclically extended guard interval. The signal is then transmitted through a channel having transfer function and the signal received at the receiver is affected by AWGN. The serial stream is converted to parallel stream which in turn is send to Fast Fourier Transform (FFT) block for conversion of time domain samples to frequency domain samples. CP is removed. The de-spreading and combining operation is preceded by frequency domain equalizer and LPF delete high frequency portion of data signals. Finally, Parallel stream is converted to serial stream and original data symbols are accessed.

3.3. Flow chart of MC-CDMA

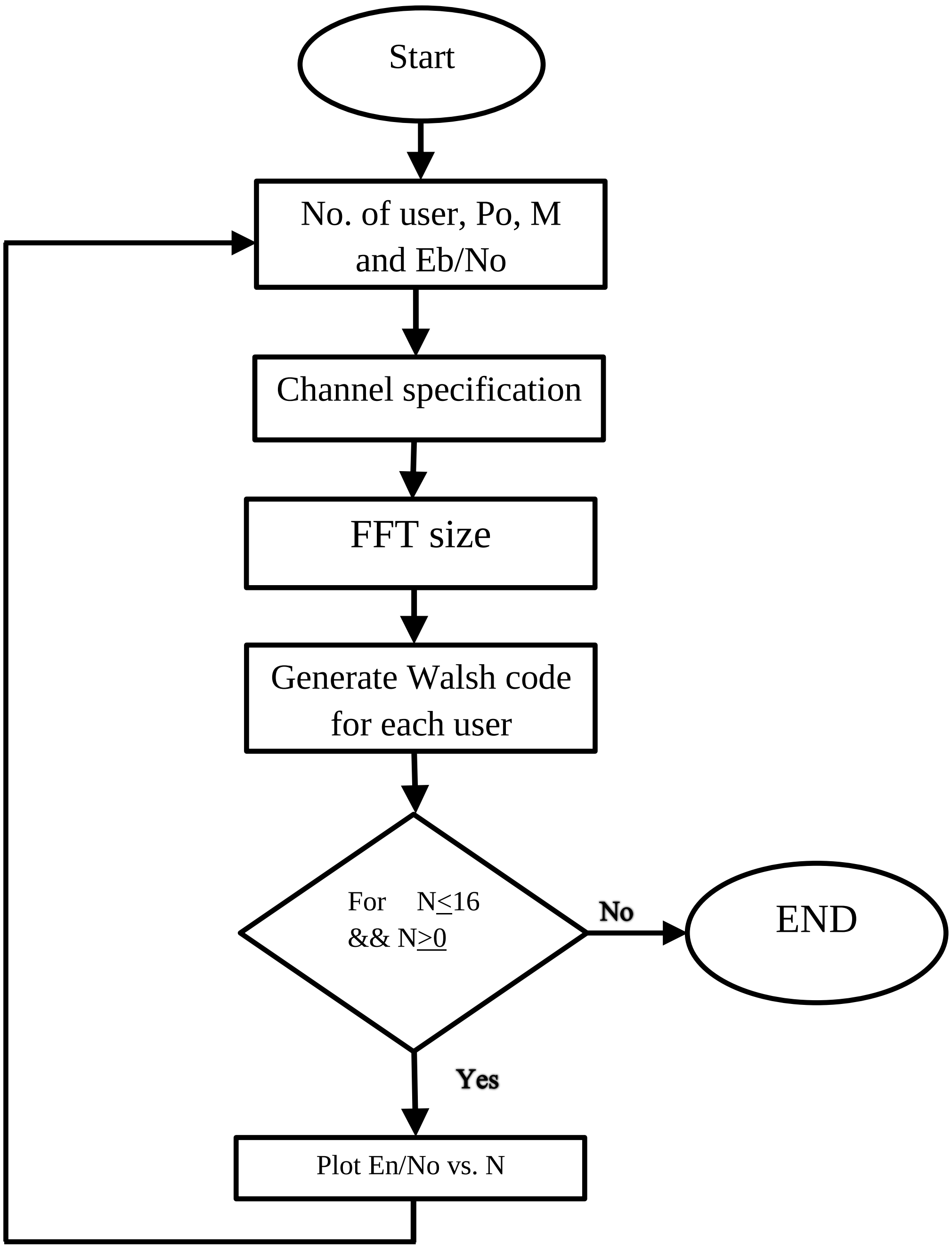

Figure 3.2 Flow chart of MC CDMA

3.4. Multi Carrier Code Division Multiple Access (MC-CDMA)

MC-CDMA is a high speed communication system defined on multiple carrier. This communication system is having the adaption to new era of communication features and defined specifically for wireless system. The wireless system is here configuring under the 3G and 4G constraints. The communication is here performed under high frequency spectral specification, communication delay reduction, multiple wavelength adaptive communication, reduction of associated ISI and immunity over the signal. Provides the fading adaptive high frequency signal so that the optimized communication will be performed over the channel. This communication system is defined under the specification high data rate for video communication. These kinds of communication systems are suitable for the high frequency and effective communication such as in case of WiFi or WiMAX network [15].

The MC-CDMA is a type of multiple accesses that utilize the benefits of both CDMA and OFDM schemes. The multi carrier part reduces the multipath fading and ISI, whereas the spread spectrum technology utilizes the limited spectrum in an efficient way. The high data rate transmission will make a resistive channel. The multi carrier part will overcome this problem by transmitting high data rate into low rate parallel subcarriers. The overlapping of carriers provides high spectral efficiency.

Compared to the other multicarrier technique, in a MC-CDMA scheme the original data symbols are first spread with a pseudorandom sequence, followed by the modulation on different carriers. That is, in a MC-CDMA system the chips of same symbol are modulated on different carriers. Hence, the spreading is said to be done in frequency domain.

3.4.1. Transmitter Structure of MC-CDMA

An MC-CDMA transmitter spreads the original data stream in the frequency domain over different sub carriers using a given spreading code. In this system the sub carriers convey the same information at one time. The MC-CDMA offers better frequency diversity to combat frequency selective fading [14].

