CHAPTER 1

INTRODUCTION

1.1 EVOLUTION OF OFDM

In the classical parallel data system, the total signal frequency band is divided into N non-overlapping frequency sub channels. Each sub channel is modulated with a separate symbol and then these N sub channels are frequency is multiplexed. It seems good to avoid spectral overlap of channels to eliminate Inter Channel Interference (ICI). However, this leads to an inefficient use of the available spectrum. To cope with this inefficiency, the idea proposed since the mid-1960s was to use parallel data streams and Frequency Division Multiplexing (FDM) with overlapping sub channels, spaced apart in frequency to avoid the use of high speed equalization and to combat impulsive noise and multipath distortion, as well as to fully use the available bandwidth. This takes advantage of frequency null of all frequencies except the desired one.

Orthogonal Frequency Division Multiplexing (OFDM) is an alternative wireless modulation technology to Code Division Multiplexing Access (CDMA). OFDM has the potential to surpass the capacity of CDMA systems and provide the wireless access method for 4G systems. OFDM is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments.
1.2 EVOLUTION OF MULTI CARRIER CODE DIVISION MULTIPLE ACCESS

The third generation wireless communication technologies for mobile networks have progressed rapidly over the past decade. Evolving from Wide band Code Division Multiple Access (WCDMA) and High Speed Packet Access (HSPA) to Long Term Evolution (LTE), the ultimate goal of these standards has been to significantly increase data transfer rates in order to meet the demand of latest wireless services such as mobile internet, video telephony, and high quality multimedia streaming.

The recent invention of Multiple Input Multiple Output (MIMO) system that uses multiple transmit and receive antennas showed that the capacity of MIMO systems can grow linearly with the number of transmit antennas provided that the number of receive antennas is greater than or equal to the number of transmit antennas. This discovery ensured a linear increase of data rate with the number of transmitting antennas without increasing the transmission bandwidth or the total transmitted power.

(Source: Egle et al. 1997)
Figure 1.1 MC-CDMA with QAM Modulation

Multi Carrier Code Division Multiple Access (MC-CDMA) combines the robustness to multipath fading accomplished by Orthogonal Frequency Division Multiplexing (OFDM), with the enhanced frequency diversity that can be achieved by Code Division Multiple Access (CDMA). When integrated with MIMO, MC-CDMA can realize very high data transfer rates in rich multipath scattering environments without increasing the transmission bandwidth of the system, which is taken as the platform for this research work.

1.3 NEED FOR MULTI CARRIER COMMUNICATION

Multi Carrier Code Division Multiple Access (MC-CDMA) is a multiple access scheme used in OFDM based telecommunication systems, allowing the system to support multiple users at the same time. MC-CDMA spreads each user symbol in the frequency domain. Each user symbol is carried over multiple parallel subcarriers, but it is phase shifted typically between 0 or 180 degrees according to a code value. The code values differ per subcarrier and per user. The receiver combines all subcarrier signals, by weighing these to compensate varying signal strengths and undo the code shift. The receiver can separate signals of different users, because these have different orthogonal code values. Since each data symbol occupies a much wider bandwidth than the data rate, a Signal to Noise Interference Ratio of less than 0 db decibel is feasible. One way of interpreting MC-CDMA is to regard it as a Direct Sequence CDMA signal (DS-CDMA) which is transmitted after it has been fed through an inverse Fast Fourier Transform (FFT).
1.4 TECHNOLOGY INVOLVED IN MULTICARRIER COMMUNICATION

Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA) are the three major access techniques used to share the available bandwidth in a wireless communication system. These techniques can be grouped as narrowband and wideband systems, depending upon the available bandwidth are allocated to the users. The duplex technique of a multiple access system is usually described along with the particular multiple access scheme.

1.4.1 Frequency Division Duplexing

Duplexing may be done using frequency or time domain technique. Frequency Division Duplexing (FDD) provides two distinct bands of frequencies for every user. The forward band provides traffic from the base station to the mobile, and the reverse band provides traffic from the mobiles to the base station. In FDD, any duplex channel actually consists of two simplex channels, and a device called a duplexer is used inside each subscriber unit and base station to allow simultaneous bidirectional radio transmission and reception for both the subscriber unit and the base station on the duplex channel pair. The frequency separation between each forward and reverse channel is constant throughout the system, regardless of the particular channel being used.

