SOFTWARE IMPLEMENTATION OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) SCHEME FOR MOBILE RADIO CHANNEL

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING

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&
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CERTIFICATE

This is to certify that the Project entitled **“SOFTWARE IMPLEMENTATION OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) SCHEME FOR MOBILE RADIO CHANNEL”** submitted by **Satish Singh** and **Rakesh Ranjan Pani** in partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Electrical Engineering** at **National Institute of Technology, Rourkela** (Deemed University) is an authentic work carried out by him under my supervision and guidance.

Place: Rourkela

Dt:

(Prof.(Dr.) Susmita Das)
Department of Electrical Engineering
NIT, Rourkela

ACKNOWLEGEMENT

We deem it to be a privilege to have been the students of Department of Electrical Engineering in National Institute of Technology, Rourkela.

We would like to thank our Project Supervisor **Prof.(Dr.) Susmita Das**, Department of Electrical Engineering, for her guidance, support, motivation and encouragement throughout the period in which this work was carried out. Her readiness for consultation at all times, her educative comments, her concern and assistance even with practical things have been invaluable.

We are grateful to **Dr. B.D.Subudhi**, *Professor and Head*, Department of Electrical Engineering for providing necessary facilities in the department.

We would also like to thank all our friends who have been a constant source of motivation for us.

Above all we would like to thank God for giving us will and determination for doing our project

Dt. SATISH SINGH (10602024)

RAKESH RANJAN PANI (10602027)

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a transmission technique which ensures efficient utilization of the spectrum by allowing overlap of carriers. OFDM is a combination of modulation and multiplexing that is used in the transmission of information and data. Compared with the other wireless transmission techniques like Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), OFDM has numerous advantages like high spectral density, its robustness to channel fading, its ability to overcome several radio impairment factors such as effect of AWGN, impulse noise, multipath fading, etc. Due to this it finds wide application in Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), and Wireless LAN. Most of the wireless LAN standards like IEEE 802.11a or IEEE 802.11g use the OFDM as the main multiplexing scheme for better use of spectrum. In fact in the 4G telecommunication system OFDMA is the backbone of it.

This project deals with the software simulation of this OFDM system in a mobile radio channel using the software tools of MATLAB® and SIMULINK®. From this simulation the performance of OFDM system in mobile radio channel is studied. Apart from this we also compare the OFDM system performance with the performance of the DS-CDMA system in the mobile radio channel. In the end we study an application of this OFDM system i.e. IEEE802.11a PHY layer is simulated and studied.

CHAPTER 1

INTRODUCTION

Wireless communication has been the talk of the town from the starting of this decade, may it be the auctioning of the 3G spectrum in various developing countries including India or the launch of wireless Internet services by different service providers. With the increasing traffic for the wireless communication the need for the more efficient use of the spectrum available holds the key. Along with that the 4G communication system are also peeping their head out in developed countries like USA and UK. Obviously as the generation is advancing it is expected to have higher data rates, high spectral efficiency. Of course achieving this data rate requires careful selection of multicarrier modulation scheme available. Many multiple access techniques like FDMA, TDMA, CDMA, WCDMA, OFDMA, etc have come up. OFDM being the newest of the lot, what attracted us is to see the performance of this system in the mobile radio channel and how it is better than the other techniques. In short, what appealed us is to find the advantage and disadvantage of this system so that the reason for its implementation in the wireless communication becomes clear.

The main objective of this project is to study and investigate the effect of several radio channel impairment factors to the performance of OFDM system as well as to study and investigate the performance of OFDM in the mobile radio channel. To do this the best way is the simulation of the system which can be done easily with the help of software like MATLAB® and SIMULINK®. Apart from this, some of the OFDM system performance is to be compared to that of a CDMA technique. Also an application of the OFDM scheme can to be studied and implemented using simulation model.

CHAPTER 2

BASIC THEORY AND LITERATURE REVIEW

2.1 Propagation Characteristic of Mobile Radio Channel: In ideal radio channel, the transmitted signal from the transmitter will pass though channel and go to the receiver. In receiver side the signal is demodulated using demodulation algorithm and get a perfect representation of the original signal. However in real channel, this is not true since some non-idealities creep in the received signal. The received signal consists of a mixture of reflected, attenuated, diffracted and refracted version of the transmitted signal. In addition to this, the noise gets added to the signal due to the channel and thus causes a shift of the carrier frequency if transmitter and receiver are moving (Doppler effect). Understanding these effects on the signal becomes necessary because the performance of radio system depends on these channel characteristic.

Attenuation: Attenuation is the drop of the signal power when it is transmitted from one point to other. It depend on distance between the transmission points, obstructions in the signal path, and various multipath effects. Any objects, which come in between the line of sight of signal from the transmitter to the receiver, causes attenuation. Shadowing of the signal occurs whenever there is an obstruction between the receiver and transmitter. This is generally caused by hills and buildings, and it is the most important environmental attenuation factor. The typical amounts of variation in the attenuation due to shadowing are shown in the following table (on next page) [15].

Description	**Typical Attenuation due to Shadowing**
Heavily Built-Up Urban center	20dB variation from street to street.
Sub-Urban Area(few large buildings)	10dB greater signal power than heavily built-up areas
Open Rural Areas	20dB greater signal power than sub-urban areas
Terrain Irregularities and tree foliage	3-12dB signal power variation

Table 2.1: Typical Attenuation in Radio Channel

Multipath Effects: In wireless channel the medium is the air. And in this case there is no specified or particular path for signal transmission. The transmitted signal may get reflected from many things like hills, trees, etc before being received at the destined receiver. This can give rise to multiple transmission paths upto the receiver. The relative phases of the multiple reflected signal causes destructive or constructive interference at the receiver. This is normally experienced for very short distances (typically at half of the wavelength distances), thus is given the term - *fast fading*. These variation can vary from10 to 30dB [4] over short distances.

The **Rayleigh distribution** which is commonly used to describe the statistical time varying nature of the received signal power describes the probability of the signal level being received due to the fading. Table 2.2 [14] shows the probability of the signal level due to the Rayleigh distribution.

Signal Level(dB about Median)	**% Probability of Signal Level being less than the value given**
10	99
0	50
-10	5
-20	0.5
-30	0.05

Table 2.2: Cumulative Distribution of Rayleigh Distribution

Frequency Selective Fading : In any radio transmission, the channel spectral response is not flat. It has fades or dips in response due to the reflection causing cancellations of certain frequencies in the receiver. Reflections from near by object(e.g. trees, ground, buildings, etc) leads to multipath signal of similar signal power as the direct signal. This results in deep nulls in received signal power due to the destructive interference.

For narrow bandwidth transmission if the null of the frequency response occurs in the transmission frequency then the entire signal might be lost. This could be partly overcome by two ways. By transmitting the wide bandwidth signal or spread spectrum as in CDMA, any dips of the spectrum only results in a small loss of the signal power [1], rather than the complete loss. Another method is to split the transmission into many small bandwidth carrier, as is done in the OFDM/COFDM transmission. The original signal is spread over the wide bandwidth thus, any null in the spectrum is unlikely to occur at all the carrier frequencies. This will result in only some of the carriers being lost, rather than the entire signal. The information contained in the lost carriers can be recovered provided enough forward error correction is sent.

Doppler Shift: This is very commonly observed phenomenon that the sound of a travelling vehicle increases as it approaches the observer and decreases when it moves away from the observer. This phenomenon is called as the *Doppler Effect.* Same is the case with transmitted signal. When transmitter and receiver are moving relative to one another then the frequency of the received signal will not be same as the source. When they are moving towards one another the relative frequency of the received signal become higher than the source, and when they are approaching each other the frequency decreases. This effect become important when developing mobile radio system. The amount the frequency changes due to Doppler effect depend on the relative motion between the receiver & source and on the speed of propagation of the wave. The Doppler shift in frequency can be written: $\mathbf{\Delta f \approx \pm f_0 (v/c)}$

Where Δf is the change of the frequency of the source seen from the receiver, f_0 is the frequency of the source, v is the speed difference between transmitter & source & c is the speed of light.

Delay Spread: This is yet another multiple path effect which affects the transmission in case of the wireless transmission system. The received radio signal from the transmitter consist of a direct signal and reflections from the objects such as mountings; building, and other structures. The reflected signal arrives at a later time than the direct signal because of the extra path length. This gives rise to slightly different arrival times which spreads the received energy in time. Delay spread is thus the time spread between the arrival of the first and last significant multipath signal seen by the receiver [15]. In digital systems, the delay spread leads to the inter-symbol interference. This is because of the delayed multipath signal overlapping with the following symbols.

This causes significant errors in high bit rate systems, especially when using time division multiplexing (TDMA). Figure 2.1 [4] shows the effect of inter-symbol interference due to delay spread on the

received signal. As the transmitted bit rate is increased the amount of inter-symbol interference also increases. The effect starts to become very significant when the delay spread is greater than ~50% of the bit time.

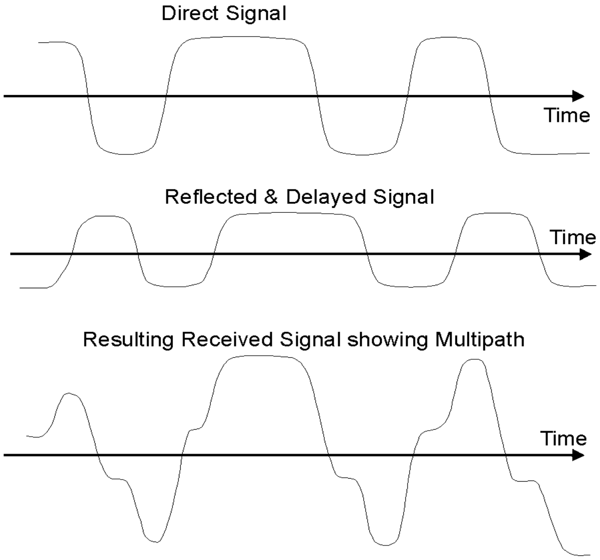


Figure 2.1: Multipath Delay Spread

2.2 The Principles of OFDM: Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the bandwidth into many carriers; each one is modulated by a low rate data stream. In term of multiple access technique, OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers. Pictorially it can be represented as shown in the figure 2.2 [11] in the next page. The figure shows the difference between the conventional non-overlapping multicarrier technique and overlapping multicarrier modulation technique. As shown in figure 2.2, by using the overlapping multicarrier modulation technique, we save almost 50% of bandwidth. To realize the

overlapping multicarrier technique, however we need to reduce crosstalk between subcarriers, which means that we want orthogonality between the different modulated carriers.