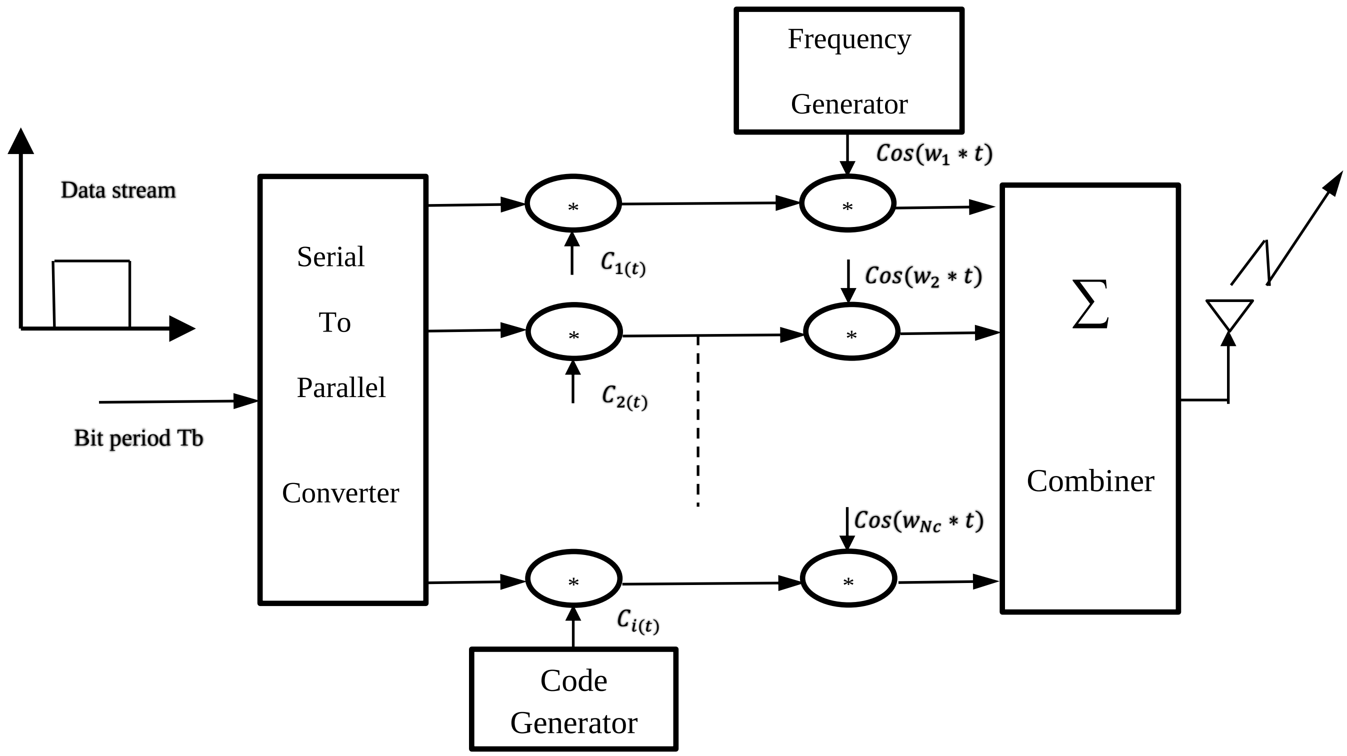

Figure 3.3 MC-CDMA transmitters

3.4.2. Receiver Structure of MC-CDMA

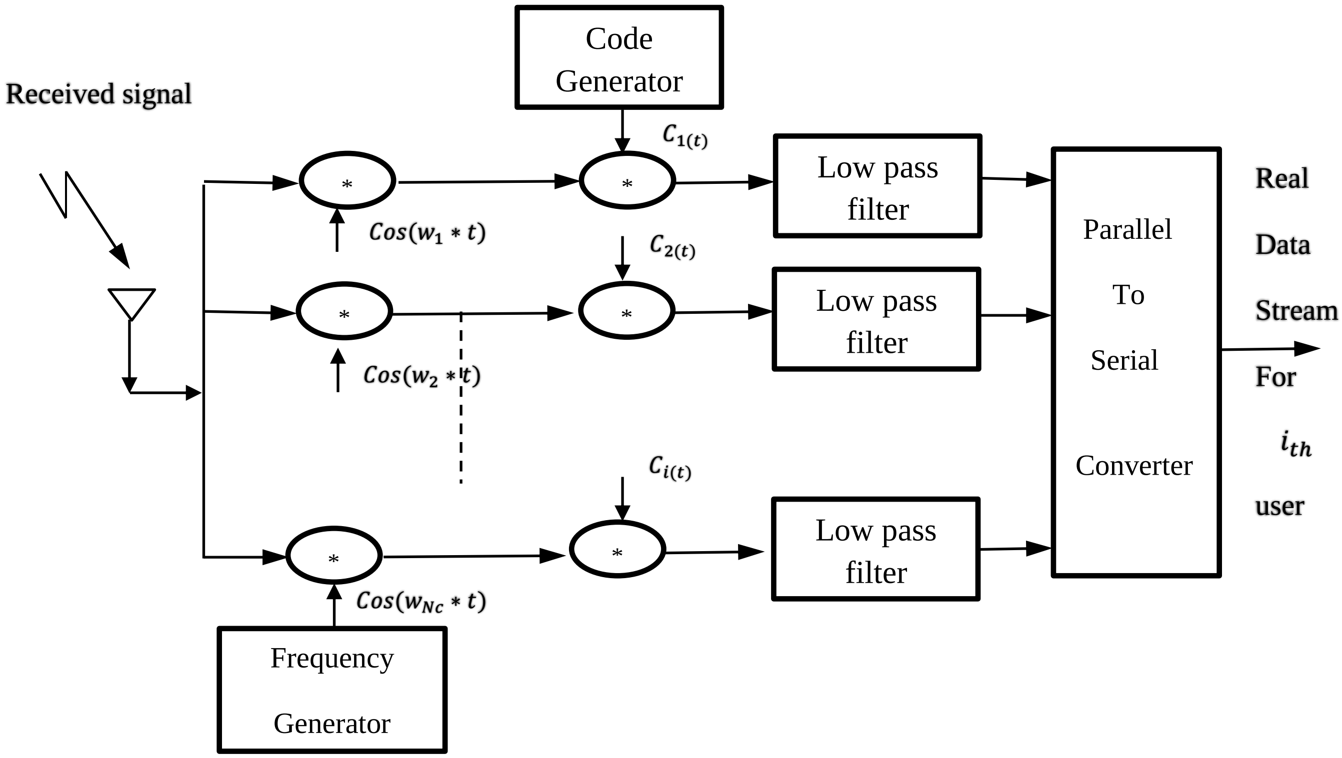

Figure 3.4 MC-CDMA receivers

In figure 3.4, the MC-CDMA receiver is designed by the capacity of i number of user. MC-CDMA receiver also receives the transmitted signal as a summation of i number of users. At first demodulates the received signal by the same career frequency of each signal and then the signals multiply with the specific codes given by the receiver code generator. Then we get the signal of i^{th} user which is same for transmitter and receiver. After that low pass filter remove the high frequencies portion of the signal. Finally, the P/S converter presents the actual digital data signal.

