Simulation Based Performance Analysis of MC-CDMA and CDMA over Rayleigh Fading Channel

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Abstract—Multicarrier Code Division Multiple Access Schemes (MC-CDMA) have been recently introduced in existing CDMA based systems to improve security, data transmission rate and to minimize Inter Symbol Interference (ISI). CDMA experiences severe multipath fading which badly affects its performance. By transmitting identical narrowband Direct-Sequence (DS) waveforms using frequency diversity, in parallel with a number of subchannels, multipath fading could be minimized. Implementation of this multicarrier modulation technique in CDMA system is known as multicarrier CDMA. We have shown that in Rayleigh Fading Channel, due to multicarrier modulation, when one subcarrier goes deep fade, another subcarrier remains safe. Therefore MC-CDMA can combat multipath fading better than CDMA and signal can be received in low bit error rate (BER).

Keywords—AWGN, BER, CDMA, MC-CDMA, Rayleigh Fading Channel.

I. INTRODUCTION

Conventional code division multiplexing (CDM) is not able to combat the multipath propagation effects because in this technique, a randomly generated pseudo noise sequence is multiplied with the original signal and spreads in frequency domain. CDMA technology performance is badly affected by Frequency Selective Fading which introduces interference in the transmitted signals [2]. Orthogonal Frequency Division Multiplexing (OFDM) introduces multicarrier concept in CDMA to give rise to new concept of MC-CDMA. MC-CDMA is the combined form of CDMA and OFDMA [4]. It combines the benefits of CDMA with natural robustness to frequency selectivity offered by OFDM [2]. Due to the use of orthogonal spreading codes, all data symbols share same subcarriers and their signals reached at receiver end remaining unchanged. Due to a suitable selection of spreading codes, the frequency diversity which occurs by multipath propagation is exploited for expected bit error rate (BER) performance over OFDM [7].

In this paper we compare the performance of CDMA and MC-CDMA over Rayleigh Fading Channel and by analyzing BER with respect to signal to noise ratio (SNR), we have shown that MC-CDMA performance is better than CDMA since its BER is less than CDMA over Rayleigh Fading Channel.

II. REVIEW OF THE STATE OF ART

Some researchers are interested in enhancing multiplexing techniques for down link multi-user system to increase capacity, security and interference rejection capability in high data-rate transmission [1]. As a combination of CDMA and OFDMA, MC-CDMA performs better than previous multiplexing systems, in wireless communications where multipath terribly influenced the transmitted signal and high data rate is necessary [4].

Spectral efficiency of MC-CDMA has been analyzed subject to Frequency Selective Fading for both uplink and downlink, conditioned/unconditioned with respect to nonergodic/ergodic channels. In conditioned nonergodic channel, spectral efficiency converges asymptotically in the number of subcarriers which depends on fading profile across subcarriers [2].

An adaptive MC-CDMA system has been proposed with a subchannel allocation method in order to allocate DS waveforms to the appropriate channel with the index information [3].

Practically, MC-CDMA systems have more than 64 subcarriers but to avoid maximum worst case cost, suboptimal detection is used. If the channels are stationary at the time of a data block, the received signal from individual subcarriers never interfere with each other at the receiving end. This observation motivates in development of the technique known as group orthogonal MC-CDMA [7].

III. PROBLEM STATEMENT AND MAIN CONTRIBUTION

CDMA suffers from Frequency Selective Fading severely particularly in the downlink where orthogonal spreading codes are employed. Frequency Selective Fading destroys the orthogonality of CDMA codes which results in heavy interference of signals. The question is whether the implementation of MC-CDMA can help to achieve higher data rate performance than CDMA over Rayleigh Fading Channel? We hypothesized that by using MC-CDMA technique which has multiple subcarriers for modulation instead of single carrier improves BER performance of
CDMA system over Rayleigh fading channel. The main advantage of MC-CDMA scheme over other schemes (DS-CDMA, MC-DSCDMA or MT-CDMA) is that the MC-CDMA receiver can always use the all received signal energy scattered in the frequency domain to detect the desired signal [6].

The main contribution of this paper is to compare the performance of CDMA and MC-CDMA in multipath fading environment by considering a bit error rate as the performance metric. Afterwards we proceed with a simulation in MATLAB to validate that MC-CDMA performs better than CDMA in Rayleigh fading channel.

