Abstract — Code Division Multiple Access (CDMA) is currently dominating air interface technique used in wireless communications for 3G and 4G systems. Multicarrier CDMA has become the focus of current research interests in wireless digital communication. Multi carrier CDMA, Orthogonal Frequency Division Multiplexing (OFDM) techniques used for 3rd Generation and 4th Generation wireless network systems allow high data rate transmission. Rapid time variations of the wireless channel have an effect on the performance of CDMA systems. The objective of the paper is to provide a survey on CDMA transmission techniques for 3G and 4G systems and performance analysis of Multicarrier CDMA system model for different spreading sequences like Walsh codes, PN codes and Gold codes implemented on Rayleigh fading channel and Additive White Gaussian Noise (AWGN) channel using MATLAB.

Index Term — CDMA, OFDM, Rake Receiver.

I. INTRODUCTION

The past decade has seen many advances in physical-layer wireless communication theory and their implementation in wireless systems. Ref [7], [8], [9] First generation mobile phones were based in frequency modulated analog technology. This system supports only voice data. Second generation technology is digital and capable of accommodating data in addition to voice. The 3G mobile is based on Code Division Multiple Access supporting voice and data service with high quality and multimedia services with higher capacity. 4G is based on Orthogonal Frequency Division Modulation (OFDM) used for Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) IEEE 802.11a & IEEE 802.11g. 2.5G, 3G, 4G comparison with respects to different parameters its existence, developments, capacity coverage area applications are considered in Table I.

Code Division Multiple Access (CDMA) is a spread spectrum technology which along with the rake receiver concept helps to minimize communication errors resulting from multipath effects. Ref [1] The spread spectrum technology aims to spread the information signal over a wide bandwidth to render jamming and interception more difficult.

CDMA 2000 has been deployed in the existing IS-95 system and will exhibit numerous enhancements. Ref [2] It allows multiple users to share the same spectrum, different types of hand-offs provided. Ref[20], [21] Due to its wide BW and rake receiver, CDMA uses the multipath signals and combines them to make a stronger signal at the receiver which provides higher BW efficiency and immunity to multipath fading.

Wideband Code Division Multiple Access (WCDMA) has attracted the most attention in the development of third generation wireless systems (International Mobile Telecommunications (IMT)-2000) in the year 2000. Ref [20] WCDMA applications include messaging, voice, web browsing, video conferencing, video surveillance, high quality audio, and database access. However, the performance of wideband CDMA is limited by Multiple Access Interference (MAI) as well as Inter Symbol Interference (ISI) in the presence of multipath fading scenario which results in possible frequency-selective fading.

Ref [3] To combat the problem of multipath and channel frequency selectively for single carrier or multicarrier transmission techniques, a Multicarrier (MC) transmission technique which is also known as Orthogonal Frequency Division Multiple Access (OFDMA) was considered. Ref[4] OFDM was first introduced in the late 60’s based on multicarrier modulation techniques used in the high frequency military radio in 1971. Weinstein introduced the idea of using a Discrete Fourier Transform (DFT) for the implementation of the generation and reception of OFDM signals, elimination the requirement for banks of analog subcarrier oscillators. OFDM eliminates Inter Symbol Interference (ISI), Inter Carrier Interference (ICI) by use of cyclic prefix. The advantages of OFDM are resistance to multipath fading, reduced cross channel interference, reduction in the amount of frequency spectrum increase in system capacity, efficient use of bandwidth and above all orthogonal subcarriers can perfectly overlap each other. However, OFDM is more sensitive to frequency offset and phase noise. OFDM has relatively large Peak to Average Power Ratio (PAPR), which tends to reduce the power efficiency of the RF Amplifier. But it is not ideal for mobile communications.
In recent years, MC-CDMA has been receiving widespread interest for future wireless communications by combining OFDM modulation and CDMA. "Ref [5]" A new scheme is developed which reaps the benefits of both techniques like high spectral efficiency, multiple access capability, robustness in case of frequency selective channels. However, OFDM signal has the large Peak to Average Power Ratio (PAPR) which severely limits its application, as long as the basic operation of MC-CDMA is identical to OFDM system. In recent years, there have been tremendous efforts in research activities related to spread spectrum techniques, CDMA, DS-CDMA, OFDM, MC-CDMA transmission techniques which have been proven to increase the application bit rates of wireless communications. MC-CDMA and OFDM are emerging key technologies for 3G and 4G wireless systems. The growing demand for multimedia services requires high data rates for transmission, but this condition is significantly limited by Inter Symbol Interference (ISI) due to existence of multiple paths. "Ref [23]" The combination of Multicarrier Modulation (OFDM) and CDMA techniques is used to combat this problem. The research on this rapidly expanding area of wireless communications field is carried out from the past two decades.

