

SPREAD SPECTRUM ANALYSIS FOR CDMA SYSTEM

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF**

Bachelor of Technology in Electronics & Communication Engineering

BY

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**DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769008**

2010

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Under the guidance of
Associate Prof. (Mrs.) Poonam Singh



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2010

CERTIFICATE

This is to certify that the thesis entitled “**Spread Spectrum Analysis For CDMA system**” submitted by *Mangat Prasad Soren* (Roll No. **10609018**) in partial fulfillment of the requirements for the award of *Bachelor of Technology* in the department of Electronics & Communication Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

Place: Rourkela
Date:
Department

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ACKNOWLEDGEMENT

It gives me immense pleasure to express my deep sense of gratitude to my supervisor **Associate Prof. (Mrs.) Poonam Singh** for her invaluable guidance, motivation, constant inspiration and above all her ever co-operating attitude enabled me in bringing up this thesis in present elegant form.

I am extremely thankful to **Prof. S. K. Patra**, Head, Department of Electronics & Communication Engineering and the faculty members of Electronics & Communication Engineering Department for providing all kinds of possible help and advice during the course of this work.

It is a great pleasure for me to acknowledge and express my gratitude to my parent for their understanding, unstinted support and endless encouragement during my study.

I am greatly thankful to all the staff members of the department and all my well wishers, class mates and friends for their inspiration and help.

Lastly I sincerely thank to all those who have directly or indirectly helped for the work reported herein.

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ABSTRACT

CDMA is technology for digital transmission of radio signal in telecommunication systems. In this technology, multiple users can transmit the data simultaneously in a channel using same frequency. Each user is assigned a distinguished code for transmission. There are different codes are used for this purpose. Here, PN sequence, Gold sequence and Walsh code are generated using Matlab Programming. Using Walsh code, the data was transmitted to receiver in AWGN and Fading channels. Here, transmitted data is generated randomly using matlab function. During transmission, SNR values of signal changes to calculate BER value to plot BER vs. SNR graph for both for single user and multi users in AWGN and Fading channel.

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Chapter 1

INTRODUCTION

1. INTRODUCTION

Code Division Multiple Access (CDMA) is used as a multiple access technique in telecommunications radio system that can transport multimedia traffic at high data rates. The communications researchers have studied CDMA and are further developing it. This has come out because of the various reasons which contributed to evolution in wireless technology.

They include:

- Need for highly reliable telecom network and most important and security against eavesdropping and cryptanalysts.
- Implementation of inexpensive data network.
- End users need new services, like new telephony and internet services.
- Explosive growth of data leading to market growth.
- Introduction of new services imposed by technology changes.

MC CDMA networks proposed for fourth generation (4G) system, that will be defined by the ability to integrate heterogeneous networks, especially radio mobile networks and wireless networks, that offers access to all services, all the time and everywhere . Above and beyond, the rapid growth of internet services and the increasing interest in portable computing devices are probable to create a strong demand for high speed wireless data services. Key issues to fully meet these evolution perspectives are based upon the multi-carrier systems which have become popular for their spectral efficiency and robustness against frequency-selective fading. Multi-carrier code division multiple access (MC CDMA) is a technique that combines the advantage of multi-carrier modulation with that of code division multiple access to offer reliable high data rate downlink cellular communication services. It is used as it has proven to be better than conventional CDMA networks, FDMA and TDMA. The eventual real effects and alternative conditions and courses of action of the network need to be thoroughly exploited before the deployment.

1.1. Spread Spectrum

Spread spectrum (SS) techniques are methods in which energy generated at a single frequency is spread over a wide band of frequencies. The basic spread spectrum technique is shown in Figure.1.1 . This is done to achieve transmission that is robust against channel impairments, and to be able to resist natural interference or jamming and to prevent hostile detection. These techniques were developed by military guidance and communication systems. The techniques are said to be spread spectrum if transmission bandwidth is much greater than minimum bandwidth needed transmit information. Bernard Sklar defines the system to be achieving spread spectrum if it fulfills the following requirements:

- Signal occupies bandwidth much in excess of the minimum bandwidth necessary to send information.
- Spreading is accomplished by means of spreading code signal which is independent of the data.
- At the receiver, despreading is accomplished by the correlation of the received spread signal with a synchronized replica of the spreading signal used to spread information.