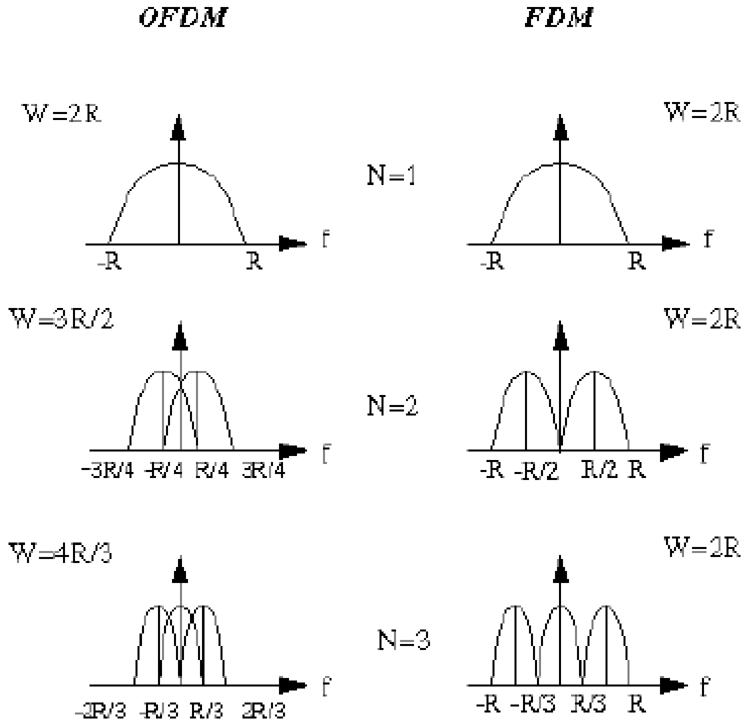


Figure 2.2: Concept of OFDM Signal: Orthogonal Multicarrier Technique Versus Conventional Multicarrier Technique

The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing then to be spaced as close as theoretically possible. This overcomes the problem of overhead carrier spacing required in FDMA. Each carrier in an OFDM signal has a very narrow bandwidth (i.e.1kHz), thus the resulting symbol rate is low. This results in the signal having a high tolerance to multipath delay spread, as the delay spread must be very long to cause significant inter-symbol interference (e.g. > 500 µsec).

2.3 OFDM Operation:

i- Definition of Orthogonality: Two periodic signals are orthogonal when the integral of their product, over one period, is equal to zero. This is true of certain sinusoids as illustrated in the equation 1[4] and 2 [4] below:

Continuous Time

$$\int_0^T \cos(2\pi nft) * \cos(2\pi mft)dt = 0 \qquad ; n \neq m \qquad (1)$$

Discrete Time

$$\sum_0^{N-1} \cos\left(\frac{2\pi kn}{N}\right) * \cos\left(\frac{2\pi km}{N}\right) = 0 \qquad ; n \neq m \qquad (2)$$

The carriers of an OFDM are sinusoids that meet this requirement because each one is a multiple of frequency. Each one has an integer number of cycles in the fundamental period.

ii- Concept of DFT and FFT: When the DFT (Discrete Fourier Transform) of a time signal is taken, the frequency domain results are a function of the *time sampling period* and the *number of samples* as shown in Figure 2.3. The fundamental frequency of the DFT is equal to 1/NT (1/total sample time). Each frequency represented in the DFT is an integer multiple of the fundamental frequency. The maximum frequency that can be represented by a time signal sampled at rate 1/T is fmax = 1/2T as given by the Nyquist sampling theorem. This frequency is located in the center of the DFT points. All frequencies beyond that point are images of the representative frequencies. The maximum frequency bin of the DFT is equal to the sampling frequency (1/T) minus one fundamental (1/NT).

The IDFT (Inverse Discrete Fourier Transform) performs the opposite operation to the DFT. It takes a signal defined by frequency components and converts them to a time signal. The parameter mapping is the same as for the DFT. The time duration of the IDFT time signal is equal to the number of DFT bins (N) times the sampling period (T). It is perfectly valid to generate a signal in the frequency domain, and convert it to a time domain equivalent for practical use. This is how modulation is applied in OFDM. In practice FFT and IFFT are used in place of DFT and IDFT respectively as they are faster than the later methods.

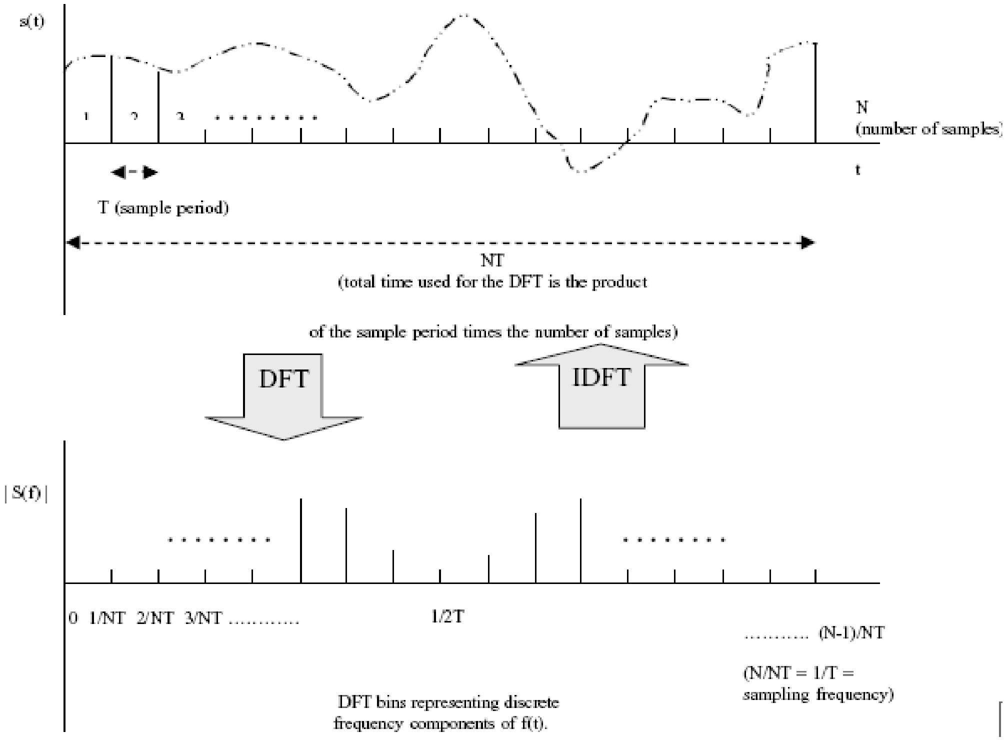


Figure 2.3: Parameter Mapping from Time to Frequency for the DFT

iii- Definition of Carriers: The maximum number of carriers used by OFDM is limited by the size of IFFT. This is determined as per the equation 3[4] shown below:

$N_{carriers} \leq (IFFT_{size}/2)-2$ (real valued time signal) (3)

$N_{carriers} \leq (IFFT_{size}/2)-1$ (complex valued time signal)

Both IFFT size and assignment (selection) of carriers can be dynamic. The transmitter and receiver just have to use the same parameters. This is one of the advantages of OFDM. Its bandwidth usage (and bit rate) can be varied according to varying user requirements. A simple control message from a base station can change a mobile unit's IFFT size and carrier selection.

iv- Modulation: Modulation is the process of modifying some properties of the high frequency carrier signal in accordance with the baseband signal. Binary data from the memory device or from a digital processing stream is used as the modulating signal. The following steps may be carried out in order to apply modulation to the carriers in OFDM:

- Combine the binary data into symbols according to the number of bits/ symbols selected.
- Convert the serial symbols stream into parallel segments according to the number of carriers and form the carrier symbol sequence.
- Apply differential coding to each carrier symbol sequence.
- Convert each symbol into complex phase representation.
- Assign each carrier sequence to the appropriate IFFT bin, including complex conjugate.
- Take IFFT of the result.

v- Transmission and Reception: The key to the uniqueness and desirability of OFDM is the relationship between the carrier frequencies and the symbol rate. Each carrier frequency is separated by a multiple of 1/NT (Hz). The symbol rate (R) for each carrier is 1/NT (symbols/sec).

The effect of the symbol rate on each OFDM carrier is to add a sin(x)/x shape to each carrier's spectrum. The nulls of the sin(x)/x (for each carrier) are at integer multiples of 1/NT[4]. The peak (for each carrier) is at the carrier frequency k/NT. Therefore, each carrier frequency is located at the nulls for all the other carriers. This means that none of the carriers will interfere with each other during transmission, although their spectrums overlap. The ability to space carriers so closely together is very bandwidth efficient. In the process of transmission and reception it is essentially required to linearly amplify the signals. This is a sort of disadvantage of the OFDM system.

vi- Demodulation: This process is the juts reverse of the modulation process. It is carried out on the receiver side of the system and is done in the frequency domain. The following steps may be taken to demodulate the OFDM signal:

- Partition the input stream into vectors representing each symbol period.
- Take the FFT of each symbol period vector.
- Extract the carrier FFT bins and calculate the phase of each.
- Calculate the phase difference, from one symbol period to the next, for each carrier.
- Decode each phase into binary data.
- Sort the data into appropriate order.

vii- Guard Period : OFDM demodulation must be synchronized with the start and end of the transmitted symbol period. If it is not, then ISI will occur (since information will be decoded and combined for 2 adjacent symbol periods). ICI will also occur because orthogonality will be lost (integrals of the carrier products will no longer be zero over the integration period).

To overcome this a guard period is inserted in the sequence such that the ISI effect is eliminated. But still we have the problem of ICI because if the complete period is not integrated then the orthogonality will be lost. As a result the guard interval that is to be added should be the cyclic extension of the end of the symbol transmitted during a period and it should be added in the front part of the next symbol. The symbol length will increase but the integration can be done between anywhere in the symbol since it is periodic extension only. Hence by this the ICI will also be eliminated from the scene. The explanation can be made very clear by the pictorial representation of it as shown in the next page in figure 2.4[7].