1.4.2 Time Division Duplexing

Time Division Duplexing (TDD) uses time instead of frequency to provide both a forward and reverse link. In TDD, multiple users share a
single radio channel by talking turns in the time domain. Individuals users are allowed to access the channel in assigned time slots, and each duplex channel has both a forward time slot and a reverse time slot to facilitate bidirectional communication. If the time separation between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous to the users at both the subscriber unit and on the base station side.

1.4.3 Multiple Access

Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA) are the three major access techniques used to share the available bandwidth in a wireless communication system. These techniques can be grouped as narrowband and wideband systems, depending upon how the available bandwidth is allocated to the users. The duplexing technique of a multiple access system is usually described along with the particular multiple access scheme.

1.4.4 Narrowband System

The term narrow band is used to relate the bandwidth of a single channel to the expected coherence bandwidth of the channel. In a narrowband multiple access system, the available radio spectrum is divided into a large number of narrow channels. The channels are usually operated using Frequency Division Duplex (FDD). To minimize interference between forward and reverse links on each channel, the frequency separation is made as great as possible within the frequency spectrum, while still allowing inexpensive duplexers and a common transceiver antenna to used in each subscriber unit.
In narrowband Frequency Division Multiple Access (FDMA), a user is assigned a particular channel that is not shared by other users in the system. This is called FDMA/FDD. Narrowband Time Division Multiple Access (TDMA), on the other hand, allows users to share the same radio channel but allocates a unique time slot to each user in a cyclical manner on the channel. A small number of users can access the channel at any instant of time. For narrowband TDMA systems, there are generally a large number of radio channels allocated using either FDD or Time Division Duplex (TDD), and each channel is shared using TDMA. Such systems are called TDMA/FDD or TDMA/TDD access systems.

1.4.5 Wideband System

Wideband Systems, the transmission bandwidth of a single channel is much larger than the coherence bandwidth of the channel. Thus, multipath fading does not greatly vary the received signal power within a wideband channel, and frequency selective fades occur in only a small fraction of the signal bandwidth at any instance of time.

Wideband Multiple Access Systems allow a large number of transmitters to transmit on the same channel. TDMA allocates time slots to the many transmitters on the same channel and allows only one transmitter to access the channel at any instant time, whereas spread spectrum Code Division Multiple Access (CDMA) allows all of the transmitters to access the channel at the same time. TDMA and CDMA system may use either FDD or TDD multiplexing techniques.

FDMA, TDMA, and CDMA, three other multiple access schemes will soon be used for wireless communications. These are Packet Radio (PR) and Space Division Multiple Access (SDMA). In the chapter, the above mentioned multiple access techniques, their performance, and their capacities
in digital wireless systems are discussed. The different multiple access techniques being used in various wireless communication systems.

1.4.6 Spread Spectrum Multiple Access

Spread Spectrum Multiple Access (SSMA) uses signals which have a transmission bandwidth that is several orders of magnitude greater than the minimum required Radio Frequency (RF) bandwidth. A Pseudo Noise (PN) sequence converts a narrowband signal to a wideband noise like signal before transmission. SSMA also provides immunity to multipath interference and robust multiple access capability. SSMA is not very bandwidth efficient when used by a single user.

Many user share the same spread spectrum bandwidth without interfering with one another, spread spectrum systems become bandwidth efficient in a multiple user environment. There are two main types of spread spectrum multiple access techniques Frequency Hopped Multiple Access (FH) and Direct Sequence Multiple Access (DS). Direct sequence multiple access is also called Code Division Multiple Access (CDMA)

1.4.7 Frequency Division Multiple Access (FDMA-MA)

Frequency Division Multiple individual Access (FDMA) assigns individual channels to individual users. Each user is allocated a unique frequency band or channel. These channels are assigned on demand to users in request service. During the period of the call, no other user can share the same channel. The Frequency Division Duplex (FDD) systems, the users are assigned a channel as a pair of frequencies, one frequency is used for the forwarded channel, and the other frequency is used for the reverse channel.
1.4.8 Time Division Multiple Access (TDMA-MA)

Time Division Multiple Access (TDMA) Systems divided the radio spectrum into time slots, and in each slot only one user is allowed to transmit or receive.