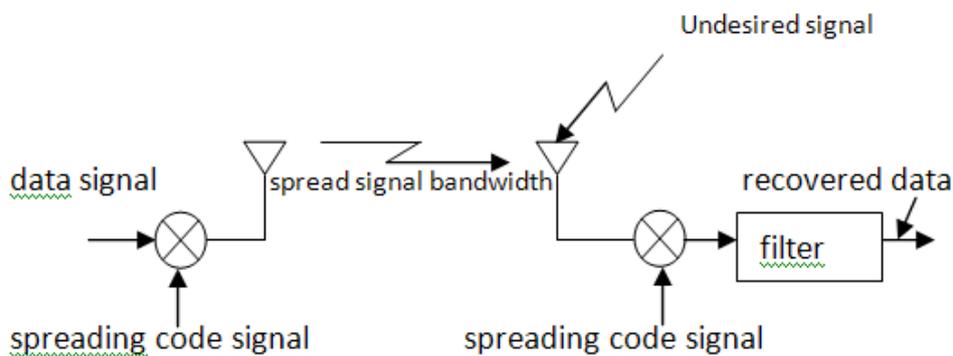


Fig:1.1. Model of basic spread spectrum technique

The SS are able to resist interference and jamming. The bottom center behind interference rejection capability of spread spectrum is achieved by:

- Multiplying signal by spreading signal once spreads the signal bandwidth.
- Multiplying signal by spreading signal twice recovers original signal.
- Desired signal gets multiplied twice and interference gets multiplied only once, and that's makes signal recovering as the noise and information would not be at the same frequencies.

Conventional modulation schemes such as frequency modulation and pulse code modulation also spread the spectrum of an information signal, but they do not qualify as spread spectrum systems since they do not satisfy all the conditions as outlined. Spread spectrum techniques are implemented where transmission has to be operated without information being detected by anyone other than the intended receiver. Communications systems designed for this task are known as low probability of detection (LPD) or low probability of intercept filter (LPI). SS systems that are designed to present LPI may also be designed to expose low probability of position fix (LPPF), thus even if the presence of the signal may be perceived, direction of the transmitter is difficult to pinpoint. They can further be made to expose low probability of signal exploitation (LPSE), meaning that identification of source is difficult to determine. The goal of these systems is to use minimum signal power and optimum signaling scheme that results in minimum probability of being detected, intercepted or demodulated. SS uses wide band, noise-like signals and because the signals are noise-like, they are hard to detect. Further, Spread Spectrum signals are harder to jam than narrowband signals. Spread spectrum techniques use code signal to perform spreading and despreading, and these spreading code signals are called pseudorandom or pseudonoise codes. They are called pseudorandom because they are not random at all; they are deterministic periodic signals that are known to both transmitter and receiver. Though these signals are said to be deterministic, they hold randomness properties and they appear random to unauthorized users. Spread spectrum techniques can be classified into three main categories namely direct sequence spread spectrum, frequency hopping spread spectrum and time hopping spread spectrum and the combination of two of the three techniques.

1.2. Direct Sequence Spread Spectrum

A direct sequence spread spectrum signal is one in which the amplitude of an already modulated signal is amplitude modulated by a high rate NRZ binary stream of digits. Thus, if the original signal is $s(t)$, where

$$s(t) = \sqrt{2P_s}d(t)\cos \omega_0 t$$

(a binary PSK signal), the DS spread spectrum signal is

$$v(t) = g(t)s(t)$$

where $g(t)$ is a pseudo-random noise (PN) binary sequence having the values +1 or -1. A direct sequence system uses a locally generated pseudo noise code to encode digital data to be transmitted. The local code runs at much higher rate than the data rate. The data is logically modulo-2 added with pseudo noise code signal. If the data signal is narrowband compared to the spreading signal, the resulting product signal will have the bandwidth approximated to that one of the spreading signal.

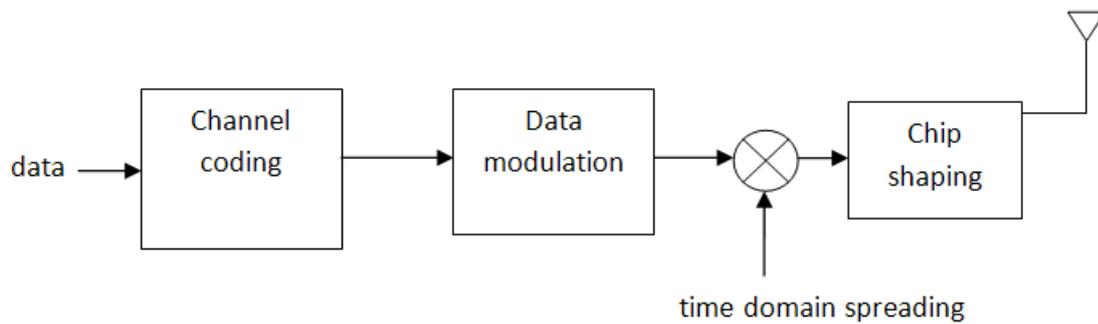
At the receiver direct sequence uses a locally generated replica pseudo noise code and a receiver correlator to separate the desired coded information from all possible signals. The correlator responds only to signals that are encoded with a pseudo noise code that matches its own code.