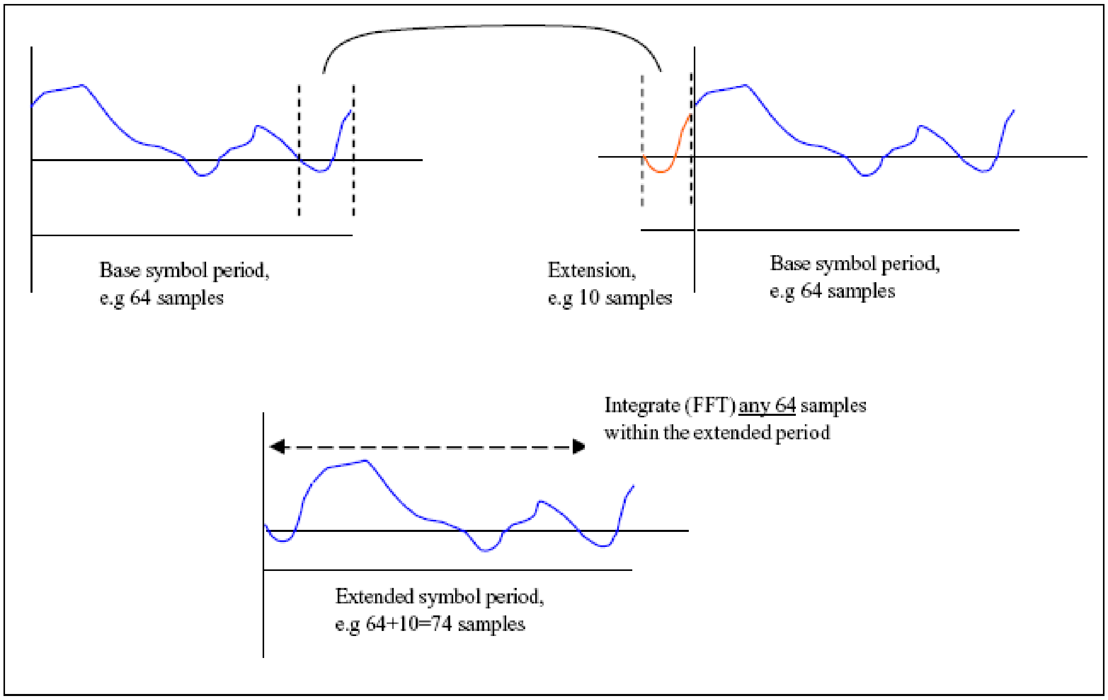


Figure 2.4: Guard Period via Cyclic Extension

2.4 Advantage and Disadvantage of OFDM: After going through a discussion on OFDM in last few sections it is evident that OFDM has certainly some advantage over the other multiple access techniques. The OFDM scheme has following key advantages:

- By allowing overlap of carriers it uses the spectrum very efficiently.
- By dividing the channel into narrow band flat fading sub channels, OFDM is more resistant to frequency selective fading than the single carrier system.[1]
- Eliminates ISI and ICI with the use of guard interval via cyclic prefix.
- Using adequate channel coding and interleaving one can recover symbols lost due to frequency selectivity of the channel.
- Channel equalization becomes simpler than single carrier system by using adaptive equalization techniques.
- In conjunction with differential modulation there is no need to implement a channel estimator.

- It is less sensitive to sample timing offset than the single carrier system.
- Provides good protection against co-channel interference and impulsive parasitic noise.

Though the OFDM scheme has numerous advantages, there are still some drawbacks in this scheme. They are indicated as below:

- The OFDM signal has a high Peak to Average Power Ratio (PAPR)
- It is more sensitive to carrier frequency offset and drift than the single carrier systems due to leakage in the DFT.
- Phase noise and Image Rejection are also a problem in OFDM [12].

2.5 Code Division Multiple Access (CDMA):

After going through the technique of the OFDM, it might strikes the readers mind that the techniques of multiple access also existed previously. So why were they replaced by the OFDM. By analysing one such scheme we can make a fair verdict why OFDM subsequently over rid other techniques. For this reason CDMA scheme is chosen because it is the so called "back bone" of the 3G tele-communication system.

Code Division Multiple Access (CDMA) is a spread spectrum technique which neither uses frequency channels nor uses time slot. With the CDMA teachnique, the narrow band message (typically digitized voice data) is multiplied by a large bandwidth signal that is pseudo random noise code (PN code). All users in a CDMA system use the same frequency band and transmit simultaneously. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter. For the specified receiver the signal is a signal and for other receiver the received signal is a noise. Hence it is discarded by other receivers. Figure 2.5 [7] on next page shows the general use of the spectrum using CDMA.

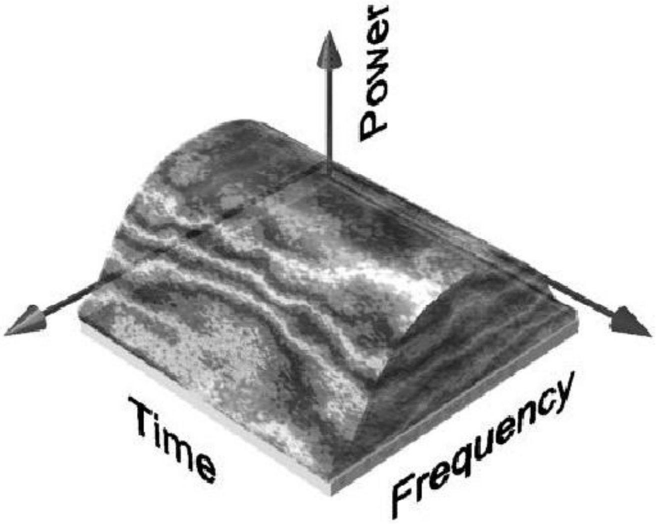


Figure 2.5: General use of Spectrum in CDMA

CDMA technology was originally developed by military during World War II. Researchers were committed into looking at different ways of communicating which would be secure and would work in the presence of jamming. So they came up with the CDMA technique. Some of the properties that have made CDMA useful are:

- Signal hiding and non-interference with existing system
- Anti-Jam and interference rejection
- Information security
- Accurate ranging
- Multiple User access
- Tolerant to Multipath effects

For many years, spread spectrum technology was considered solely for military purposes. However, with rapid developments in LSI and VLSI technology commercial systems have been used and that too very successfully. In fact the 3G- telecommunication system is based on CDMA technology mainly.

CDMA PROCESS GAIN: One of the most important concepts required in order to understand spread spectrum techniques is the idea of process gain. The process gain of a system is an indicator of the signal to noise improvement exhibited by a spread spectrum system when the signal is made to spread and de-spread. The process gain of a system is equal to the ratio of the spread spectrum bandwidth used, to the original bandwidth of the information signal. Thus, the process gain can be written as:

$$G_p = BW_{RF}/BW_{info}$$

Where BW_{RF} is the transmitted bandwidth after the data is spread, and BW_{info} is the bandwidth of the information data being sent.

CDMA Generation: CDMA is achieved by modulating the data signal by a pseudo random noise sequence (PN code), which has a chip rate higher than the bit rate of the data. The PN code as its name suggests is a virtual random code consisting of zeros and one in a random fashion. The CDMA signal is generated by modulating the data by the PN sequence. The modulation is performed by multiplying the data (XOR operator for binary signals) with the PN sequence. The PN code used to spread the data can be of two main types. A short PN code [4] (typically 10-128 chips in length) can be used to modulate each data bit. The short PN code is then repeated for every data bit allowing for quick and simple synchronization of the receiver. Alternatively a long PN code can be used. Long codes are generally thousands to millions of chips in length, thus are only repeated infrequently. Because of this they are useful for added security as they are more difficult to decode.

CDMA Forward Link Encoding: The forward link, from the base station to the mobile, of a CDMA system can use special orthogonal PN codes, called Walsh codes [4], for separating the multiple users on the same channel. These are based on a Walsh matrix, which is a square matrix with binary elements and dimensions that are a power of two. Walsh codes are orthogonal, which means that the dot product of any two rows is zero. Each row of a Walsh matrix can be used as the PN code of a user in a CDMA system. By doing this the signals from each user is orthogonal to every other user, resulting in no interference between the signals. However, in order for Walsh codes to work the transmitted chips from all users must be synchronized. If the Walsh code used by one user is shifted in time by more than about 1/10 of chip period, with respect to all the other Walsh codes, it loses its orthogonal nature resulting in inter user interference. This is not a problem for the forward link as signals for all the users originate from the base station, ensuring that all the signal remain synchronized.

CDMA Reverse Link Encoding: The reverse link is different to the forward link because the signals from each user do not originate from a same source as in the forward link. The transmission from each user will arrive at a different time, due to propagation delay, and synchronization errors. Due to the unavoidable timing errors between the users there is little point in using Walsh codes as they will no longer be orthogonal. For this reason, simple pseudo random sequences are typically used. These sequences are chosen to have a low cross correlation to minimize interference between users.

The capacity is different for the forward and the reverse links because of the differences in modulation. The reverse link is not orthogonal, resulting in significant inter-user interference. For this reason the reverse channel sets the capacity of the system.

2.6 Application of OFDM: OFDM find application in many of the wireless LAN (WLAN) structures. It is a general scheme used in the IEEE WLAN standards starting from 802.11a, 802.11b, 802.11g to even in 802.16 WLAN standards. Also HIPERLAN/2 wireless LAN network uses this OFDM technique. Along with that they are mainly used in digital audio broadcasting (DAB) and digital video broadcasting (DVB). These transmission techniques combine with them advanced technology of high data compression and efficient use of spectrum in transmission. Hence in these techniques OFDM plays a very significant role.

CHAPTER 3

SOFTWARE MODELLING OF OFDM AND CDMA USING SIMULINK

The OFDM and CDMA systems were modeled and simulated using SIMULINK Version 7.4 (R2009b). SIMULINK provides graphic user interface for simulating dynamic systems. It has a well defined communication system block set that contains all the functions required for modeling and simulating a communication system such as data generators, different modulation schemes, vector scopes, equalizers, error correction and detection blocks etc. The results obtained can easily displayed by the help of spectrum scopes and time scopes during the runtime thus giving a feel of the actual communication systems.

3.1 SIMULINK MODEL OF OFDM SYSTEM

This model implements a simple OFDM transmitter and receiver. The transmitter blocks are shown in yellow colour, the receiver blocks are shown in blue colour, the channel is shown in green colour while the output blocks are shown in brown colour.

Following are the configuration parameters set for this model:

Simulation time: 1000 seconds

Solver type: Variable step, ode45 (Dormand-Prince)

Relative tolerance: 1e-3

Number of consecutive zero crossings: 1000

The SIMULINK model of OFDM system is shown in Figure 3.1.