3.5.Problems in an MC-CDMA System

The important limiting factor in every communication system is the interference affecting the system. The MC-CDMA system is a combination of both CDMA and OFDM. Hence, it will have the drawbacks of both the schemes.

A. Interference affecting the system

The performance of a CDMA system will depend on the interference affecting the system, so that it is known as interference limited system. The interference affecting the system can be multi path interference (MPI) due to multi path delays and multiple access interference (MAI) due to multiple access delays. Both MPI and MAI cause self-interference as well as multi-user interference (MUI) that degrade the performance and capacity of CDMA systems. The MPI occurs when the signal from the transmitter travels through two or more path to the receiver under the right condition. These two or more signal components will interfere resulting in MPI. The MAI is one of the major factors that limits the performance and capacity of CDMA systems. It is actually the interference between the direct sequence users which occur due to the random time offset between the signals. Due to MAI, the design of orthogonal code waveforms becomes difficult.

B. Peak to average power ratio

The OFDM scheme used in a MC-CDMA system is capable of providing improved quality of service at high data rates. At high data rates single carriers are more susceptible to fading and multipath propagation, however multicarrier techniques eliminates the need for complex equalizers by maintaining high data rate transmission.

The OFDM scheme transforms a wideband channel in to a narrowband channel and the use of narrow band signals will reduce frequency selective multipath fading because narrow band signals are less sensitive to fading and inter symbol interference (ISI). However, in a multicarrier system, at the output of the transmitter several subcarriers add in phase which creates high PAPR. The PAPR of a MC-CDMA signal x (t) is actually defined as the ratio of maximum power of a sample in a given OFDM symbol to the average power of that OFDM symbol.

3.6. Solutions to Reduce the Problems in a MC-CDMA System

The CDMA scheme used in a MC-CDMA system is interference limited. Therefore, the performance and capacity it can handle will depend on the interference affecting the system.

A. Interference cancellation techniques

The user capacity of a system is mainly limited due to the domination of interference affecting the system. There are several ways to improve the user capacity by using optimum detection, interference cancellation (IC) methods, or methods such as decor relating receiver. The use of multi user algorithms improves the performance of the system, however the complexity increases exponentially with increase in the number of users and code length. In IC techniques, it attempts to remove the multiple user interference from each user's received signal prior to making data decisions. IC cancellation techniques can be mainly classified as serial or successive and parallel cancellation techniques. In serial cancellation techniques, the interference caused by the remaining users is removed from each user in succession. However, in order to achieve this, a specific geometric power distribution must be assigned to each user. Another disadvantage of this scheme is that there is a delay in accomplishing the interference cancellation of all users in the system. In parallel processing the interference produced by the remaining users accessing the channel is simultaneously removed from each user.

B. Use of efficient spreading sequence

The interferences such as MPI and MAI are closely related to the Auto-correlation function (ACF) and Cross correlation function (CCF) of the spreading sequence used to spread the data sequence. Hence the use of spreading sequence with good correlation properties can replace the need of complicated interference cancellation techniques. The commonly used spreading sequences are Pseudo noise sequence, Walsh codes, Gold codes etc. The spreading sequence set that have ideal impulsive ACF and zero CCF can significantly reduce the interference affecting the system. But such ideal sequences are difficult to design. A set of spreading sequence known as zero correlation zone (ZCZ) sequence are defined to be a sequence set with zero correlation zone at out of phase state. Hence, if the entire multi path and multiple access delays are within this zero correlation zone, then the use of ZCZ sequences in the system can effectively eliminate MPI and MAI. Both binary and ternary codes are a type of ZCZ code in which ternary ZCZ sequence have longer zero correlation zone and large family size. The figure clearly shows that ZCZ code performs better than other spreading codes.

Among binary and ternary ZCZ code, the performance of the system using ternary ZCZ code is superior to the system using binary ZCZ code.

C. PAPR reduction techniques

Also compared to a CDMA system, the use of narrow band signals in an MC-CDMA system makes the system less sensitive to ISI and multipath fading. However, in a multi carrier system the transmitted signal exhibit high PAPR which reduces the efficiency of high power amplifier and degrades the system performance. Hence to improve the system performance, it is required to reduce the PAPR. There are different PAPR reduction techniques, which are mainly classified as signal scrambling techniques and signal distortion techniques. Partial transmit sequence

(PTS), selected mapping (SLM), Block coding techniques etc., are signal scrambling techniques and peak windowing, envelope scaling, peak reduction carrier etc., are signal distortion techniques.

The PAPR reduction techniques should be selected by considering the following factors such as, it should create only few harmful side effects such as in-band distortion, out of band radiation, reduced BER degradation, low implementation complexity etc. However, most of the PAPR reduction techniques reduces PAPR at the cost of loss in data rate, increases complexity and transmit signal power etc. PTS is a special case of SLM and also the performance of system using PTS is superior to that of the one using SLM. However, the use of both PTS and SLM increases the implementation complexity at the receiver.

3.7. Analysis of MC-CDMA

Here we discuss about the Bit Error Rate on the MC-CDMA system. After combining the transmitted signals, the CDMA antenna transmits the signals over the wireless media. In receiver side we get the all combing signal with some unexpected signal which is MUI, ICI and Noise signal. So in the receiver side after combining all sub-carrier signals we get the received signal is

X= X_0+X_{mui}+X_{ICI}+X_{noise}……………………………………………………………….… (3.1)

Where,

X_0= wanted signal;

X_{mui}=multi-user interference (due to imperfect restoration of the sub-carrier amplitudes);

X_{ICI}= inter-carrier interference (due to crosstalk β_(m,n) between a_n andy_m);

X_{noise}= noise;

We can write the wanted signal as,

X_0=$b_0 \frac{T_S}{N}\left[\sum_{n=0}^{N-1} \beta_{n,n}\, \omega_{n,n} + \sum_{m\neq 0}\sum_{n=0}^{N-1} \beta_{m,n}\, \omega_{n,n} C_0[n]C_0[n,m]\right]$………………………….. (3.2)

Where,

N = number of subscriber
n = subscriber number
$\beta_{n,n}$= crosstalk between the user
T_S= Sampling time
$\omega_{n,n}$= weight factors which is constant
$C_0[n]C_0[n,m]$= orthogonal spreading codes

The variance of X_0became zero for large number of, i.e., the system working like non fading channel.