1.3. Direct Sequence CDMA

Direct sequence (DS) CDMA is used in the third-generation mobile communication standard to provide high capacity and high transmission rate over conventional schemes such as frequency division multiple access and time-division multiple access. However, due to inherent wide bandwidth of the spread spectrum systems, severe frequency selective fading degrades system performances. When transmitting data in the downlink, DS CDMA relies on the orthogonality of the spreading codes to separate the different user signals.

However, it suffers from inter channel interference (ICI) and it destroys the orthogonality among users, giving rise to Multi User Interference (MUI). Since the multi user interference is in actual fact caused by the multipath channel, it can be suppressed by linear chip level equalization, followed by correlation with the user's spreading code.

Transmitter Model:



Receiver Model:

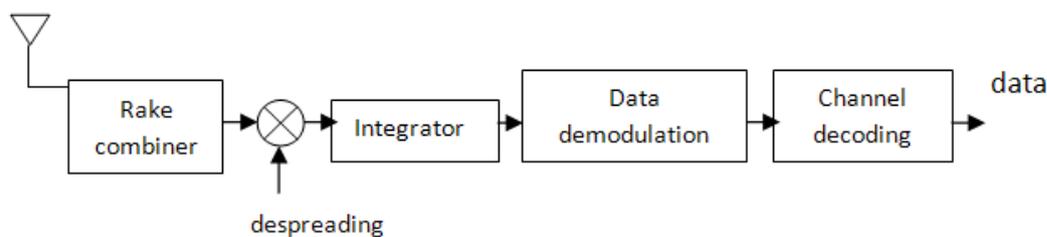


Fig:1.2. Transmitter and receiver model of CDMA system

At the transmitter, the information is encoded using codes. The encoded information is then transformed into a data modulated symbol sequence with a baseband modulator. The modulated symbol sequence is spread in time domain by a chip sequence of orthogonal code generator, usually Walsh code and PN sequence. The information is shaped and passed through a channel for transmission. At the receiver, the information is multiplied with the chip sequence by the correlators in the rake receiver. The information is then summed and multiplied by local generated spreading code, which is despreading. The information is demodulated and decoded and original data can be recovered.

1.4. Code Division Multiple Access

Code Division Multiple Access is a technology for digital transmission of radio signals in telecommunications systems. It can be both synchronous and asynchronous. In CDMA, each user is assigned a distinguished code and multiple users can transmit data simultaneously using same frequency. They are distinguished by their codes.

The idea of CDMA was originally developed for military use developed by Allies in World War II.

In a traditional hard handoff, the connection to the current cell is broken and then the connection to the new cell is made. Since CDMA uses the same frequency, the connection to the new cell site can be made without breaking the connection of the current cell which is known as soft handoff. Soft handoff requires less power, which reduces interference and increases capacity. The network chooses one or more alternative sites that it feels are handoff candidates while a call is in progress. It simultaneously broadcasts a copy of the call in each of these sites. It can then choose one of the sites and can move between them whenever it feels like it. This puts the phone in complete control of the handoff process.

These are the following features of the CDMA technology:-

- The technology allows multiple calls to be carried over one channel.
- It is used as a multiplexing platform and offers the opportunities to be improved.
- It is considered efficient and secure technology as it provides communications privacy since transmission cannot be interpreted by unauthorized users without code.
- Operates at lower power level.
- The technology is more robust to fading channels.
- Spread spectrum techniques used affords the jamming resistance.

Advantages of CDMA:

One of the main advantages of CDMA is that dropouts occur only when the phone is at least twice as far from the base station. Thus it is used in the rural areas where GSM cannot cover. Another advantage is its capacity; it has a very high spectral capacity that it can accommodate more users per MHz of bandwidth. It uses a EVRC for noise reduction where the background noise is reduced. This is exclusively available in CDMA technology only.

Disadvantages of CDMA:

One major problem in CDMA technology is channel pollution, where signals from too many cell sites are present in the subscriber's phone but none of them is dominant. When this situation arises the quality of the audio degrades. Another disadvantage in this technology when compared to GSM is the lack of international roaming capabilities. The ability to upgrade or change to another handset is not easy with this technology because the network service information for the phone is put in the actual phone unlike GSM which uses SIM card for this. One another disadvantage is the limited variety of the handset, because at present the major mobile companies use GSM technology.