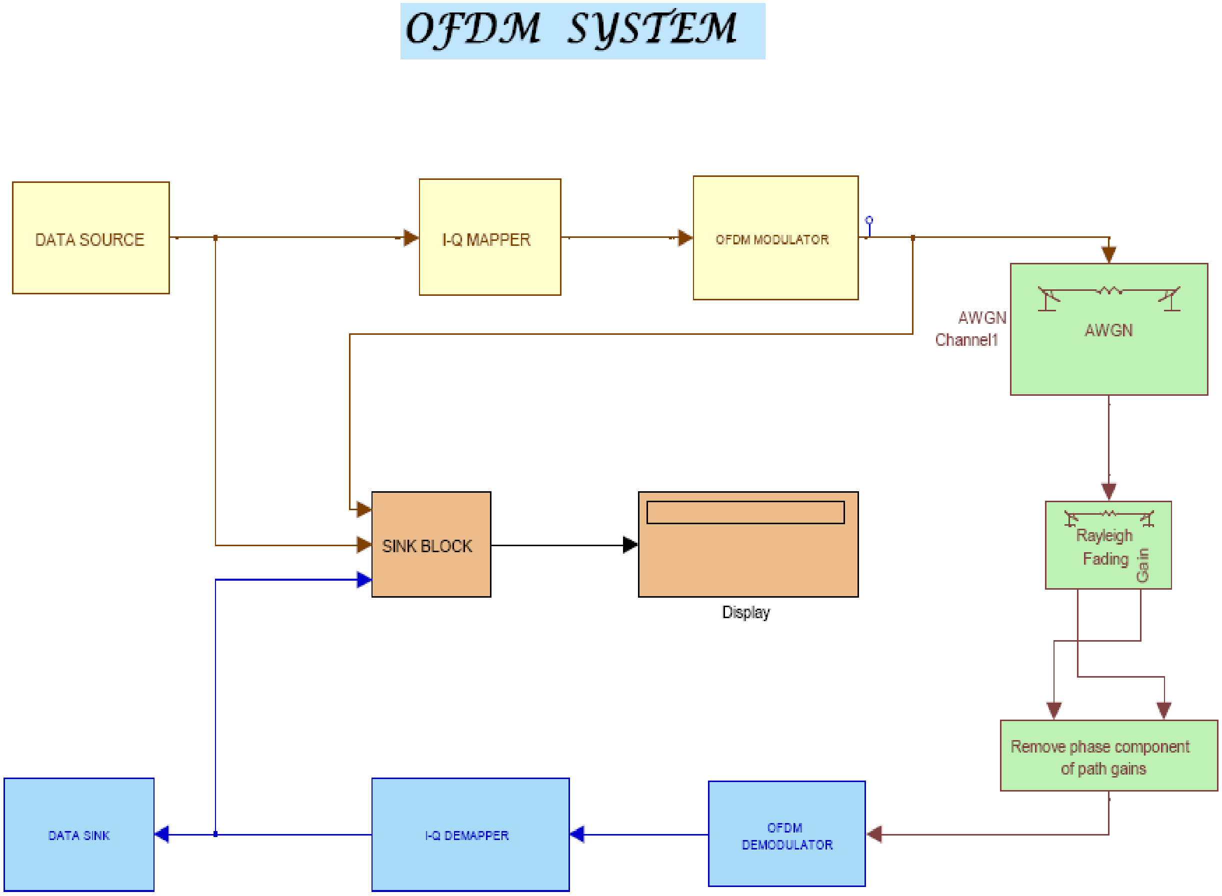
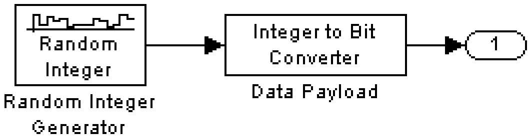


Figure 3.1: SIMULINK Model of OFDM System

In the subsequent sections different components of this system is explained.

(a) DATA SOURCE

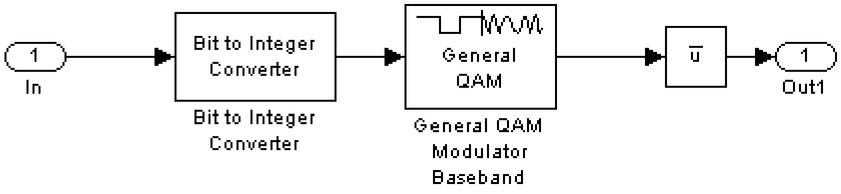
This block is used to generate frame based input data. It consists of two sub blocks as shown below:



Random integer generates a 4-ary number and outputs the data in a frame based form containing 192 samples per frame with a sampling time of 1/192 seconds. The output data type is double. Integer to bit converter block is used to convert the integers to bits in order to facilitate the computation of BER.

(b) MODULATOR / IQ MAPPER

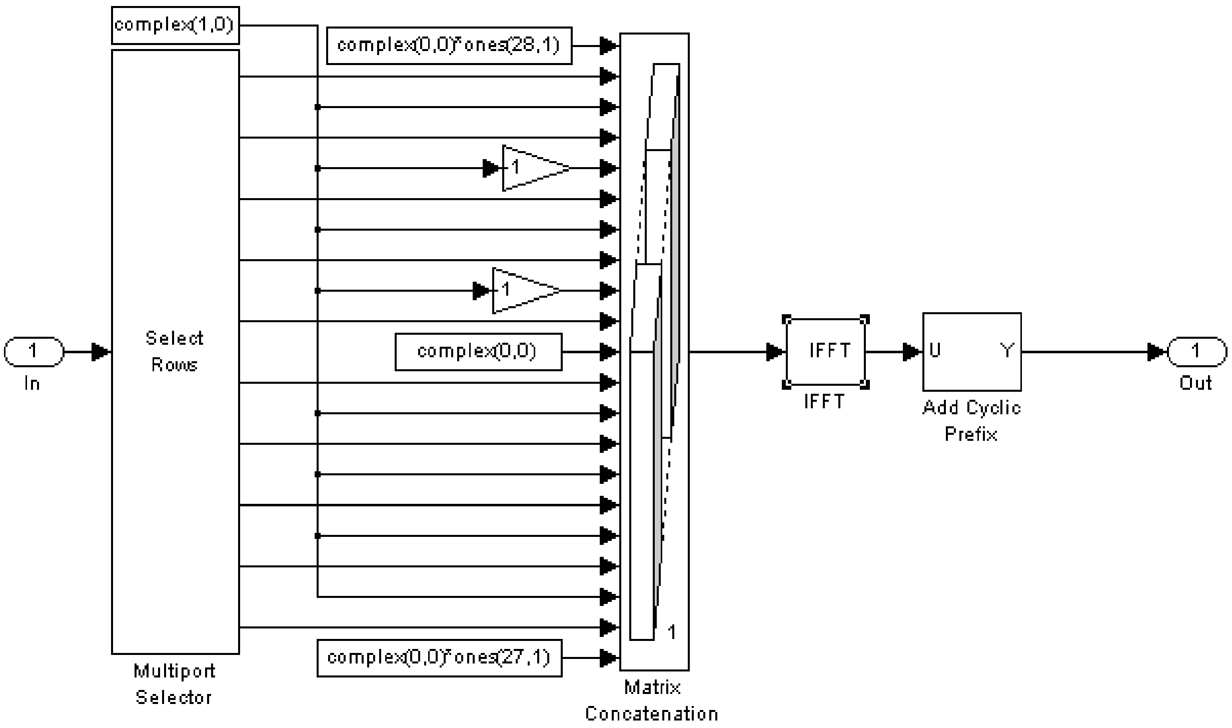
This block is used to modulate the input data stream using QAM. An bit to integer converter is used to convert the bits back to integers. This is because the QAM blocks can opeartes only upon integers and not on bits.



The signal constellation specified for the QAM is [0.7071 + 0.7071i 0.7071 - 0.7071i -0.7071 + 0.7071i -0.7071 - 0.7071i]. The conjugate block finds the complex conjugates of the data sample.

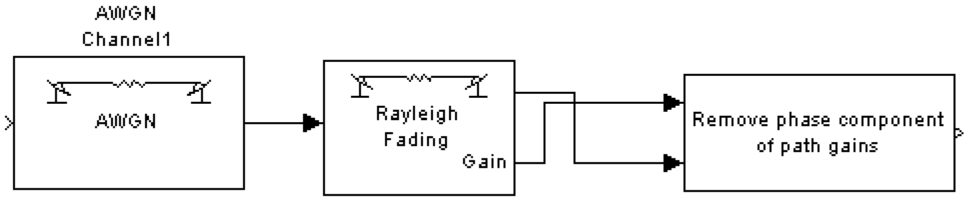
(c) OFDM MODULATOR

This blocks basically consists of IFFT block that computes inverse fast fourier transform of the input data. The IFFT operation is mathematically identical to OFDM operation. Hence it could be said that this is the block that actually implements OFDM. Before feeding the data samples to the IFFT block, the input data stream should be formatted so that the total number of input samples are a power of 2 as is required by the IFFT block. In order to do this a multiport selector block is used to select the rows and then unit data samples are added in between to maintain uniformity and finally they are concatenated vertically to get the data in which number of input samples are a power of 2. In this case since the input data consisted of 192 samples per frame, an extra 64 pilot samples are added to it.Finally a cyclic prefix block is added to add cyclic prefix to the data.



(d) TRANSMISSION CHANNEL

In order to model the actual transmission channel both the AWGN and Rayleigh fading channels are connected in series.



The signal to noise ratio of the AWGN channel can be adjusted by varying the SNR parameter value. The rayleigh fading block provides additional parameters like doppler shift, path delay gain etc to make the channel resemble the actual channel as closely as possible.

(e) OFDM DEMODULATOR

This operations performed by this block is basically opposite to that performed by the OFDM modulator block. At first the cyclic prefix is removed by using a remove cyclic prefix block and then FFT block is used to find the fast fourier transform of the data samples. Finally select rows block is once again used to remove the pilot samples added and output the exact data samples.

(f) I-Q DEMAPPER / DEMODULATION

This block demodulates the input data using quadrature amplitude demodulation method. The constellation for this block was set to [0.7071 + 0.7071i 0.7071 - 0.7071i -0.7071

+ 0.7071i -0.7071 - 0.7071i]. Finally the ouput integer samples are converted to bits using an integer to bit converter block to facilitate the compuation of BER.

(g) DATA SINK

The data is sent to a data sink. But in actual block this will be processed by the communication systems.

(h) OUTPUT

The sink block computes the BER and displays them. It also displays the time domain signal and frequency domain signal of OFDM through vector scope and spectrum scope respectively.

3.2 SIMULINK MODEL OF CDMA SYSTEM

This SIMULINK model implements a simple CDMA transmitter and receiver. The transmitter blocks are shown in orange colour, the receiver blocks are shown in blue colour, while the channel and the output blocks are shown in green colour.