The multi-user interference signal is

X_{muI}=$T_S \sum_{K-1}^{N-1} b_k \left[\sum_{n=0}^{N-1} \beta_{n,n}\, \omega_{n,n} C_0[n]C_k[n]\right]$ …………………………………………….. (3.3)

We can write the X_{MUI} as

$X_{MUI} = T_S \sum_{K-1}^{N-1} b_k \left[\sum_{n\in A_+} \beta_{n,n}\, \omega_{n,n} C_0[n]C_k[n] - \sum_{n\in A_-} \beta_{n,n}\, \omega_{n,n}\right]$ ……………………… (3.4)

Where,

A_-=$\{n: c_j[n]C_k[n] = {}^{-1}/_{N}\}$ is the sets of orthogonal code of the sub career index n

A_+=$\{n: c_j[n]C_k[n] = {}^{1}/_{N}\}$= is the sets of orthogonal code of the sub career index

$A_+ \cup A_-$=A is the value of $\sum A_+ \cup A_-\, c_j[n]C_k[n]$ =0

So the variance of MUI,

σ_{mui}^2=E_{ch}E $X_{MUI}X_{mui}^*$ = $\frac{(N-1)}{N^2} T_s \left[E_{ch}\left(\sum_{n\in+} \beta_{n,n}\, \omega_n\right)^2 + E_{ch}\left(\sum_{n\in A_-} \beta_{n,n}\, \omega_n\right)^2 - 2E_{ch}\left(\sum_{n\in A_+} \beta_{n,n}\, \omega_n\right) \times\right.$ $\left.\left(\sum_{n\in A_-} \beta_{n,n}\, \omega_n\right)\right]$ ………………………………………………. (3.5)

If we may assume that fading of the sub-carriers is independent, we can write

$E_{ch}\left(\sum_{n\in A_+} \beta_{n,n}\, \omega_n\right)^2$=$\frac{N}{2} M_{22}$ +$\frac{N}{2}\left(\frac{N}{2} - 1\right) M_{11}^2$ ……………………………………………… (3.6)

$E_{ch}\left(\sum_{n\in A_+} \beta_{n,n}\, \omega_n\right) \times \left(\sum_{n\in A_-} \beta_{n,n}\, \omega_n\right)$=$\left(\frac{N}{2}\right)^2 M_{11}^2$ …………………………………………..(3.7)

Where

m_{11}=E$^{\beta_{n,n}^2}/_{N_0}$=$^{p_0}/_{n_0}$

M_{22}= E$^{\beta_{n,n}^4}/_{N_0^2}$ = 2$^{P_0^2}/_{N_0^2}$

P_0= power of the signal

N_0= power of the noise signal

After simplify all the equation we get the variance,

σ_{mui}^2=$\frac{(N-1)}{N} T_S^2 (M_{22} + M_{11}^2)$ ……………………………………………………… (3.8)

X_{ICI}=$T_S \sum_{n=0}^{N-1} a_n \sum_{\Delta\neq 0} \beta_{n+\Delta,n}\, \omega_{n+\Delta,n+\Delta} C_0[n+\Delta]$ …………………………….......... (3.9)

Here,

Δ = distance of signal between two subscribers,

Now after putting

a_n=$\sum_k c_k\, [n]b_k$ in the equation

X_{ICI}=$\sum_{\Delta\neq 0}\sum_{n=o}^{N-1}\sum_{k=0}^{N-1} b_k\, C_k[n]\beta_{n\Delta,n} \times \omega_{n+\Delta,n+\Delta}C_0[n+\Delta]$……………………………….……. (3.10)

So, the variance of ICI

σ_{ICI}^2=E_{ch}E$X_{ICI}X_{ICI}^*T_S^2E_{ch}E\left[\sum_{m=o}^{N-1}\sum_{k=1}^{N-1} b_k\beta_{m,n}\omega_n\, C_0(n)C_k(n-m)\right]^2$……………………..…. (3.11)

After simplify the equation we get the variance

σ_{ICI}^2=$\sum_{\Delta\neq 0} p_\Delta\, m_{02}T_S^2$ ……………………………………………………………………... (3.12)

Where m_{02} = E$^{\beta_{n,n}^2}/_{N_0^2}$ =$^{p_0}/_{N_0^2}$

p_Δ= variation of the signal power between of any two subscriber

The variance of the noise collected over all sub-carriers weighted by $\omega_{n,n}$ becomes

σ_{noise}^2=N$m_{02}N_0T_S$ ……………………………………………………………..……….. (3.13)

Now

$$\frac{E_N}{E_o} = \frac{(M_{11}T_S)^2}{\sigma^2{}_{ICI}+\sigma^2{}_{MUI}+\sigma^2{}_{noise}} = \frac{M^2{}_{11}}{\left|(M_{22}+M^2{}_{11})+M_{02\left[\sum_{\Delta\neq 0} P_\Delta+\frac{N_0}{T_S}\right]}\right|} \quad \text{……………… …………………} \quad (3.14)$$

Since we consider many different channels, x_{MUI}, x_{ICI} and x_{noise} are zero-mean complex Guassian. So BER is,

$B = \frac{1}{2}\, erfc\sqrt{\frac{E_N}{N_o}}$…………………………………………………………………………... (3.15)

CHAPTER FOUR

4. IMPLEMENTATION OF THE PROJECT

Implementation techniques with spread spectrum communications systems have led to the idea of code division multiple access. In other words, we cannot talk about with code division multiple access without also discuss the principles of spread spectrum. Spread spectrum transmission signal occupying a bandwidth in excess of the minimum necessary to transmit information. Band scattering is achieved by means of a code that is independent of the data. Dispreading and then data recovery is done using the same code used to broadcast that synchronizes reception. CDMA protocols are a class of protocols in which multiple access capability is achieved through encoding.

4.1. MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran. In this work, 2016a version of MAT LAB is used.

4.2. Walsh Code

Walsh codes are mutually orthogonal error correcting codes. They have many interesting mathematical properties and vital applications in communication systems. Pseudo random sequences play an important role in encoding of messages for efficient transmission of messages. Further, many encryption schemes use pseudo random sequences. They are easily implemented in hardware as well as software.The Walsh code is a linear code which maps binary strings of length 'n' to binary code words of length 2n. Further these codes are mutually orthogonal.

4.3. Hadmard Matrix

Hadmard transform is applied on a zero matrix in order to obtain the Hadmard matrix. Every row and column of the Hadmard matrix is a walsh code of length n.

Example of a Hadmard matrix: $H_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$

A Hadamard matrix H of order n is an n × n matrix of 1s and -1s in which HHT = nIn. (In-is the n×n identity matrix). For Walsh codes, we use an Hadamard matrix of the order 2N. Hadamard matrices are conjectured to exist for all orders which are multiple of 4. Walsh codes can be generated from Hadamard matrices of orders which are a power of 2. The rows of the matrix of order 2N constitute the Walsh codes which encodes N bit sequences. Now, instead of 1 and -1 consider 1 and 0. That is considering the matrix and the codes over the field F2 or modulo 2.