1.5. Fading

Small-scale fading or fading is used to describe the rapid fluctuations of the amplitudes, phases or multipath delays of a radio signal over a short period of time or travel distance, so that large-scale path loss effects may be ignored. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These waves, called multipath waves, combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal.

Multipath in the radio channel creates small-scale fading effects. The three most important effects are:

- Rapid changes in signal strength over a small travel distance or time interval.
- Rapid frequency modulation due to varying Doppler shifts on different multipath signals.
- Time dispersion (echoes) caused by multipath propagation delays.

Factors Influencing Small-Scale Fading

- **Multipath propagation**--The presence of reflecting objects and scatterers in the channel creates a constantly changing environment that dissipates the signal energy in amplitude, phase, and time. These effects result in multiple versions of the transmitted signal that arrive at the receiving antenna, displaced with respect to one another in time and spatial orientation. The random phase and amplitudes of the different multipath components cause fluctuations in signal strength, and causes small-scale fading and signal distortion.
- **Speed of the mobile**--The relative motion between the base station and the mobile results in random frequency modulation due to different Doppler shifts on each of the multipath components.
- **Speed of surrounding objects**--If objects in the radio channels are in motion, they induce a time varying Doppler shift on multipath components. If the surrounding objects move at a greater rate than a mobile, then this effect dominates the small-scale fading.
- **The transmission bandwidth of the signal**—If the transmitted radio signal bandwidth is greater than the bandwidth of the multipath channel, the received signal will be distorted, but the received signal strength will not fade much over a local area.

Rayleigh fading Distribution

In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution.

The Rayleigh distribution has a probability density function (pdf) given by

$$p(r) = \frac{r}{a^2} \exp(-r^2/(2a^2))$$

Where a is the rms value of the received voltage signal before envelope detection and a^2 is the time-average power of the received signal before envelope detection.

Chapter 2

PROPOSED WORK

2. PROPOSED WORK

The objective of project is to study and analysis the spread spectrum application for CDMA systems. This includes

- Generation of various codes like PN codes, Gold codes, Walsh codes.
- Using these codes, a CDMA system is to be designed.
- Analysis of spread spectrum by using Walsh code.
- To design CDMA systems for both single and multi users.
- Introduced coded transmitted signal through AWGN channel.
- Plot BER vs. SNR graphs for both AWGN and fading channel.

Chapter 3

WORK DONE

3.1. Generation of Codes

3.1.1. PN Sequence Generation

A piece of hardware which is widely used to generate PN sequences is shown in figure.3.1. It consists initially of a shift register. We have selected D-type flip-flops and arranged that each data input except D_0 is the Q output of the preceding flip-flop. The input D_0 is the output of the parity generator. A parity generator is generally constructed of an array of exclusive-or logic gates. The character of the PN sequence generated depends on the number N of flip-flops employed and on the selection of which flip-flop outputs are connected to the parity generator.