Following are the configuration parameters set for this model:

Simulation time: 20 seconds
Solver type: Variable step, ode45 (Dormand-Prince)
Relative tolerance: 1e-3
Number of consecutive zero crossings: 1000

The SIMULINK model of CDMA is shown in Figure 3.2 on next page

SIMULINK MODEL OF CDMA TECHNOLOGY

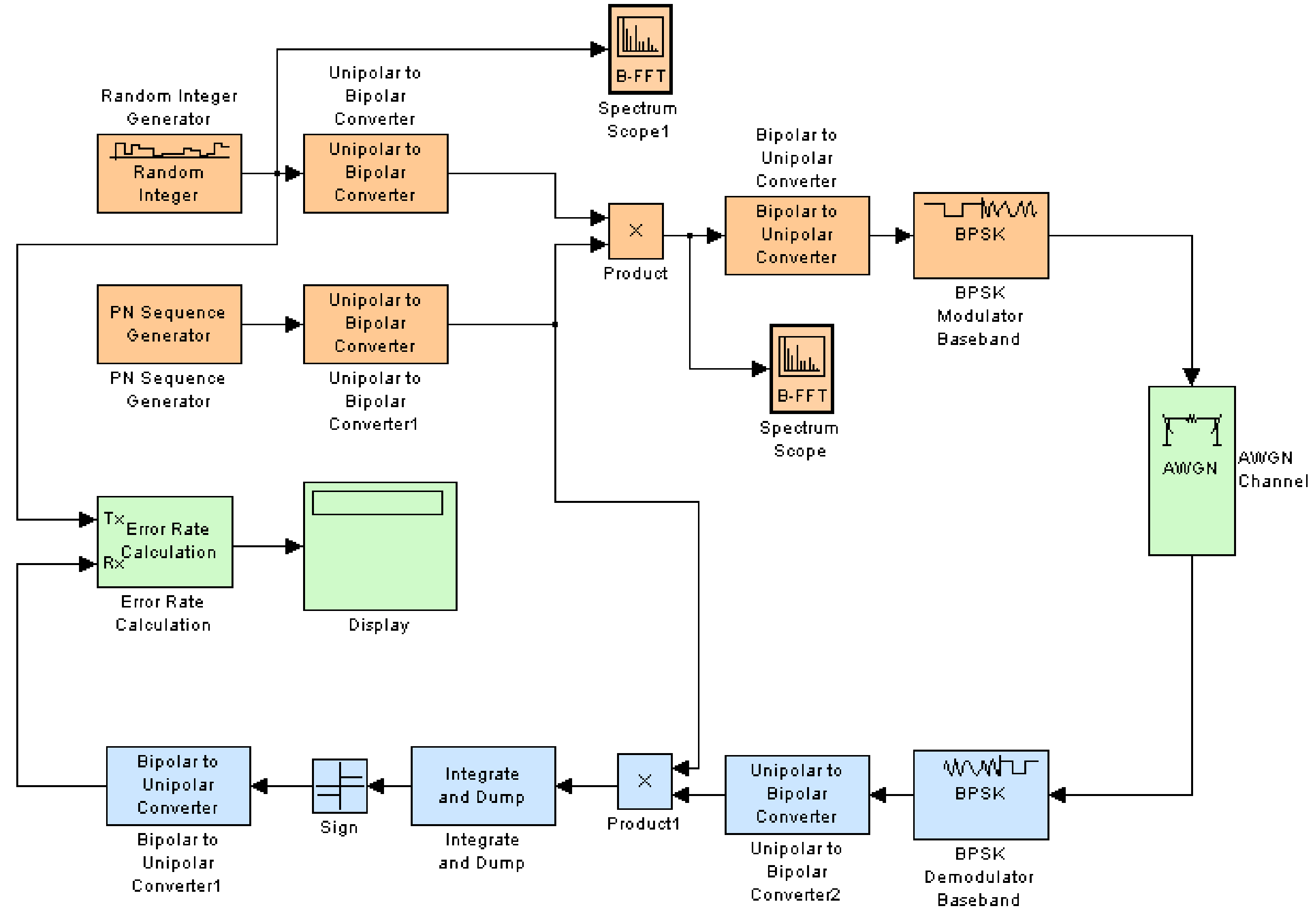


Figure 3.2: DS-CDMA Structure for Single User

Different components of this model is explained below.

(a) RANDOM INTEGER GENERATOR

This block generates a 2-ary number with a sampling time of 1/1000. The output data type is of double type.

(b) PN SEQUENCE GENERATOR

This block generates a sequence of pseudo random binary numbers. These sequences are used for modulating the data sequences. For multiuser system, different set of pseudo random sequences are generated which are orthogonal to one another. The generator polynomial parameter can be specified using any one of the following formats:

- A vector can be specified that lists the coefficients of the polynomials in descending order of powers. The first and last enteries should be set to 1. The length of this vector should be one more than the degree of the generator polynomial.
- A vector can be specified that contains the exponents of z for nonzero terms in descending order of powers.

The initial state parameter is a vector that specifies the initial states of the register. All the elements of the initial state vector must be binary numbers. The length of the initial state parameter should be equal to the length of the initial state vector. Atleast one element of the initial state vector must be nonzero for the block to generate a nonzero sequence. Different initial states lead to different set of orthogonal pseudo random codes.

(c) UNIPOLAR TO BIPOLAR CONVERTER

This block converts the unipolar input signal to bipolar output signal. That means if the input consists of integers from 0 to M-1, then the output of this block will consist of integers from –(M-1) to (M-1).

(d) PRODUCT

This block simply multiplies the bipolar input data with the pseudo random noise code. After that the bipolar data is converted back to the unipolar data.

(e) BPSK MODULATOR

This block modulates the input data by using BPSK modulation scheme. After this the data is transmitted through the AWGN channel.

(f) INTEGRATE AND DUMP BLOCK

This block is present on the receiver side. In the receiver side the the demodulation of the received data is carried out using the BPSK demodulator and then it converted to bipolar form. After this this data signal is multiplied by the same pseudorandom noise code as was used in the receiver side. The output signal is then fed to the integrate and dump block. The integrate and dump block creates a cummulative sum of the discrete-time input signal, while resetting the sum to zero according to a fixed schedule. When the simulation begins, the block discards the number of samples specified in the Offset parameter. After this initial period the block sums the input signal along columns and resets the sum to zero every N input samples, where N is the integration period parameter value. The reset occurs after the block produces its output at that time step. The integrate and dump operation is often used in a receiver model when the system's transmitter uses a simple square pulse model.

(g) SIGN

The sign block gives the sign of the input. If the input is greater than zero it outputs a 1, if the input is zero it outputs a 0, and if the input is less than 1, it outputs a -1.

(f) ERROR RATE CALCULATION

This block calculates the BER. The receive delay of this block is set to 1. The output is displayed using a display block.

For implementing a multiuser system, the same transmitter and receiver arrangement is used with the same generating polynomial but each of the user should be assigned different set of initial state.

CHAPTER 4

SIMULATION RESULT AND ANALYSIS

In this chapter we discuss about the results obtained from the simulation and their analysis is presented. The simulation results were plotted in terms of performance of the OFDM system, that is Bit Error Rat (BER). Mainly the modulation techniques of BPSK, QPSK, 16-PSK and 64-PSK were used to see the tradeoff between system capacity and system robustness. The standard BER that was used to determine the minimum performance of the OFDM system is minimum BER for voice transmission system i.e. 10^{-3}. Analysis was done by observing the simulation result and tabulating the analysis result to make it more convenient to read. Along with that the DS-CDMA system's result are also presented here so that a comparison can be made of the OFDM and CDMA system.

4.1 OFDM SIMULATION RESULTS

1- Time Domain and Frequency Domain Signal Obtained from the SIMULINK model:

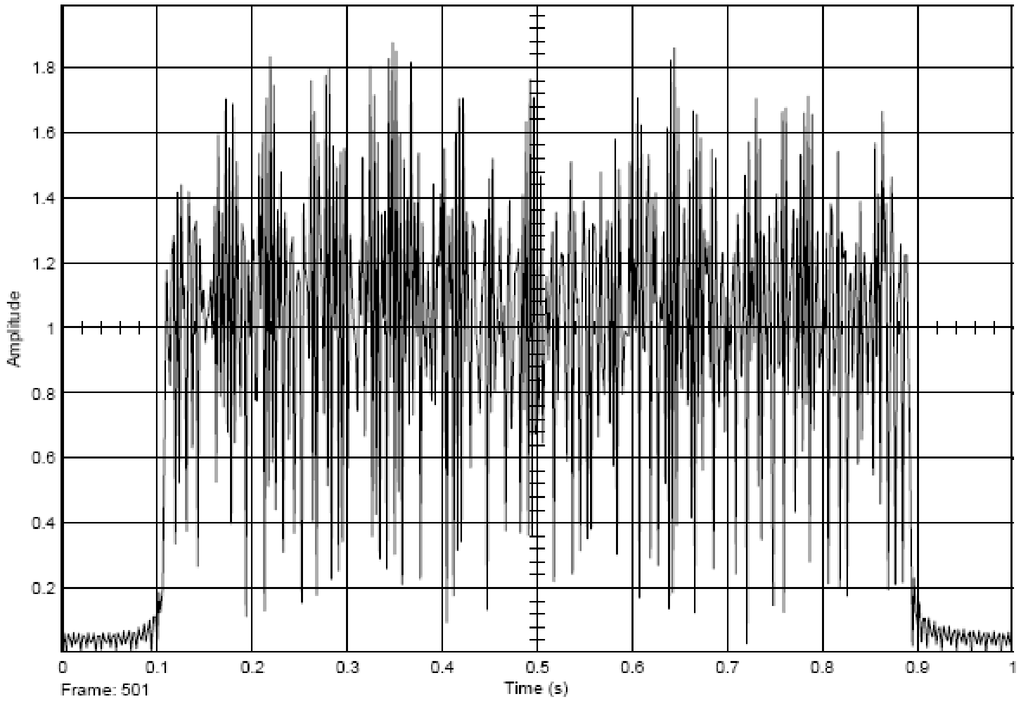


Figure 4.1: Time Domain Signal

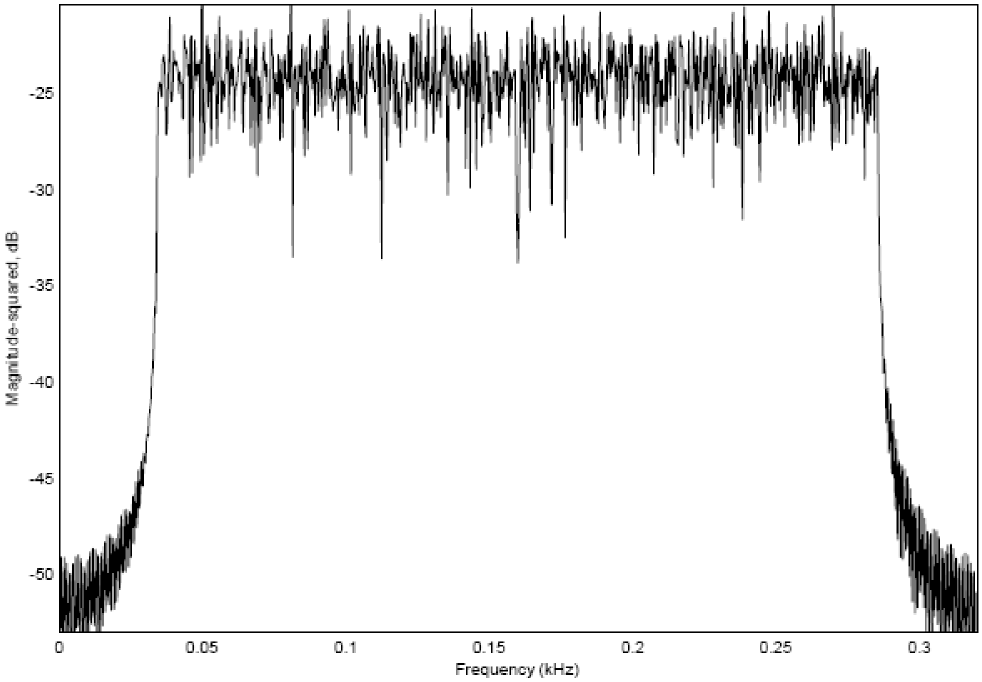


Figure 4.2: Frequency Domain Signal

2- **The Effect of Adaptive White Gaussian Noise (AWGN) to the Performance of OFDM Signal:** The effect of Additive White Gaussian Noise (AWGN) channel to the performance of the OFDM system for four modulation techniques namely BPSK, QPSK, 16PSK and 64-PSK are shown in the figure 4.3. It can be observed from the above figure to achieve a BER of 10^{-3}, the OFDM system using BPSK modulation needs at least a SNR of 11dB, the OFDM system using a QPSK modulation needs at least 14dB, the OFDM system using 16-PSK modulation needs at least SNR around 25dB and the OFDM system using 64-PSK modulation needs at least SNR around 36dB. It can also be analyzed that since OFDM technique is not intended to overcome the effect of AWGN, hence the performance of OFDM is similar to a BPSK, QPSK, 16PSK and 64-PSK standard single carrier digital transmission. However, the OFDM has an ability to overcome the effect of burst error [4] due to sudden noise such as lightning by using parallel data transmission, so that instead of several adjacent bits being completely error, many symbols are only slightly distorted, and they can be fixed using a simple Forward Error Correction (FEC) method.