![TDMA Frame Structure](#)

(Source: El Badry et al. 2012)

Figure 1.2 TDMA Frame Structure

Each user occupies a cyclically repeating time slot, so a channel thought of as a particular time slot reoccurs every frame, where N time slots comprise a frame. TDMA systems transmit data in buffer and burst method, thus the transmission for any user is non continuous. This implies in FDMA systems accommodate Analog Frequency Modulation (FM), digital data and digital modulation must be used with TDMA. The transmission from various users in interlaced into a repeating frame structure. A frame consists of a number of slots. Each frame is made up of a preamble, an information message, and trail bits.

The Time Division Multiplexing Access / Time Division Duplex (TDMA/TDD), half of the time slots in the frame information message would be used for the forward link channels and half would be used for reverse link
channels. In Time Division Multiplexing Access / Frequency Division Duplex (TDMA/FDD) systems, an identical or similar frame structure would be used solely for either forward or reverse transmission, but the carrier frequencies would be different for the forward and reverse links.

In general, TDMA/FDD systems intentionally induce several time slots of delay between the forward and reverse time slots for a particular user, so that duplexers are not required in the subscriber unit.

A TDMA frame contains the address and synchronization information that both base station and the subscribers use to identify each other. Guard times are utilized to allow synchronization of the receivers between different slots and frames.

1.4.9 Code Division Multiple Access (CDMA-MA)

The Code Division Multiple Access (CDMA) systems, the narrow band message signal is multiplied by a very large band width signal called the spreading signal. The spreading signal is a pseudo noise coded sequence has a chip rate is orders of magnitudes greater than the data rate of the message. All users in CDMA systems use the same carrier frequency and may transmit simultaneously.

Each user has its own pseudo random code word is approximately orthogonal to all other code words. The receiver performs a time correlation operation to detect only the specific desired code word. All other code words appear as noise due to de correlation. For detection of the message signal, the receiver needs to know the code word used by the transmitter. Each user operates independently with no knowledge of the other users.
In CDMA, the power of multiple users at a receiver determines the noise floor after decoder relation. If the power of each user within a cell is not controlled such that they appear equal at the base station receiver, then the near far problem occurs.

The near far problem occurs many mobile users share the same channel. In general, the strongest received mobile signal will capture the demodulator at a base station. In CDMA, stronger received signal levels raise the noise floor at the base station demodulators for the weaker signals, decreasing the probability that weaker signals will be received. The near–far problem, power control is used in most CDMA implementations. Power control is provided each base station in a cellular system and assures the each mobile within the base station coverage area provides the same signal level to the base station receiver.

1.4.10 Frequency Hopped Multiple Access

Frequency Hoped Multiple Access (FHMA) is a digital multiple access system in which the carrier frequencies of the individuals users are varied in a pseudorandom within a wideband channel. FHMA allows multiple users to simultaneously occupy the same spectrum at the same time, where each user dwells at a specific narrowband channel at a particular instance of time, based on the particular Pseudo Noise (PN) code of the user. The digital data of each user is broken into uniform sized bursts which are transmitted on different channels within the allocated spectrum band. The instantaneous bandwidth of any one transmission burst is much smaller than the total spread bandwidth.

The pseudorandom change of the channel frequencies of the user randomizes the occupancy of a specific channel at any given time, thereby
allowing for multiple access over a wide range of frequencies. The Fast Hopping (FH) receiver, a locally generated PN code is used to synchronize the receiver’s instantaneous frequency with that of the transmitter. At any given point in time, a frequency hooped signal only occupies a single, relatively narrow channel since narrowband Frequency Modulation (FM) or Frequency shift Keying (FSK) is used. The difference between Frequency Hop Multiplexing Access (FHMA) and a traditional Frequency Division Multiple Access (FDMA) system is that the frequency hopped signal changes channels at rapid intervals. If the rate of change of the carrier frequency is greater than the symbol rate, then the system is referred to as a fast frequency hopping system. If the channel changes at a less than or equal to the symbol rate, it is called slow frequency hopping.

A fast frequency hopper may thus be thought of as an FDMA system which employs frequency diversity. FHMA systems often employ energy efficient constant envelope modulation. Inexpensive receivers may be built to provide non-coherent detection of FHMA. This implies that linearity is not an issue, and the power of multiple users at the receiver does not degrade FHMA performance.