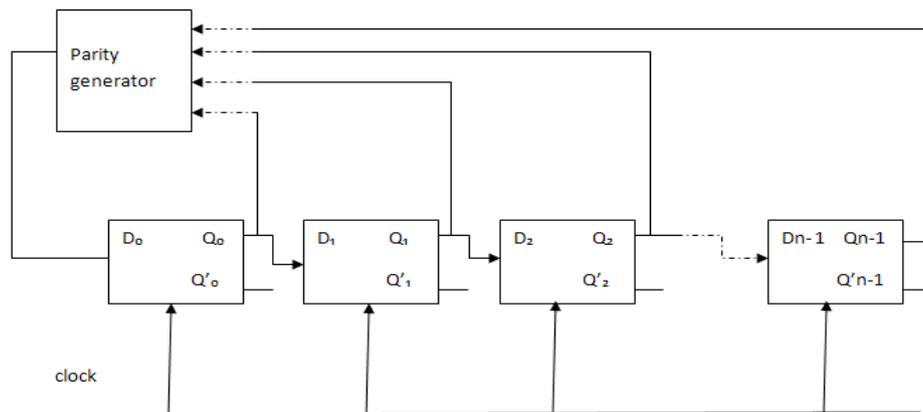


Figure: 3.1. PN sequence generator

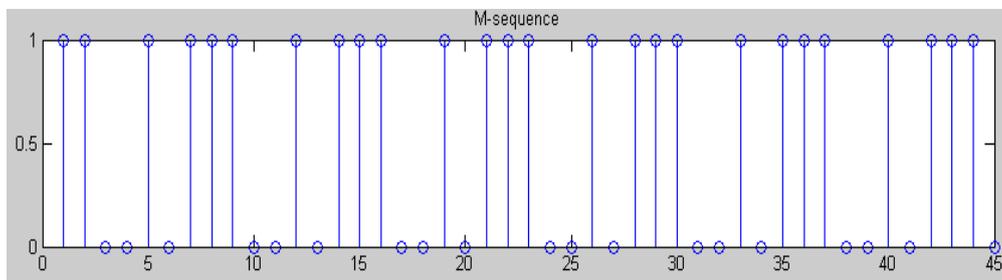


Figure:3.2. Output of PN sequence generation using matlab

3.1.2. Gold Sequence Generation

Gold sequences have been proposed by Gold in 1967 and 1968. These are constructed by EXOR-ing two PN sequences of the same length with each other.