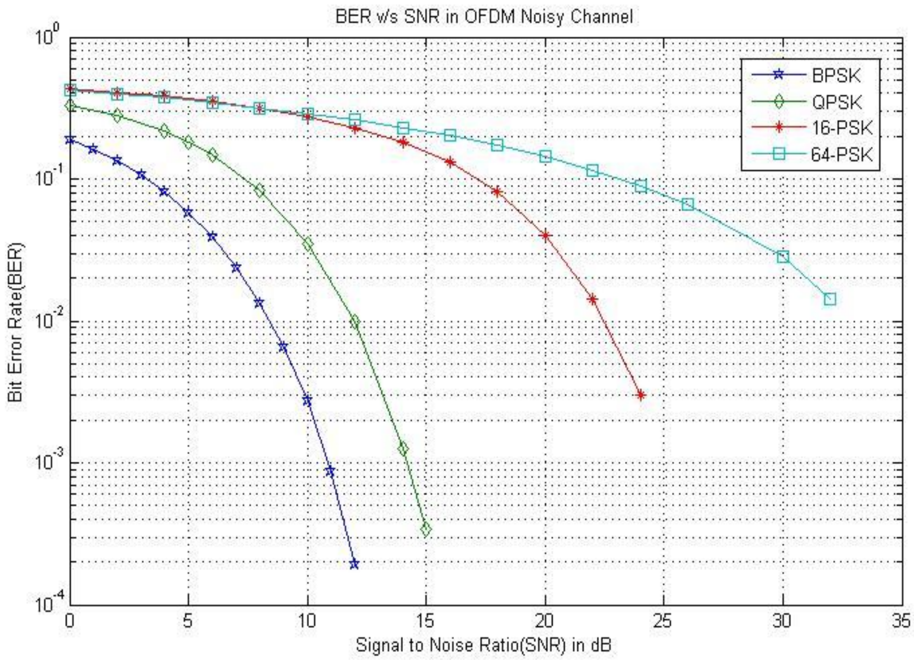


Figure 4.3: BER v/s SNR for OFDM in AWGN Channel

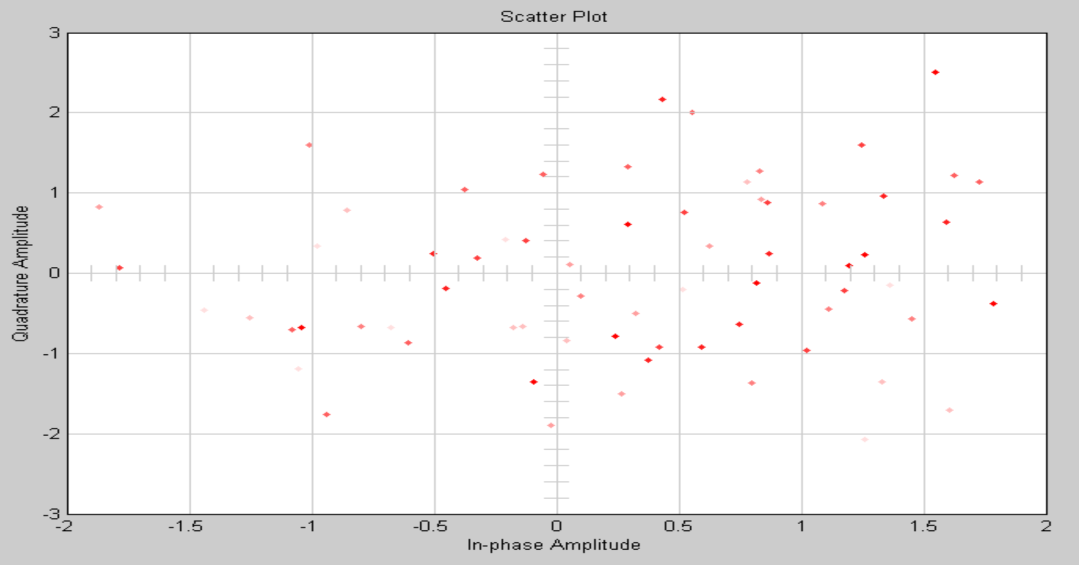


Figure 4.4: Constellation Diagram when SNR=1dB

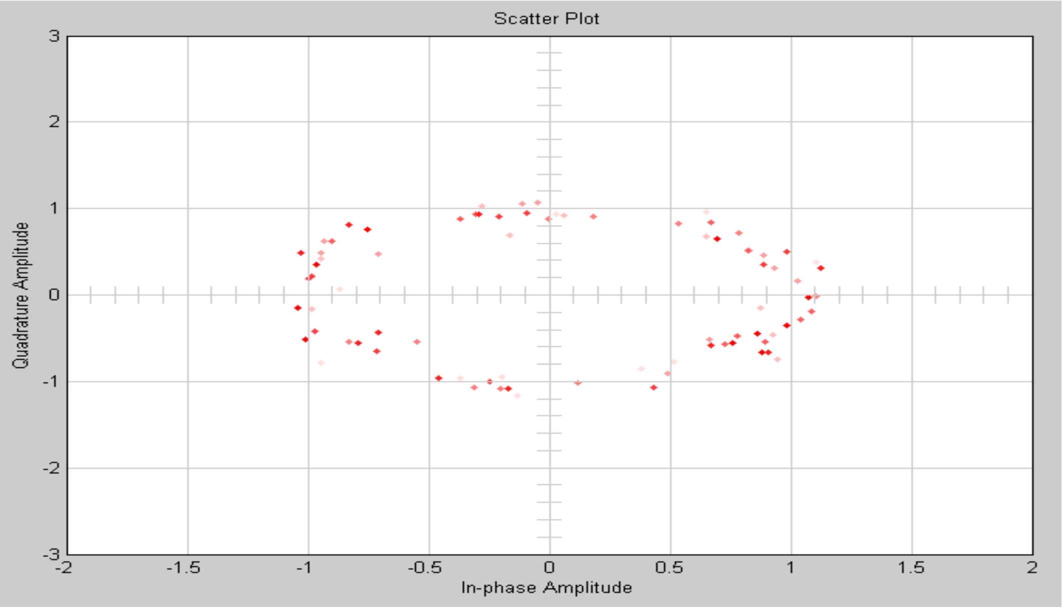


Figure 4.5: Constellation Diagram when SNR=20dB

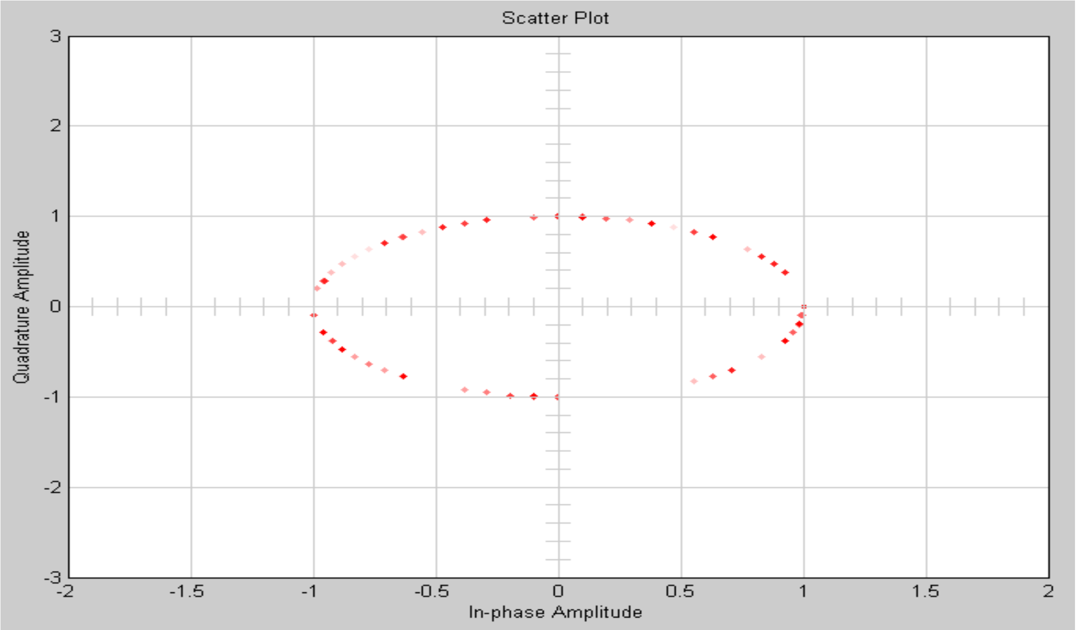


Figure 4.6: Constellation Diagram when SNR=60dB

The above figures i.e. figure 4.4 to 4.6 shows the constellation diagram of the signal transmitted using OFDM system for a modulation scheme of 64-PSK. It can be seen very clearly that the scatter plot converges to a circle as the SNR is increased. This indicates that the BER using low SNR is high as compared to the channel using a high SNR. The cluster in case of a low SNR is very random as observed in case of a channel having SNR of 1dB (as shown above figures). But the cluster slowly converges to a circle having 64 points on it with a very high SNR i.e. in this case SNR=60dB. This cluster diagram analysis is in line with the BER v/s SNR plot where it was indicated that the channel needs at least a SNR of 36dB to have a BER of less than 10^{-3}.