Since Walsh codes is a linear code, there exist a generator or a transformation matrix for the same. Consider the following n×2n generator matrix for encoding bit strings of length n:

$$G_n = \begin{pmatrix} \uparrow & \uparrow & & \uparrow \\ g_0 & g_1 & \cdots & g_{2^{n-1}} \\ \downarrow & \downarrow & & \downarrow \end{pmatrix}$$

Where, g_(i)∈{0,1}^n is the binary representation of i. Walsh code WC (x)=x.G_n . For instance, Generator matrix for n=2 is given by

$$G_n = \begin{pmatrix} 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \end{pmatrix}$$

Notice that, G_n is in fact a basis 2 for H.2n

4.4. Additive white Gaussian noise(AWGN)

Additive white Gaussian noise (AWGN) is one of the most utilized channel models. The noise parameter that is added in AWGN is a white noise with spectral density that is relatively constant and amplitude which follows a Gaussian distribution.

The channel does not take in to account channel impairment parameters like fading, interference or dispersion. However, it generates simple mathematical models that can be used to study the behavior of a system without involving other phenomena.

The capacity C for AWGN channel is given as:

$$\frac{C}{B} = log_2 \frac{E_b}{\eta} \frac{C}{B} \qquad \text{4.1}$$

4.5. Rayleigh Fading Channel

Rayleigh fading models are bases on the assumption that after the passage through a transmission media, the signal magnitude will fade randomly according to a Rayleigh distribution. This model is most effective when no line of sight component exists between the receiver and transmitter.

Here the amplitude of channel fading given by 'a' is distributed as:

$$p_\alpha(\alpha) = \frac{2\alpha}{\Omega}\ exp\left(-\frac{\alpha^2}{\Omega}\right), \alpha \geq 0 \qquad \text{4.2}$$

CHAPTER FIVE

5. RESULT AND DISCUSSION

The system parameters:

N- number of subscribers (users)

BER- The amount of transferred data bit per second.

SNR or En/No- signal to noise ratio

σ^2MUI- Variance of multi-user interference

σ^2ICI- Variance of inter-carrier interference

Power of signal

L- code-length

Common Values Taken for below results

N=16, L=16, bit rate (Rb= 10000)

Noise power, No=10Mw

In this project, number of users and amount of powers used are assumed.

1. Variance of Multicarrier interference (σ^2MUI) versus Number of user(N)

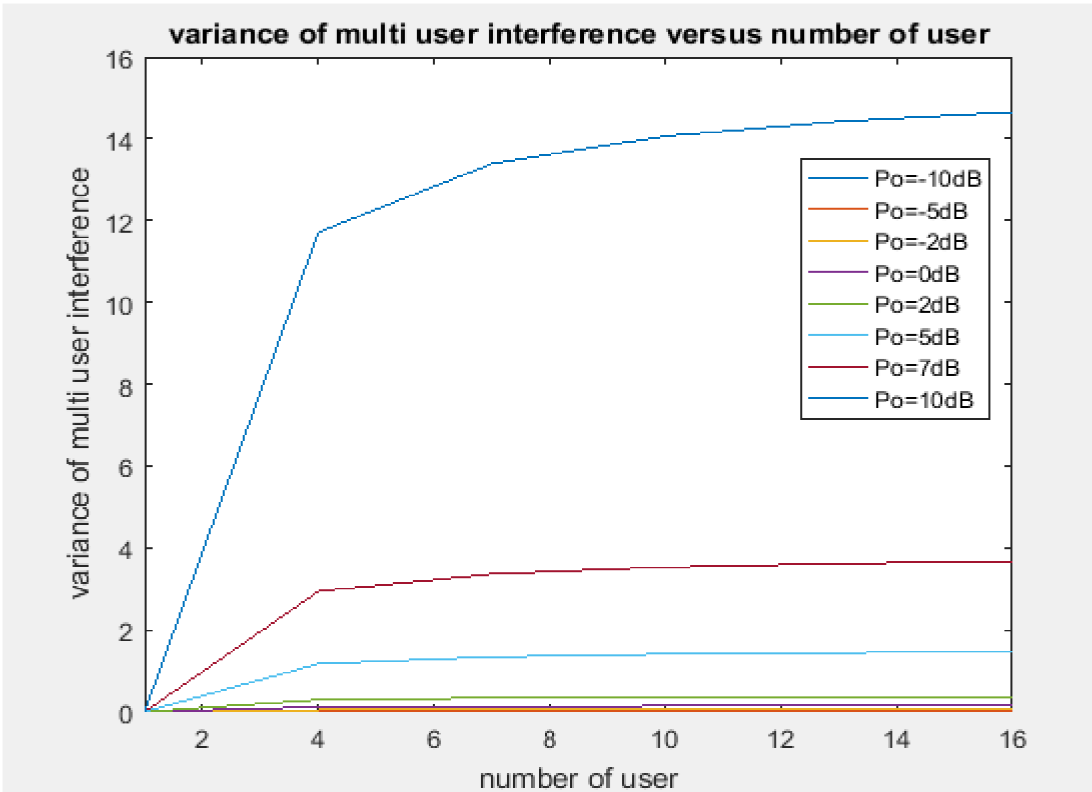

Figure 5.1Variance of multiuser interface versus number of user

We see that if we increase the number of user then the interference between different user increases. The variance of the multi user interference depends on signal power. If we increase the power, then the interference increases gradually. For example, in this graph variance of MUI for 10dB power is very high and it is more than 14. Whereas, for low power like 5dB variance of MUI is less than 2 dB. And it is close to zero for very low power like -10dB.