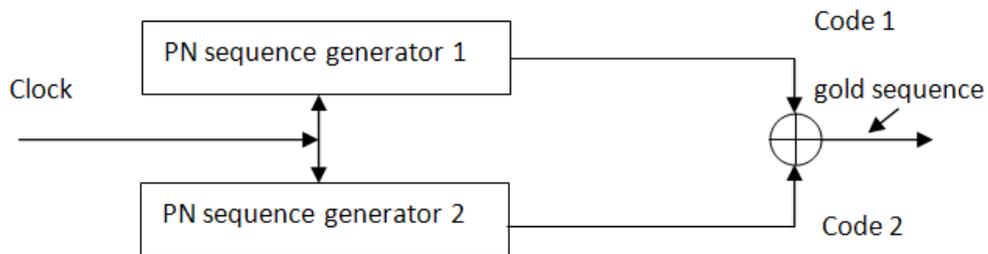


Figure:3.3. Gold sequence generator

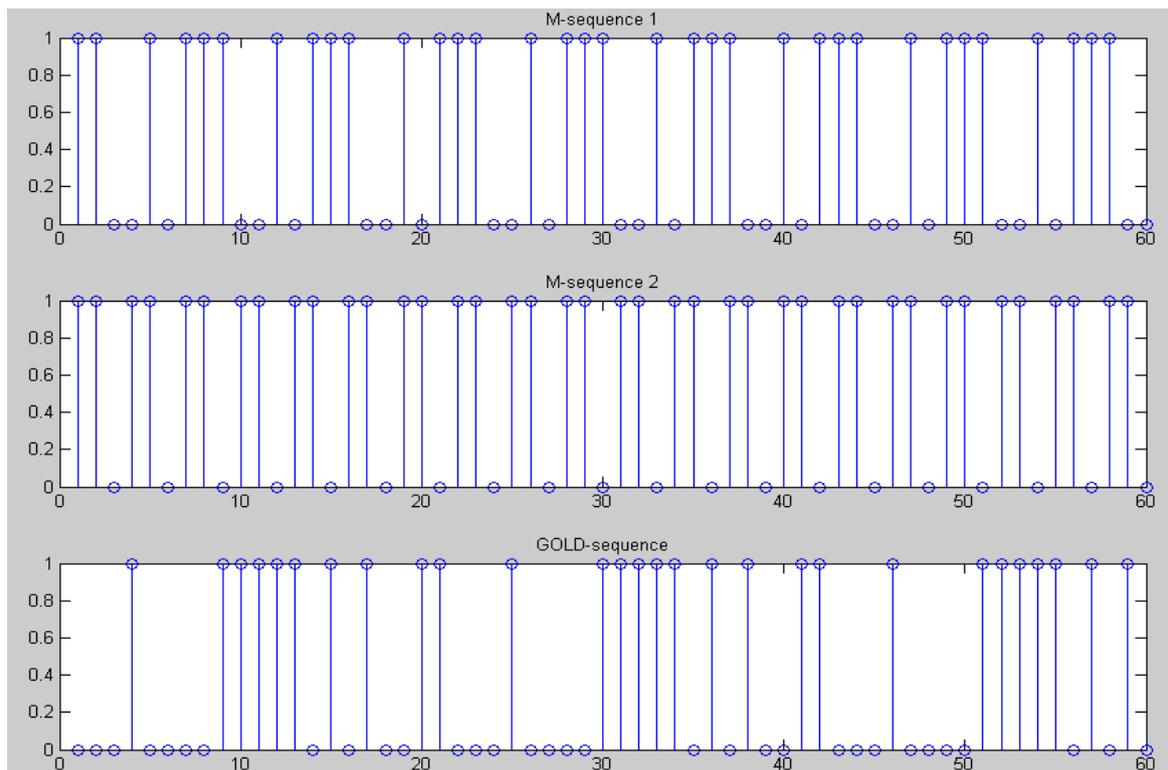


Figure:3.4. Output of gold sequence generation using matlab

3.1.3. Walsh Code Generation

The Hadamard code, named after Jacques Hadamard, is a system used for signal error detection and correction. It is one of the family of $[2^n, n + 1, 2^{n-1}]$ codes. Especially for large n it has a poor rate but it is capable of correcting many errors. Hadamard codes can be considered as a special case of Reed–Muller codes. In particular, first order Reed–Muller code is equivalent to Hadamard codes. These Hadamard codes are called Walsh codes.

:

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad H_4 = \begin{bmatrix} -1 & -1 \\ -1 & 1 \end{bmatrix} \quad H_{2n} = \begin{bmatrix} H & H \\ H & H^* \end{bmatrix}$$

$$W = H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$$

8 X 8 Walsh code

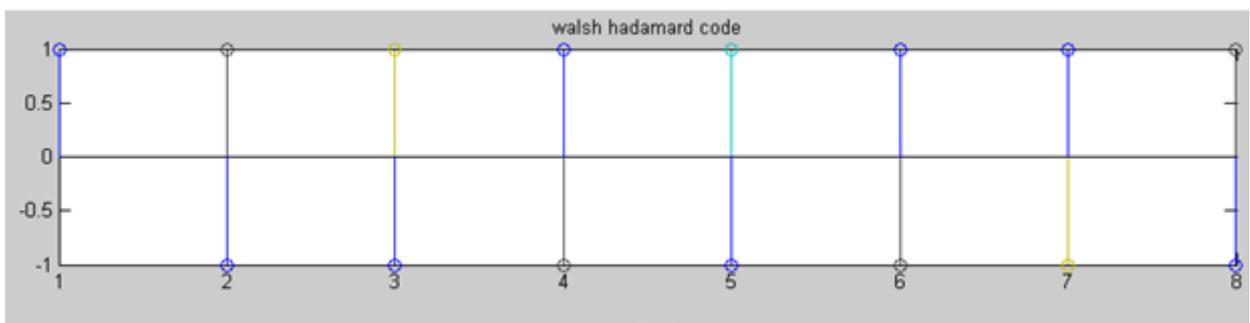


Figure:3.5. Output of Walsh code generation using matlab

3.2. Single User CDMA in AWGN Channel

Using 8 bits Walsh code, the single data which will be transmitting through channel to receiver is multiply with same Walsh code. This is called spreading. This coded data will be transmitted through AWGN channel. At receiver end, the local generated Walsh code will multiply with received signal for despreading. For receiving data at receiver end rake receiver is used. The despread data will pass through filter to get back desired data.

3.3. Multi-Users CDMA in AWGN Channel

Here instead of taking single Walsh code, eight Walsh codes will take for sending eight different data from different users. The whole process is same as process of sending single data in AWGN channel in CDMA. The number of Walsh code required is depend upon how much data bits will send at transmitter end. The Walsh code can be generated using Hadamard matrix. Since these Walsh codes are orthogonal to each other, inter signal interference is very low.

3.3. Multi-Users CDMA in AWGN and Fading Channel

Here encodes (spread) signals will transmit through both AWGN channel and Fading channel. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. Here fading channel is Rayleigh fading channel. The method of regenerating data signal from received signal is multiplying Walsh code and despread the received signal which will pass through filter to recover desired data.

Chapter 4

RESULTS

4.1. Introduction

Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits, independent of rate of transmission. There are many ways of reducing BER. Here, we focus on spreading code & modulation techniques.

In our case, we have considered the most commonly used channel: the Additive White Gaussian Noise (AWGN) channel where the noise gets spread over the whole spectrum of frequencies.

BER has been measured by comparing the transmitted signal with the received signal and computing the error count over the total number of bits. For any given modulation, the BER is normally expressed in terms of signal to noise ratio (SNR).