3- Effect of Fading Channel on the performance of OFDM Signal:

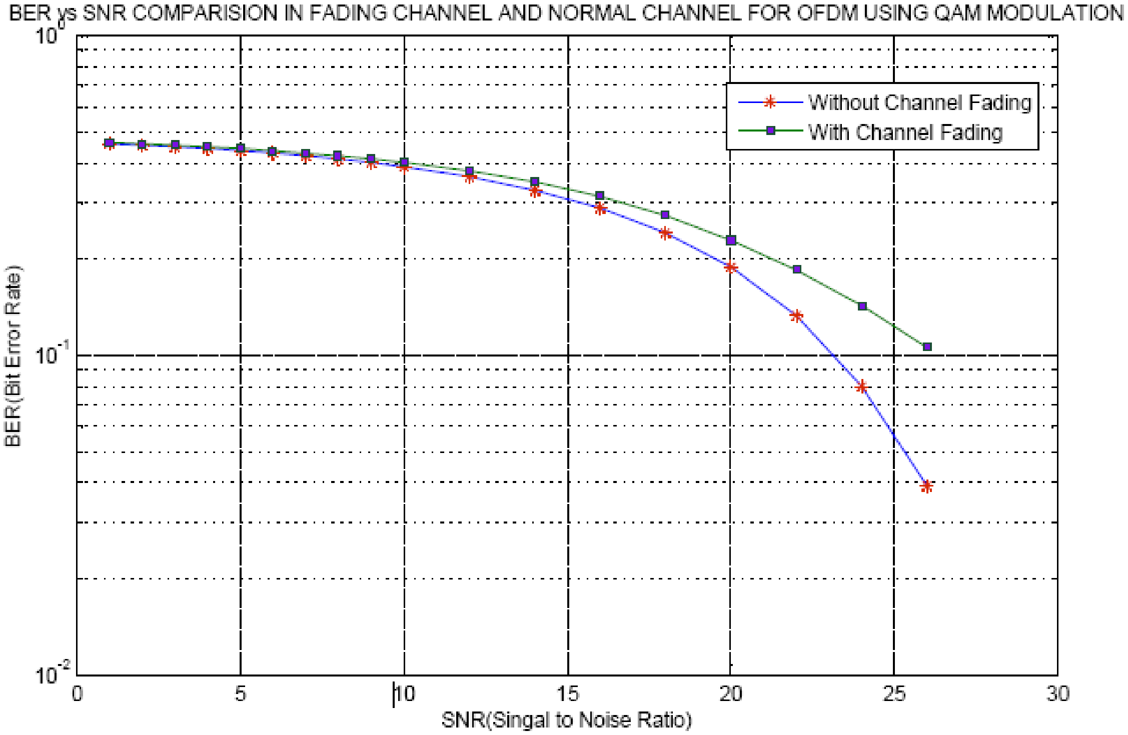


Figure 4.7: BER v/s SNR in Fading Channel

Figure 4.7 shows the performance of the OFDM signal in the Fading channel versus that in a normal AWGN channel. The fading channel used in the above case is that of the Rayleigh Fading Channel. The modulation used in this case is the QAM modulation. It is very much evident from the graph that OFDM is very much tolerable to the fading effect in the channel. To achieve a BER of 10^{-3} in a fading channel approximately a SNR of 33dB is required. In case of a normal channel that SNR value is around 27dB. So we can see even if the channel characteristic is changing drastically the SNR requirement is not much affected. Only an additional 6dB is required. So it is evident that OFDM scheme is very robust to the channel fading effects like Rayleigh fading or frequency selective fading.

4- The Effect of Power Clipping to OFDM Signal:

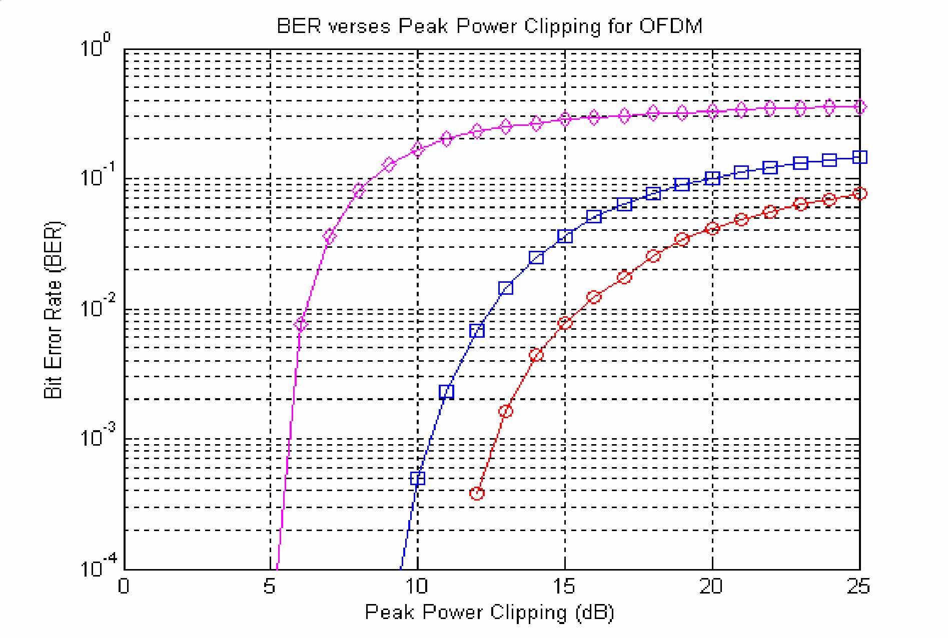


Figure 4.8: BER v/s Power Clipping for an OFDM system

The effect of power clipping to the performance of OFDM system for three modulation techniques including BPSK, QPSK and 16PSK is shown in Figure 4.8 above. It can be observed from Figure 4.8 that to have the BER of 10-3 or below, the OFDM signal using BPSK modulation can be clipped up to about 13 dB, the OFDM signal using QPSK modulation can be clipped up to about 10 dB and the OFDM signal using 16PSK modulation can be clipped up to about 5 dB. It can be concluded from the analysis result that the OFDM signal is resistant enough to clipping distortion caused by nonlinearity in power amplifier used in transmitting the signal.

5- The effect of Doppler Shift on performance of OFDM Signal:

The study of the effect of Doppler Shift in Fading Channel on the Bit Error Rate in the signal transmission in OFDM system is done using the model designed using SIMULINK. The result obtained is shown in the tabular format as below:

The parameters concerning the Fading Channel used are:

Initial Speed=73

Gain Value= [0 -3]

Delay Vector=[0 2e-6]

Sl.No.	**Maximum Doppler Shift Frequency (Hz)**	**Error Rate**	**No. of Error Bit**	**Total No. of Bits**
1	0.0001	1	384384	384384
2	0.0005	0.4485353	172410	384384
3	0.001	0.2708515	104111	384384
4	0.009	0.2482387	95419	384384
5	0.01	0.4181625	160735	384384
6	0.1	0.481544	185098	384384
7	1	0.495858	190600	384384
8	10	0.499607	192041	384384

Table 4.1 Variation of BER with Doppler Shift Effect

It can be seen from the tabulation that at a very high Doppler Shift Frequency and at a very low Doppler Shift Frequency the Bit Error Rate (BER) tend to increase and have a very high value as compared to mid range frequency.

4.2 CDMA SIMULATION RESULTS: The DS-CDMA structure is simulated for number of users like 2, 4, 6, etc. The simulated results are shown and analyzed as follows.

1- The Effect of AWGN channel on CDMA signal: This is a result between the BER and SNR in an AWGN channel for different number of user. It can be seen that as the number of user in the CDMA system rises the SNR requirement for a BER of 10^{-2} also increases. The SNR requirement for the 2 user network is very low as 2.5dB. But as the number of user increases in the system the SNR requirement also increases drastically. In fact it can be seen from figure 4.9 that for 6 users the BER of 10^{-2} is achieved at a very high SNR.

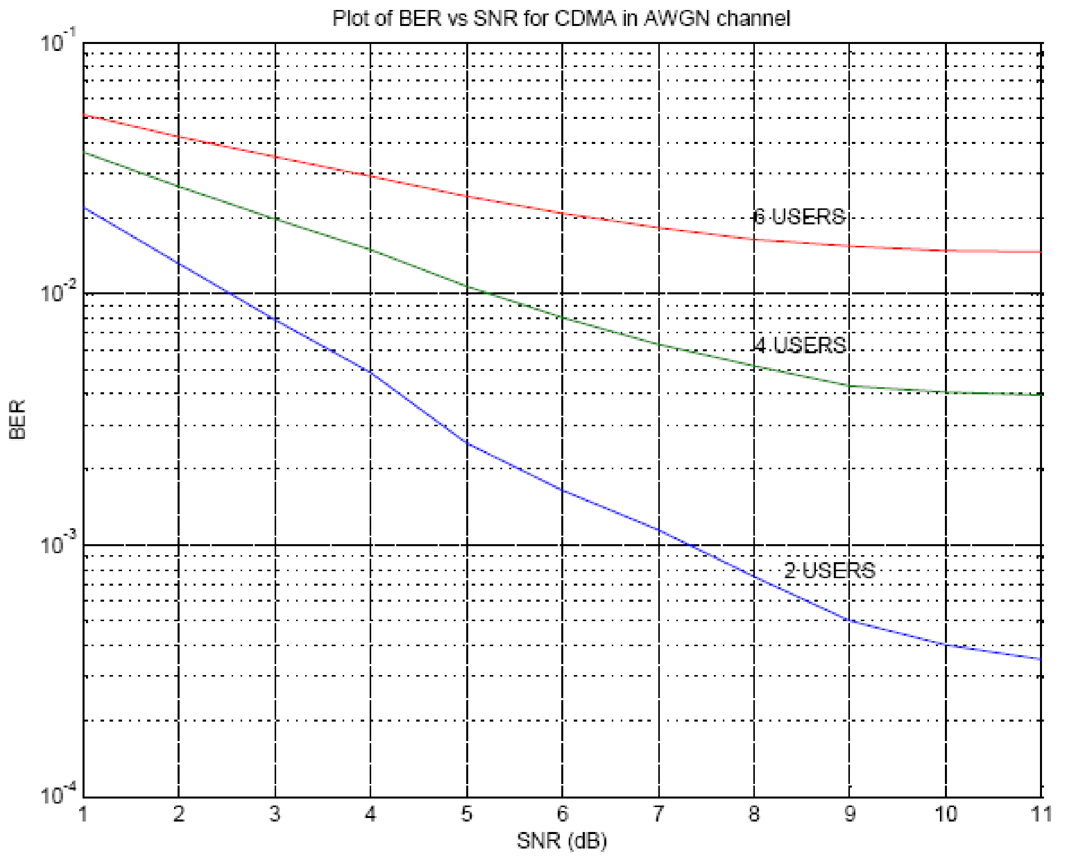


Figure 4.9: BER v/s SNR in AWGN channel for CDMA system

2- The Effect of Number of Users on BER in CDMA system: This is a interesting data simulated though the use of the DS-CDMA model in SIMULINK®. It is a plot showing how the BER varies as the number of user in the system increases for a specific SNR. In this case the SNR value used is around 5dB. It is very evident from the figure 4.10 that BER increases almost exponentially as the number of user in the system increases upto a certain limit. Hence it can be concluded that the DS-CDMA system becomes vulnerable when the number of users in the system goes up. But the BER does not keep on increasing as number of users goes up. From a certain number of users the BER saturates and remains constant at a particular SNR level. Apart from these other CDMA techniques are used likes of MC-CDMA, WCDMA to name a few.