2. Variance of Inter-carrier interference (σ^2ICI) versus Number of subscriber (N)

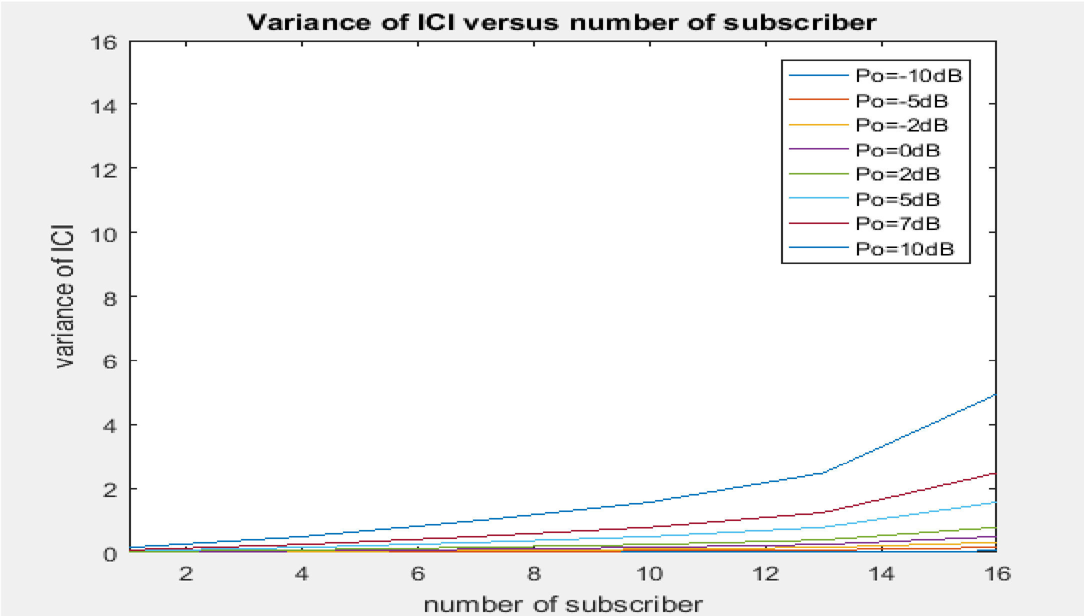

Figure 5.2 Variance of ICI versus number of user

The figure shows that, if we increase the number of user, then the variance of ICI increase. The variance of the ICI also depends on the signal power. If power is low, then the interference between the carrier is very low but when we increase the power then the inter carrier interference also increase and that case the crosstalk between the sub carrier occurs very rapidly.

3. E_N/N_O versus number of user (N)

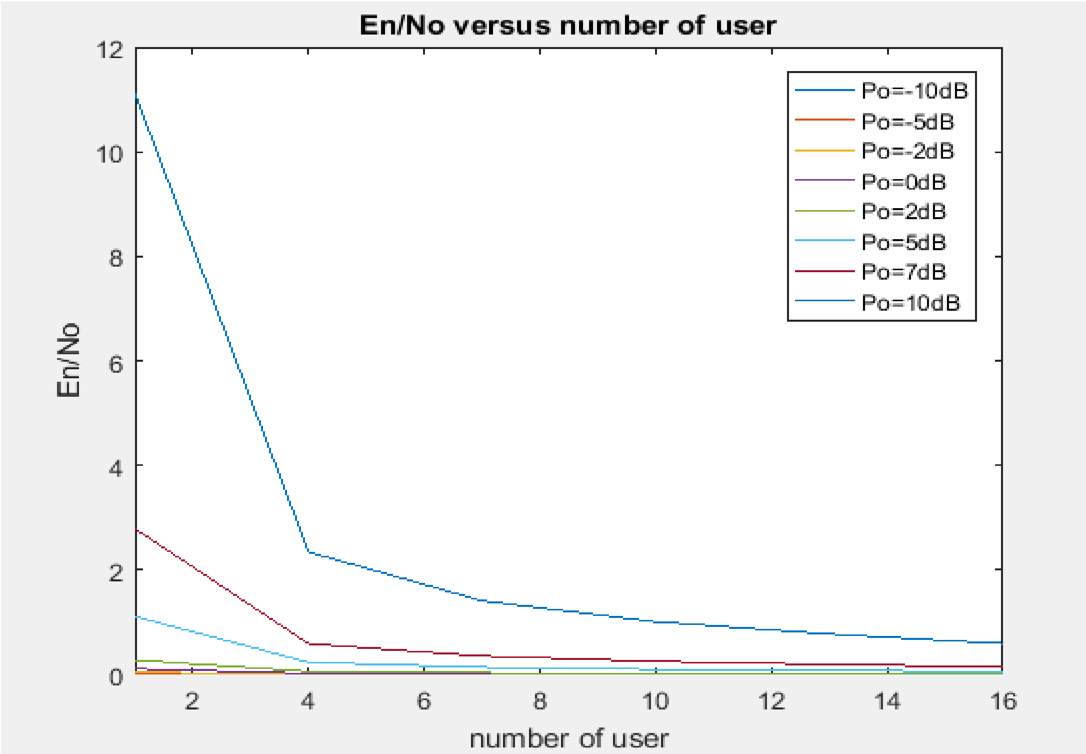

Figure 5.3 E_N/N_O versus number of user

E_N/No have an inverse relationship with no of subscriber. If we increase number of user, then E_N/No decreases. As a number of users increases, then the power of signal becomes decreases w.r.t En/No. But, we need high En/No and power in wireless communication, otherwise there is fading at somewhere in the channel.

4. BER versus E_N/N_O

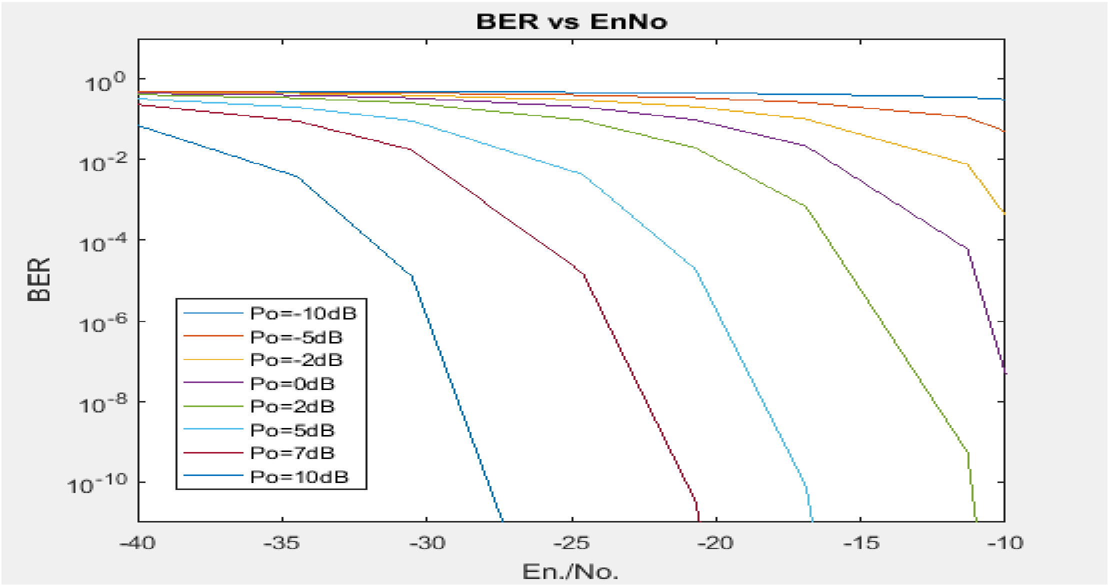

Figure 5.4 BER versus E_N/N_O

BER decreases with respect to E_N/No for a particular signal power. If signal power is very high, then BER decrease rapidly with respect to E_N/No. But if signal power is very low, then BER decreases very slowly with respect to E_N/No. We prefer lower BER in Wireless communication system and that's why we should use high signal power.