4.2. BER vs. SNR graph for single user CDMA in AWGN channel

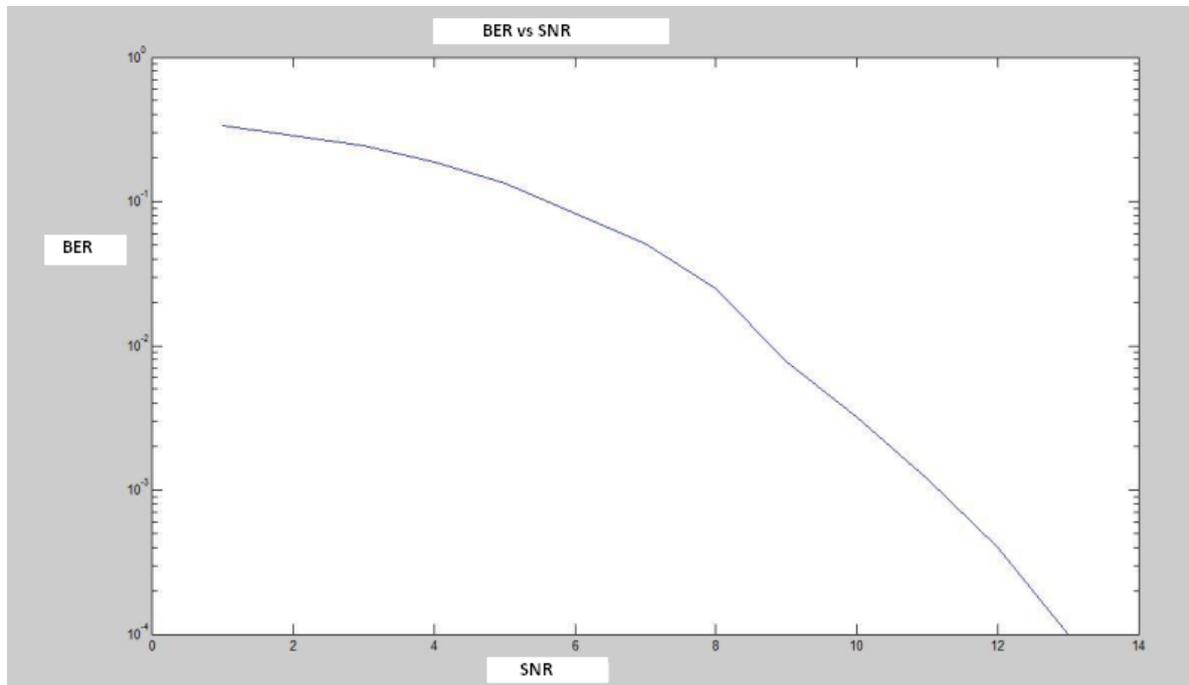


fig:4.1. BER vs. SNR garph

4.3. BER vs. SNR graph for Multi-user CDMA in AWGN channel

To plot BER vs. SNR graph in AWGN channel, a predefined function we have used in matlab programming. Here, “awgn” function is used to define a AWGN channel. Then gradually the values of SNR increases in AWGN channel and calculate the BER value. Using these values the graph was plotted. This was done for both single and multi user.