1.4.11 Space Division Multiple Access

Space Division Multiple Access (SDMA) controls the radiated energy for each user in space. It can be seen from that SDMA serves different users by using spot beam antennas. These different areas covered by the antenna beam may be served by the same frequency in a TDMA or CDMA or different frequencies in FDMA system.
1.4.12 Evolution Data Optimized

Evolution Data Optimized (EVDO) is a telecommunications standard for the wireless transmission of data through radio signals, typically for broadband internet access. EVDO is an evolution of the CDMA2000 (IS-2000) standard that supports high data rates and can be deployed along side a wireless carriers voice services. It uses advanced multiplexing techniques including Code Division Multiple Access (CDMA) as well as Time Division Multiplexing (TDM) to maximize throughput. It is a part of the CDMA2000 family of standards and has been adopted by many mobile phone service providers around the world particularly those previously employing CDMA networks. It is also used on the Global star satellite phone network.

An EVDO International Standard channel has a bandwidth of 1.25 MHz, the same bandwidth size that IS-95A (IS-95) and IS-2000 use. The channel structure, on the other hand, is very different. Additionally, the back end network is entirely packet based, and thus is not constrained by the restrictions typically present on a circuit switched network.

The EVDO feature of CDMA2000 networks provides access to mobile devices with forward link air interface speeds of up to 2.4 M bit/s with real value and up to 3.1 M bit/s. The reverse link rate for real value can operate up to 153 k bit/s, while the real value. A can operate at up to 1.8 M bit/s. It was designed to be operated end-to-end as and Internet Protocol (IP) based network, and so it can support any application which can operate on such a network and bit rate constraints.
1.5 ROLE OF MC-CDMA:

1. MC-CDMA is a form of CDMA or spread spectrum, but apply the spreading in the frequency domain (Rather than the time domain as in Direct Sequence CDMA).

2. MC-CDMA is a form of Direct Sequence CDMA, but after spreading, a Fourier Transform (FFT) is performed.

3. MC-CDMA is a form of Orthogonal Frequency Division Multiplexing (OFDM), but we first apply an orthogonal matrix operation to the user bits. Therefore, MC-CDMA is sometimes also called "CDMA-OFDM".

4. MC-CDMA is a form of Direct Sequence CDMA, but our code sequence is the Fourier Transform of a Walsh Hadamard (WH) sequence.

5. MC-CDMA is a form of frequency diversity. Each bit is transmitted simultaneously in parallel on many different subcarriers. Each subcarrier has a constant phase offset. The set of frequency offsets form a code to distinguish different users.

The MC-CDMA method described here is not the same as Direct Sequence Code Division Multiple Access (DS-CDMA) using multiple carriers. In the latter system the spread factor per subcarrier can be smaller than with conventional DS-CDMA. Such a scheme is sometimes called MC-DS-CDMA. This does not use the special OFDM like waveforms to ensure dense spacing of overlapping, orthogonal subcarriers. Multi Carrier Direct Sequence Code Division Multiple Access (MC-DS-CDMA) has advantages over DS-CDMA as it is easier to synchronize to this type of signals.
1.6 ORGANIZATION OF THE THESIS

The thesis is organized in the form of six chapters.

**Chapter 1** of the thesis provides the required introductory concept of evolution OFDM and Multi carrier CDMA techniques. The challenges involved in high data transfer among modulation techniques are discussed.

**Chapter 2** reviews the previous research equalization techniques in the literature. An extensive survey on Multiple input Multiple output communication systems and different modulation techniques are listed and a detailed analysis is carried out.

**Chapter 3** discusses the implementation of OFDM based Multi carrier CDMA technique is used for interconnecting channel estimation like Additive White Gaussian Noise (AWGN) are used and also evaluate the QAM modulation technique various levels are discussed.

**Chapter 4** deals with the evaluation of wireless system to use the multiple antennas in transmitter and receiver section. This work focuses on the advantages of 5G wireless networks and implement OFDMA technologies and discussed.

**Chapter 5** concerned with developing channel estimation with various modulation techniques are used to the BER performance of AWGN and Rayleigh channel are discussed.

**Chapter 6** discussed the developed implementation of OFDM and MC-CDMA in communication channels and concludes the study with a research work. Future research issues related to the present work are discussed.