This paper is organized as follows. Section II-V describes the Direct Sequence Spread Spectrum (DSSS) system model, Multi User Detection (MUD) model, Orthogonal Frequency Division Multiplexing (OFDM) and Multicarrier Code Division Multiple Access (MC-CDMA) system models. In section VI, the performance of MC-CDMA transmission system at Rayleigh fading channel and AWGN channel properties are studied and analyzed by using MATLAB simulations. Within these simulations, Walsh codes, PN codes, Gold codes are used for spreading sequences for MC-CDMA. Conclusions are drawn in section VII.

### II. DSSS Technique

In Direct sequence spread spectrum base band wave form is XOR by PN sequence in order to spread the signal. After spreading, the signal is modulated using Binary phase shift keying then transmitted as shown in Figure 1. "Ref [14]" The transmitted signal is represented by

\[ x(t) = (\sqrt{2E_b|T_s|})[b(t) \times c(t)] \cos(2\pi f_c t + \theta) \]

The demodulator, demodulates the BPSK signal first, filters the same and then disperses the filtered signal, to obtain the original data as shown in Figure 2. The process of original data is represented by

\[ b(t) = [x(t) \cos(2\pi f_c t + \theta) \times c(t)] \]

- \( b(t) \) is binary information.
- \( c(t) \) is PN spreading code.
- \( f_c \) is carrier frequency.
- \( T_s \) is duration of data symbol.
- \( \theta \) is carrier phase angle.
- \( E_b \) is transmitted energy per bit.

![Figure 1. DS SS Transmitter Block Diagram](image)
III. MUD BPSK SIMPLIFIED MODEL

“Ref [15]” In CDMA systems all users transmit simultaneously in the same frequency band. Therefore if k users are active. The received base-band, continuous signal is a superposition of all k signals. The base band signal for the k\textsuperscript{th} user is

\[ X_k(t) = \sum_{n=0}^{N} b_k(n) c_k(n) p_k(t - (T_c - T_s)) \]

\( b_k(n) \) is the n\textsuperscript{th} input signal for the k\textsuperscript{th} user,
\( c_k(n) \) is the real positive channel gain
\( p_k(t) \) is the signature waveform containing the PN sequence

\[ T_s \] = Transmission delay

For synchronous CDMA \( T_s = 0 \)

Received signal at base band

\[ y(t) = \sum_{K=1}^{K} X_k(t) + n(t) \]

K is the number of the users and \( n(t) \) is the complex Additive White Gaussian Noise (AWGN).

IV. OFDM SYSTEM

OFDM transmission scheme is used to eliminate multipath fading for wireless broadband multimedia communication systems (WBMCS). “Ref [22]” OFDM is based on a parallel data transmission scheme that reduces the effects of multipath fading and renders complex equalizers unnecessary. “Ref [17]” In general, OFDM systems are implemented using a combination of Fast Fourier transform (FFT) and Inverse Fourier Transform (IFFT) blocks that are mathematically equivalent versions of the DFT and IDFT respectively. The transmitter block diagram as shown in Figure 3. An OFDM system treats the source symbols as though they are in the frequency domain.

These symbols are fed to an IFFT block which brings the signal into the time domain. If the N number of subcarriers are chosen for the system, the basic functions for the IFFT are N orthogonal sinusoidal of distinct frequency and IFFT receive N symbols at a time. Each of N complex valued input symbols determines both the amplitude and phase of the sinusoidal for that subcarrier. The output of IFFT is the summation of all N sinusoidal and makes up a single OFDM symbol. The length of the OFDM symbol is NT where T is the IFFT input symbol period. At the receiver block diagram as shown in Figure 4, the FFT block diagram performs the reverse process on the received signal and brings it back to frequency domain.

V. MC CDMA SYSTEM

In 1993, new multiple access schemes based on a combination of CDMA and multicarrier (OFDM) techniques are proposed, such as multicarrier-CDMA (MC-CDMA). “Ref [16], [18], [19]” Different users transmit the same set of subcarriers but with a spreading code that is orthogonal to the codes of other users. The resulting signal has an orthogonal code structure in the frequency domain. Multicarrier CDMA system as a form of spread spectrum with spreading in the frequency domain as the spreading code is fixed over time while varying the subcarrier frequency. MC-CDMA is a form of frequency diversity. Each sub carrier has a constant phase offset that forms the code to separate users.