IV. PROBLEM SOLUTION

In conventional CDMA, only one carrier signal is modulated and thus if the signal undergoes any multipath fading, then the total signal may be distorted. Multiple carrier modulation technique like MC-CDMA allows the receiver to receive information correctly even when some of subcarriers are affected by multipath fading [2]. In Figure 1, which is the block diagram of MC-CDMA, each serial data symbol $a(i)$ of user $j$ is converted to parallel data stream and then spread over frequency domain with an user defined spreading code $g$ where each spread is associated with a subcarrier and transformed into time domain by performing Inverse Fast Fourier Transform (IFFT).

![Fig.1: General MC-CDMA system block diagram [1]](image)

Finally, the signal is converted back to serial and modulated to send through the communication channel which is mathematically defined in (1). At the receiver, data are converted to parallel streams and each block with spread signals is decomposed by Fast Fourier Transform (FFT) into subcarriers and transformed into frequency domain for despreading to recover original data.

The transmitted signal for $j^{th}$ user is written as

$$s_{MC}^j(t) = \sum_{i=-\infty}^{\infty} \sum_{m=1}^{G_{MC}} a'(i) g_m \cos \left[ 2\pi (f_0 + m\Delta f)t \right] \ldots \ldots (1)$$

Where $\Delta f = 1/T_s$ is the subcarrier, $g_m$ is the spreading code at $m$ subcarrier and $a'(i)$ is the original data stream at time $i$ [3].

The equation models the MC-CDMA transmitter for Coherent Binary Phase Shift Keying (CBPSK). Dividing a single carrier signal to multiple subcarrier signals means that data are actually divided in to several parallel data streams or channels, one for each subcarrier. Each subcarrier signal is then modulated with low symbol rate such that the total data rate of these subcarrier signals will be equal to conventional single carrier data rate. The main idea behind this technique is that a signal with long symbol duration time is less affected by multipath fading as compare to signal with short symbol duration, like in CDMA [2].

A. Implementation and Result

Implementation of our model has been performed in MATLAB 7.0. Table I shows the simulation parameters where we have one user for CDMA and two users for MC-CDMA. We used Additive White Gaussian Noise (AWGN) channel model just to see the initial behavior of the system before introducing Rayleigh Fading Channel. We modeled our channel as Rayleigh Fading Channel where we assume that the spread signals from Figure 1 will vary or fade randomly according to Rayleigh Distribution. In this distribution, total sum of each different components of diffracted signal is considered. That is why Rayleigh Fading Channel has been used when there is no clear line of sight path between the transmitter and the receiver. Spreading code $g$ in (1) was modeled as Walsh-Hadamard code which is a commonly used code for error correcting capability in CDMA systems. These codes are mathematically orthogonal codes and each of them indicates a unique communication channel. Therefore when two codes are correlated to each other, they are intelligible if and only if they are exactly the same. As a consequence, this code appears to be a pseudo random noise to a mobile device if it does not use the same code before encoding the incoming signal. BPSK has been used as a modulation scheme.

![Fig.2: Performance analysis of MC-CDMA and CDMA.](image)
Figure 2 shows the results in MATLAB simulation where it can be observed that MC-CDMA performs better even for an increased number of users than CDMA over Rayleigh Fading Channel. As a result it better combats with multipath fading as compared to CDMA. MC-CDMA is a striking technique for high speed wireless communication as it overcomes the ISI problem and exploits frequency diversity created by multipath propagation. In case of providing high speed data communications for multiple users, MC-CDMA has been introduced to deal with these challenges [5].

V. CONCLUSIONS

In this paper, we analyze MC-CDMA and CDMA technologies and simulated its BER performance over Rayleigh Fading Channel in MATLAB . An effect that can be observed in this simulation is that the multipath propagation creates deep fade of transmitted signal in conventional CDMA technique. In MC-CDMA in order to use different subcarrier it mitigates the effect of multipath propagation. By comparing BER performances of both technologies, we observe that for low SNR initially, BER performance of both systems are close to each other but for higher values, BER of MC-CDMA is much less than CDMA. In case of MC-CDMA, the received signal will not be corrupted because of the same transmitted signal over all subcarriers and due to orthogonality, error or overlapping of signal will never occur.

MC-CDMA will be the common standard for wireless communication systems in the future such as 4th generation and higher generation mobile communication systems where videoconferencing will gain more importance.

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REFERENCES


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