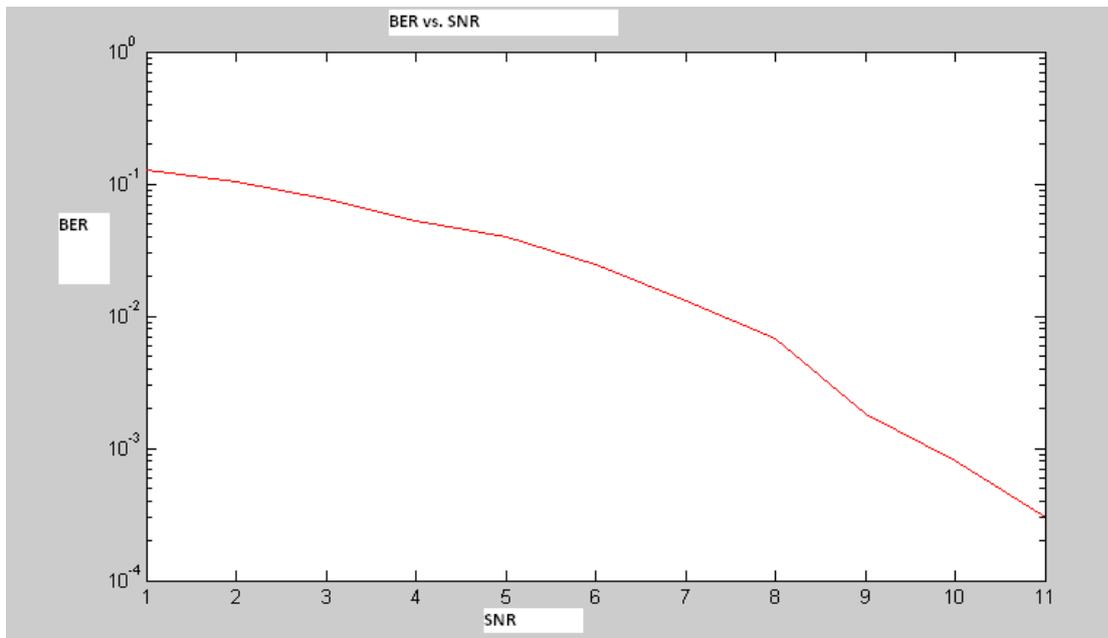


fig:4.2. BER vs. SNR garph

4.4. BER vs. SNR graph for Multi-user CDMA in AWGN and Fading channel

To plot BER vs. SNR graph in AWGN and Fading channel, predefine functions we have used in matlab programming. Rayleigh fading channel is used as fading channel. Here, “awgn” and “rayleighchan” functions are used to define a AWGN channel and a fading channel simultaneously. Then gradually the values of SNR increases and calculate the BER value. Using these values the graph was plotted. This was done for both single and multi user

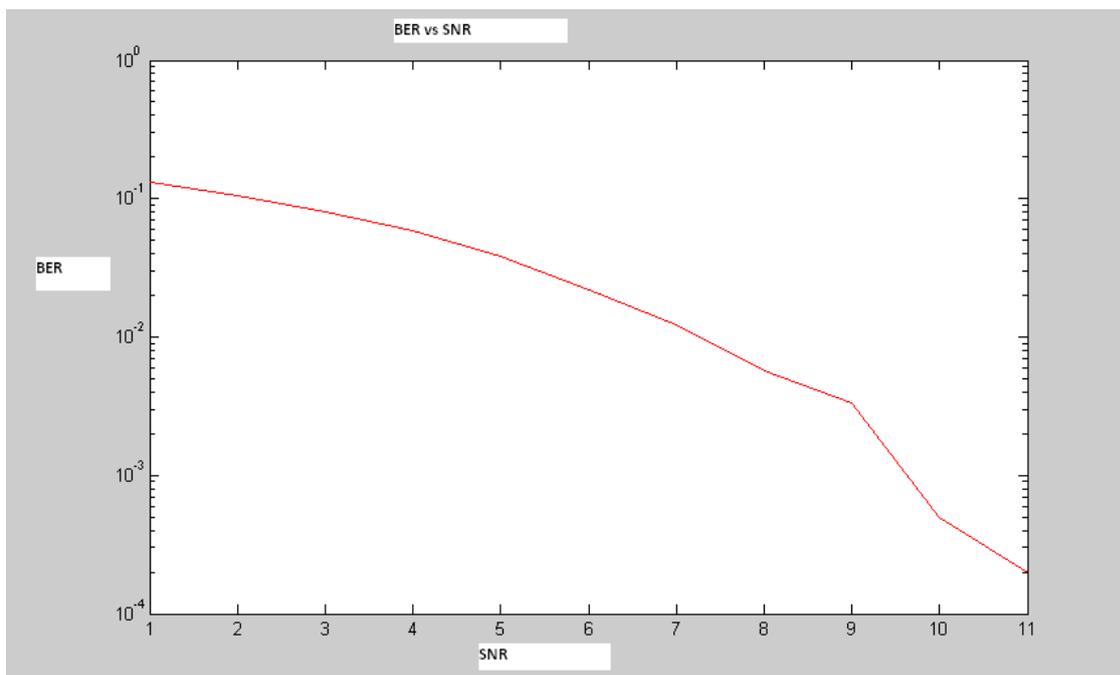


fig:4.3. BER vs. SNR garph

Chapter 5

CONCLUSIONS

5. CONCLUSIONS

- This work shows that successfully completion of analysis of spread spectrum for CDMA systems.
- The generation of PN codes, Walsh codes and gold codes was successfully obtained by using matlab programming.
- BER vs. SNR graphs for single user and multi users in both AWGN and Fading channel plotted and analysed successfully using matlab programming. Matlab provides a simple, systematic and efficient methodology for solving communication and data signal processing problems. This is one of the approaches to solve and design communication model before fabricating a system.
- The results indicate that after certain value of SNR, BER value will be zero in each channel.

5.1. Scope for Future Work

- This study leaves wide scope for future investigations. It can be extended to analysis of interference in CDMA due to fading channel and how to cancel that interference.
- CDMA technology is more useful for 3G and 4G mobile generations. There is a very wide scope for future scholars to explore this area of research in the field of CDMA. Many other problems like capacity, high data speed rate and low interference are require further investigation.

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