The transmitter is basically an OFDM system with additional spreading used by a specific spreading sequence like Walsh codes, Gold codes, PN codes are used mostly at the input. The spread symbols are modulated by MC modulation by Inverse Fast Fourier Transform (IFFT) operation as shown in Figure 5.

“Ref [12], [13]” The receiver is an OFDM receiver with an additional combining operation to isolate the transmitter for the user of interest as shown in Figure 6, by using a general interval; the receiver selects the portion of the signal that is free from ISI. This is progressed by an FFT block to demodulate the multiple accesses.
“Ref [5]” MC-CDMA combines the advantages of CDMA and OFDM against multipath and impulse noise. “Ref [9], [20], [21]” The specifications of different CDMA systems are tabulated in the form of a table as shown in Table II.

<table>
<thead>
<tr>
<th>Receiver</th>
<th>CDMA - 2000/WCDMA</th>
<th>OFDM</th>
<th>MC-CDMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAKE + MUD</td>
<td>Multicarrier Receiver</td>
<td>Multicarrier Receiver</td>
<td></td>
</tr>
<tr>
<td>Carrier spacing (MHz)</td>
<td>1.225, 3.1, 10, 20</td>
<td>20 MHz sub carrier spacing 312.5 KHz</td>
<td>20 MHz sub carrier spacing 312.5 KHz</td>
</tr>
<tr>
<td>Frequency length ms</td>
<td>10ms</td>
<td>10ms, 20ms, 30ms</td>
<td>10ms, 20ms, 30ms</td>
</tr>
<tr>
<td>Channel coding</td>
<td>Rate 1/2, 1/3</td>
<td>Rate 1/2, 1/3, 1/4</td>
<td>Rate 1/2, 1/3, 1/4</td>
</tr>
<tr>
<td>Interleaving</td>
<td>Inter frame</td>
<td>Inter frame</td>
<td>Interleaving</td>
</tr>
<tr>
<td>Data</td>
<td>144 Kbps</td>
<td>6, 9, 12, 18, 24, 36, 48, 54 Mbps</td>
<td>Up to 10 Mbps</td>
</tr>
<tr>
<td>Modulation</td>
<td>FL-QPSK</td>
<td>BPSK, QPSK, 16QAM, 64 QAM</td>
<td>BPSK, QPSK, 16QAM, 64 QAM</td>
</tr>
</tbody>
</table>

VI. SIMULATION RESULTS

The Bit Error Rate (BER) performance of the Multicarrier CDMA system using frequency domain spreading has been evaluated using MATLAB and the obtained graphs as shown in figures 7, 8 & 9. The BER is computed as a function of the Signal to Noise Ratio (SNR) per bit namely $E_b/No$, using parameters of $K = 2$ (Number of users), $N_c = 4$ (Number of subcarriers). The Performance of the three spreading codes for MC-CDMA viz. Walsh codes, Gold codes and PN code sequences to determine the system with the least BER and minimum Multiple Access Interference (MAI). The study of MC-CDMA transmission system using Rayleigh fading channel and AWGN channel for K users and three spreading sequences has been carried out successfully. The orthogonal Walsh codes in MC-CDMA give better results than PN m-sequence codes and Gold codes.
VII. CONCLUSION

In this paper, a quick review has been made on various wirelesses CDMA systems in the field of mobile communications. The performance of the same has been studied and analyzed. DSSS Transmission technique finds its applications in personal communication networks. CDMA provides higher bandwidth efficiency with corresponding capacity increase, speech privacy, immunity to multipath fading, and suffers from Multiple Access Interference (MAI) due to non orthogonal spreading. WCDMA offers variable spreading factor and multiple codes for user to enable features like high data rates and multiple services for the same connection. MUD reduces the effect of interference and hence increases the system capacity. In MC CDMA systems the interference is considerably reduced. It can be concluded that MC-CDMA technique can be used to transmit and receive the data especially in a noisy environment. This technique thwarts undesirable effects like ISI, ICI, burst errors, multipath fading etc., and the data can be retrieved without any errors.

Our main conclusions are as follows:

i. Comparison of the CDMA, MUD-CDMA, and OFDM to MC-CDMA, shows that MC-CDMA gives better results.

ii. The performance of the Walsh Code spreading sequence in MC-CDMA is the better of other two spreading sequences (Gold Codes & PN codes).

MC-CDMA transmission system can be extended for channel estimation by making use of suitable Adaptive filters.

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REFERENCES