5. Code Length(L) versus number of subscriber (N)

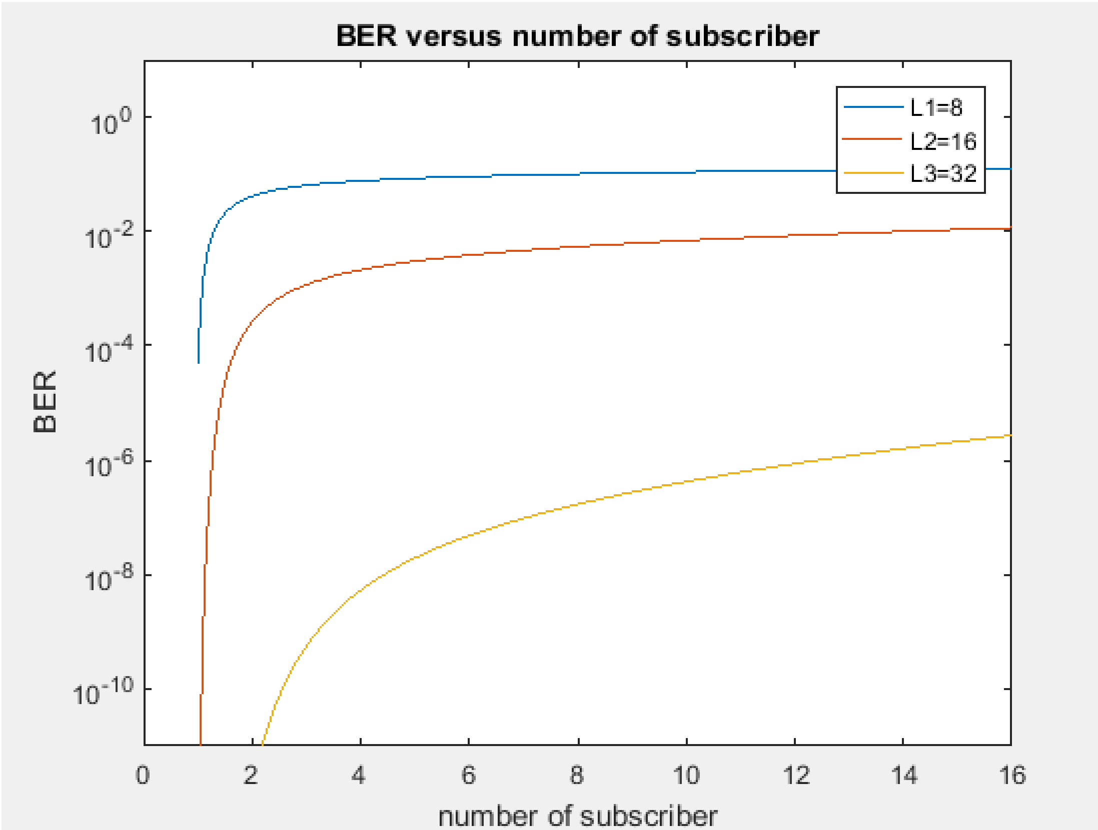

Figure 5.5 Code Length versus number of subscriber

The figure shows that as we increase the code length then system BER become decreases, this results that some optimization of our system. The other point is that, for a large code length we have to gate small BER and large number of users can access the channel. This two points are describing the modification of our systems.

CHAPTER SIX

6. CONCLUSION AND FUTURE WORK

6.1. Conclusion

In this paper, we have used some basic equation to find out our expected results. No new equation was derived on this paper. We saw the performance result for Multi-user interference and Inter carrier interference for certain number of user. If we increase the user, then the MUI and ICI occurs more and more. By BER versus ratio of Energy of bit and Noise density analysis we saw that if we increase the value of EN /No, then the BER became low. In communication system, we can't prefer high BER. If BER is low, then the channel can transfer the signal more perfectly. We also saw that how can the Code length affect the user capacity in the system. For a particular accepted BER, we can easily serve more number of users if the code length is high. In this project, the selected preferable optimum power from the power range [-10,10] dB is 5 dB. The major problem of MC-CDMA is Multi carrier interference and inter carrier interference occur. We saw that in CDMA system due to code difference between the users they can easily share the same frequency. That's why the capacity of serving user easily can increase.

6.2. Future work

- Further research can be carried out on MC-CDMA system considering the effect of fading and frequency offset between the sub-carriers in the receiver.
- Work can be carried out to find the improvement in BER performance while using Rake Receiver to combat the effect of fading and delay spread.
- Works can be initiated to find optimum user code length for a given number of users in a MC-CDMA system in presence of channel effects.

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APPENDIX

MATLAB code:

Matlab Code for Variance of Multi user interference versus number of user:

```
clc

clear all

close all

N=1:3:23;

N0=10^-6;

Rb=10000;

L=8;

P0dB=[-10 -5 -2 0 2 5 7 10 ];

for s=1:length(P0dB)

P0(s)=10.^(P0dB(s)./10);

end

Tb=1./Rb;

Eb=P0.*Tb;

SNR=Eb./N0;

M11=P0/N0;

M02=P0/N0^2;

M22=2*P0.^2/N0.^2;

Pdel=0.1*P0;

Ts=Tb/L;

for j=1:length(SNR)

for i = 1:length(N)

sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts.^2*(M22(j)-M11(j).^2));
```

```
end
SMUI(:,j)=sMUI;
end
Smui=(SMUI.^2)./1000;
for k=1:length(Pdel);
for l = 1:length(SNR);
sICI(l)=sqrt((Pdel(k).*M02(l)).*Ts.^2);
snoise(l)=sqrt(N(l).*(M02(k).*N0).*Ts);
end
SICI(:,k)=sICI;
Snoise(:,k)=snoise;
end
format long
for y=1:length(P0);
for z = 1:length(P0)
EN(z)=(N0*(M11(y).^2.*Ts.^2))./(SICI(z).^2+SMUI(z).^2+Snoise(z).^2);
end
En(:,y)=EN;
En1(:,y)=EN/N0;
EndB(y)=10*log10(En1(y));
end
Sici=(SICI.^2)./100;
en=En1./1000;
BER=(1./2)*erfc(sqrt(En./N0));
plot(N,Smui)
```

axis([1 16 0 16])

legend('Po=-10dB','Po=-5dB','Po=-2dB','Po=0dB','Po=2dB','Po=5dB','Po=7dB','Po=10dB',8)