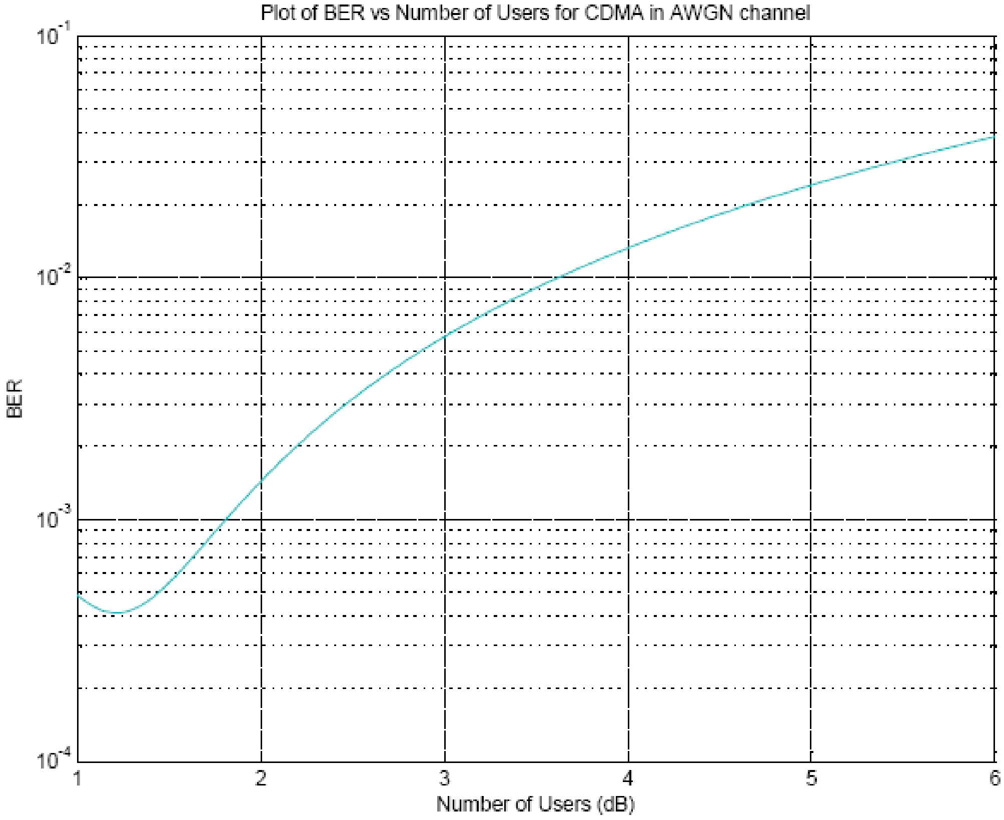


Figure 4.10: BER v/s No. of User plot

The following graph in figure 4.11 has been taken from reference [7]. It shows the variation of BER when the number of users go as high as 64. It can be seen for the figure 4.11 that when the number of users becomes greater than 8 then the BER becomes significantly higher. This indicates that the inter-user interference is a weak point of the CDMA system. And the number of users in the cell is limited from 8 to 12.

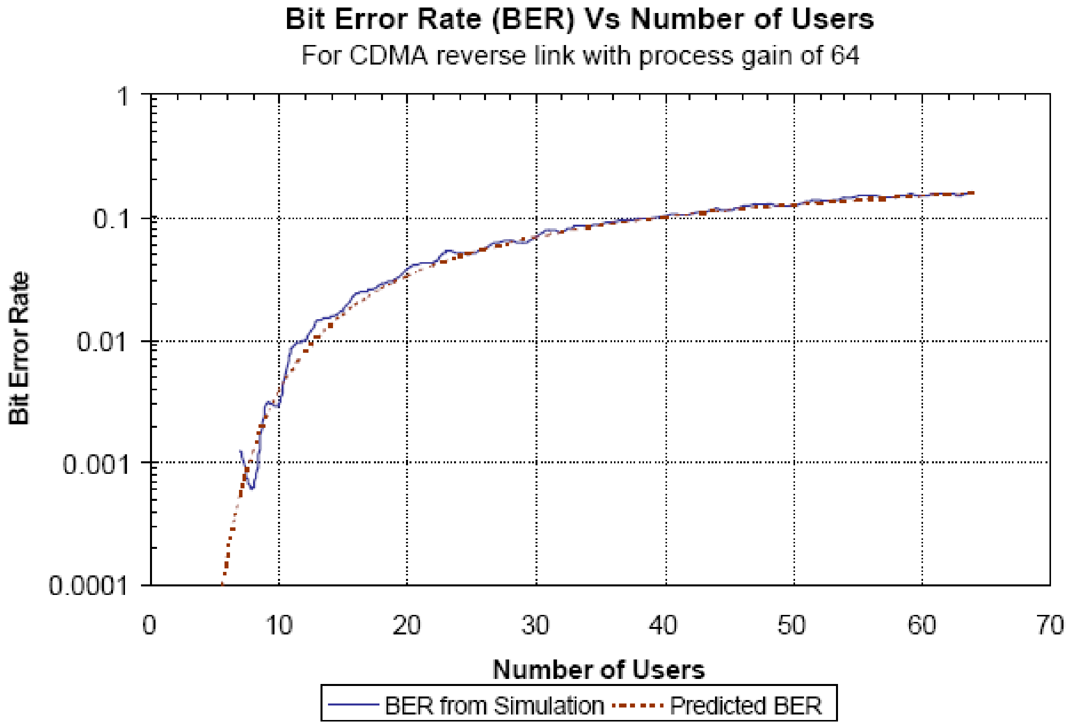


Figure 4.11: BER v/s No. of user in a cell for reverse link in CDMA

CHAPTER-5

CONCLUSION

In this project the performance of OFDM technique in mobile radio channel has been studied. Its performance in the presence of noise, various fading effects like multipath fading, frequency selective fading, and Doppler Effect has been analyzed. It has been found that –

1. From the BER vs. SNR in a fading channel, it was observed that OFDM is very tolerant to the channel fading effects. Although the BER for higher SNR is somewhat greater in fading channel than an AWGN channel but the difference is very less and the two responses are almost similar. Hence it can be concluded that OFDM is suitable for use in a fading channel.
2. From the BER vs. Peak power clipping curve, it can be concluded that OFDM is resistant enough to clipping distortion caused by the nonlinearity in the power amplifier used in transmitting the signal.
3. The effect of Doppler shift on the performance of OFDM system has also been analyzed. It was observed that at very high and very low Doppler shift frequency, BER tend to increase and have a high value as compared to that in the mid-frequency region.
4. It was found that the performance of OFDM is comparable to CDMA in many respects and in some cases, it is even better than CDMA in various single and multi-cell environment. For instance the number of users allowed by the OFDM system was found to be around 10 times more than that in CDMA in a single cell environment and around 4 times more in a multi-cell environment.
5. It was observed that in a multi-cellular environment where a single frequency is used in all the cells, CDMA performance is better than OFDM. Also in a multi-user environment,

in case of OFDM, the receiver may require a very large dynamic range for the purpose of handling large signal strength in between various users.

This project was basically concentrated on OFDM and the study of its performance in the mobile radio channel. However much work needs to be done to study the forward error correction schemes for OFDM. Also in our project we used a particular modulation technique irrespective of the type of data that is to be transmitted like BPSK, QPSK etc. However suitable techniques can be studied whereby different modulation schemes could be used for different types of data. In our model we used a fixed data rate. However a study of adaptive modulation and coding over a dispersive multipath fading channel can be carried out whereby the simulation varies the data rate dynamically.

Finally it could be concluded that OFDM promises to be a suitable technique for data communication in a mobile radio channel and is going to play a major role in wireless communication in the present and the future.

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APPENDIX

SIMULATION DATA IN OFDM USING VARIOUS MODULATIONS:

BPSK Modulation:

SNR	**BER**	**No. of Error Bit**	**Total No. of Bits**
0	0.189	36376	192192
1	0.161	31050	192192
2	0.134	25765	192192
5	0.057	11098	192192
7	0.023	4557	192192
10	0.002	523	192192
12	0.00019	37	192192
15	0	0	192192

QPSK Modulation:

SNR	**BER**	**No. of Error Bit**	**Total No. of Bits**
0	0.329	126554	384384
2	0.277	106623	384384
4	0.215	82916	384384
5	0.182	70007	384384
6	0.147	56691	384384
8	0.083	32190	384384
10	0.035	13466	384384
12	0.009	3761	384384

16-PSK Modulation:

SNR	BER	No. of Error Bit	Total No. of Bits
0	0.428	329706	768768
2	0.408	313741	768768
4	0.382	293819	768768
6	0.350	269795	768768
8	0.314	241593	768768
10	0.274	210656	768768
12	0.229	176716	768768
14	0.181	139593	768768

***64-PSK Modulation*:**

SNR	BER	No. of Error Bit	Total No. of Bits
0	0.419	242111	577152
2	0.399	230376	577152
4	0.374	216417	577152
6	0.346	200252	577152
8	0.317	183362	577152
10	0.287	166155	577152
12	0.259	149692	577152
14	0.230	133104	577152
16	0.202	116587	577152
18	0.172	99777	577152

SIMULATION DATA FOR COMPARING FADING AND NON FADING CHANNEL:

SNR	Non-Fading Channel(only AWGN)		Fading Channel included(Rayleigh Fading)		Total No. of Bits
	BER	No. of Error Bits	BER	No. of Error Bits	
1	0.460	176870	0.465	178597	384384
2	0.455	174964	0.460	176970	384384
3	0.450	172979	0.455	175043	384384
4	0.444	170652	0.450	172955	384384
5	0.437	168076	0.444	170698	384384
6	0.430	165098	0.437	168150	384384
7	0.421	161955	0.429	165245	384384
8	0.412	158362	0.421	161973	384384
9	0.401	154249	0.412	158462	384384
10	0.389	149681	0.402	154561	384384
12	0.363	139382	0.378	145315	384384
14	0.329	126418	0.349	134034	384384
16	0.289	111072	0.314	120598	384384
18	0.242	92882	0.274	105261	384384
20	0.189	72609	0.229	88283	384384
22	0.133	51267	0.185	70950	384384
24	0.080	30968	0.143	54914	384384
26	0.03	14848	0.106	40914	384384