MATLAB Code for Inter carrier Interference versus Number of user:

```
clc
clear all
close all
N=1:3:23;
N0=10^-6;
Rb=10000;
L=8;
P0dB=[-10 -5 -2 0 2 5 7 10 ];
for s=1:length(P0dB)
P0(s)=10.^(P0dB(s)./10);
end
Tb=1./Rb;
Eb=P0.*Tb;
SNR=Eb./N0;
M11=P0/N0;
M02=P0/N0^2;
M22=2*P0.^2/N0.^2;
Pdel=0.1*P0;
Ts=Tb/L;
for j=1:length(SNR)
for i = 1:length(N)
sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts.^2*(M22(j)-M11(j).^2));
```

```
end
SMUI(:,j)=sMUI;
end
Smui=(SMUI.^2)./1000;
for k=1:length(Pdel);
for l = 1:length(SNR);
sICI(l)=sqrt((Pdel(k).*M02(l)).*Ts.^2);
snoise(l)=sqrt(N(l).*(M02(k).*N0).*Ts);
end
SICI(:,k)=sICI;
Snoise(:,k)=snoise;
end
format long
for y=1:length(P0);
for z = 1:length(P0)
EN(z)=(N0*(M11(y).^2.*Ts.^2))./(SICI(z).^2+SMUI(z).^2+Snoise(z).^2);
end
En(:,y)=EN;
En1(:,y)=EN/N0;
EndB(y)=10*log10(En1(y));
end
Sici=(SICI.^2)./100;
en=En1./1000;
BER=(1./2)*erfc(sqrt(En./N0));
plot(N,Sici)
```

```
axis([1 16 0 16])
legend('Po=-10dB','Po=-5dB','Po=-2dB','Po=0dB','Po=2dB','Po=5dB','Po=7dB','Po=10dB',8)
```

MATLAB Code for En/No versus Number of user:

```
clc
clear all
close all
N=1:3:23;
N0=10^-6;
Rb=10000;
L=8;
P0dB=[-10 -5 -2 0 2 5 7 10 ];
for s=1:length(P0dB)
P0(s)=10.^(P0dB(s)./10);
end
Tb=1./Rb;
Eb=P0.*Tb;
SNR=Eb./N0;
M11=P0/N0;
M02=P0/N0^2;
M22=2*P0.^2/N0.^2;
Pdel=0.1*P0;
Ts=Tb/L;
for j=1:length(SNR)
for i = 1:length(N)
sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts.^2*(M22(j)-M11(j).^2));
```

```
end
SMUI(:,j)=sMUI;
end
Smui=(SMUI.^2)./1000;
for k=1:length(Pdel);
for l = 1:length(SNR);
sICI(l)=sqrt((Pdel(k).*M02(l)).*Ts.^2);
snoise(l)=sqrt(N(l).*(M02(k).*N0).*Ts);
end
SICI(:,k)=sICI;
Snoise(:,k)=snoise;
end
format long
for y=1:length(P0);
for z = 1:length(P0)
EN(z)=(N0*(M11(y).^2.*Ts.^2))./(SICI(z).^2+SMUI(z).^2+Snoise(z).^2);
end
En(:,y)=EN;
En1(:,y)=EN/N0;
EndB(y)=10*log10(En1(y));
end
Sici=(SICI.^2)./100;
en=En1./1000;
BER=(1./2)*erfc(sqrt(En./N0));
plot(N,en)
```

```
axis([1 16 0 12])

legend('Po=-10dB','Po=-5dB','Po=-2dB','Po=0dB','Po=2dB','Po=5dB','Po=7dB','Po=10dB',8)
```

Matlab Code for BER versus EnNo:

```
clc

clear all

close all

N=1:3:25;

N0=10^-6;

Rb=10000;

L=8;

P0dB=[-10 -5 -2 0 2 5 7 10];

for s=1:length(P0dB)

P0(s)=10.^(P0dB(s)./10);

end

Tb=1./Rb;

Eb=P0.*Tb;

SNR=Eb./N0;

M11=P0/N0;

M02=P0/N0^2;

M22=2*P0.^2/N0.^2;

Pdel=0.1*P0;

Ts=Tb/L;

for j=1:length(SNR)

for i = 1:length(N)

sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts.^2*(M22(j)-M11(j).^2));
```

```
end
SMUI(:,j)=sMUI;
end
Smui=(SMUI.^2)./1000;
for k=1:length(Pdel);
for l = 1:length(SNR);
sICI(l)=sqrt((Pdel(k).*M02(l)).*Ts.^2);
snoise(l)=sqrt(N(l).*(M02(k).*N0).*Ts);
end
SICI(:,k)=sICI;
Snoise(:,k)=snoise;
end
SICI;
format long
for y=1:length(P0);
for z = 1:length(P0)
EN(z)=(N0*(M11(y).^2))./(((M22(z)-(M11(z).^2))+M02(z).*(Pdel(z)+(N0./Ts))));
end
En(:,y)=EN;
En1(:,y)=EN/N0;
EndB(y)=10*log10(En1(y));
end
BER=(1./2)*erfc(sqrt(En./N0));
semilogy(EndB,BER)
axis([-40 -10 10e-12 10e-0])
```

legend('Po=-10dB','Po=-5dB','Po=-2dB','Po=0dB','Po=2dB','Po=5dB','Po=7dB','Po=10dB',8)

MATLAB Code for BER vs Number of user:

```
clc
clear all
close all
P0=10;
N=1:0.05:16
N0=10^-6;
Rb=10000
;Tb=1/Rb;
L=[32 16 8]
for a=1:length(L)
Ts(a)=Tb/L(a)
end
Eb=P0*Tb;
SNR=Eb/N0;
M11=P0/N0;
M02=P0/N0^2;
M22=2*P0.^2/N0.^2;
Pdel=0.1*P0;
for j=1:length(L);
for i = 1:length(N);
sMUI(i)=sqrt(((N(i)-1)/N(i))* Ts(j)^2*(M22-M11^2));
end
SMUI(:,j)=sMUI;
```

```
end
for k=1:length(L);
for l = 1:length(N);
sICI(l)=sqrt((Pdel.*M02)*Ts(k)^2);
snoise(l)=sqrt(N(l).*(M02*N0)*Ts(k));
end
SICI(:,k)=sICI;
Snoise(:,k)=snoise;
end
format long
for y=1:length(L);
for z = 1:length(N);
EN(z)=(N0*(M11^2*Ts(y)^2))/(SICI(z)^2+SMUI(z)^2+Snoise(z)^2);
end
En(:,y)=EN;
En1(:,y)=EN/N0;
end
BER=(1/2)*erfc(sqrt(En1))
semilogy(N,BER)
axis([0 16 10e-12 10e-0])
legend('L1=8','L2=16','L3=32',3)
```