Effect of Spreading Sequence, Modulation Schemes, Number of Users and Detection Technique on the Performance of MC-CDMA System

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Abstract

In this paper the BER performance of the Multi Carrier Code Division Multiple Access (MC-CDMA) is evaluated over Rayleigh fading channel. MC-CDMA is a promising technique to full fill the high speed data transmission requirements of today's diversified wireless networks. MC-CDMA system incorporates the advantage of two schemes which are Orthogonal Frequency Division Multiplex (OFDM) and the code division multiple access (CDMA). In this paper we present MATLAB simulation results to show the effect of various parameters such as: Spreading sequence, Modulation schemes, Number of users and Detection technique on the performance of the MC-CDMA system. Bit Error Rate (BER) and Signal to Noise Ratio (SNR) are chosen as the performance metrics for comparison of the simulation results.

Keywords

MC-CDMA, Spreading Sequence, Modulation Schemes, Number of Users and Detection Techniques

I. Introduction

In [1] a hybrid technique named Multi Carrier Code Division Multiple Access (MC-CDMA) is proposed which combines the Inter Symbol Interference cancelation (ISI) capabilities of the OFDM technique and spectrum utilization capabilities of CDMA technique. Hence MC-CDMA becomes promising technique for today's high speed diversified wireless communication system to provide better and better services for voice, data, images and video transmission to the customer [2].

Various studies have been proposed in literature to investigate the effect of various parameters on the system performance. In [3] authors present comparative performance analysis of MC-CDMA over Saleh and Rapp model for different spreading sequences such as: Walsh, Golay, Gold, orthogonal Gold, Zadoff-Chu with MMSE-MUD and MSF-MUD receiver. In [4] the BER and peak to average power ratio of MC-CDMA system for different spreading codes over Rayleigh multipath fading channel is analyzed. The degradation of communication quality due to nonlinear characteristics when performing Forward error correction (FEC) coding is investigated in [5]. In [6] authors present comparative performance analysis of equalization techniques for an MIMO MC-CDMA system.

In this paper the effect of various parameters such as: Spreading sequence, Modulation schemes, Number of users and Detection technique on the performance of the MC-CDMA system is evaluated through MATLAB simulation. Considered system employing ½ rate convolutional channel coding technique and link between the transmitter and receiver undergoes Rayleigh fading. BER and SNR are chosen as the performance metrics for comparison of the simulation results.

In this paper Section II explains the MC-CDMA system model. Spreading codes and modulation schemes are briefly explained in section III and IV respectively. Section V presents detection techniques. Simulation parameter and simulation results are discussed in Section VI. Brief conclusion is provided in section VII.

II. System Model

System under consideration is shown in the figure 1. MC-CDMA system is divided in two parts which are CDMA and OFDM. In the first part user data is generated in form of binary 1 and 0 then encoded using ½ rate convolutional encoder. After the symbol mapping encoded data spreading is done using Walsh-Hadamard code and Gold code with code length L=16

$$C^{(k)} = \{c_0^{(k)}, c_1^{(k)}, c_2^{(k)}, \ldots c_{15}^{(k)}\}^T \quad (1)$$

Complex valued sequence after spreading is given by

$$S^{(k)} = d^{(k)} C^{(k)} = \{ s_0^{(k)}, s_1^{(k)}, s_2^{(k)}, .. s_{15}^{(k)}\}^T \quad (2)$$

This spreaded sequence processed through second part of the MC-CDMA system which is OFDM block. Sequence received at the receiver includes channel information as well as noise added given by the equation (3)

$$r = Hs + n \quad (3)$$

Where H and n represents channel matrix and noise vector respectively. After channel equalization sequence is detected using MRC, EGC, ZF and MMSE scheme in order to get an estimate of the transmitted data.

III. Spreading Codes

Interference cancellation between the different users can be achieved by proper selection of Spreading sequence. In this paper two types of spreading codes are considered namely Walsh codes and Gold codes.

A. Walsh Codes

Walsh–Hadamard codes can be generated by using the Hadamard matrix which is given by [8],

$$C_L = \begin{bmatrix} C_{\frac{L}{2}} & C_{\frac{L}{2}} \\ C_{\frac{L}{2}} & -C_{\frac{L}{2}} \end{bmatrix} \quad \forall L = 2^m, \qquad m \geq 1, \quad C_1 = 1 \quad (4)$$

B. Gold codes

Preferred pairs of m-sequences are used to generate Gold code. We perform cyclically shifted modulo-2 additions on the preferred pair. $\{-1, -t(m), t(m)-2\}$, are the values for taking autocorrelations and cross-correlations of Gold codes because we are using preferred pair, where t(m) is given by

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$$t(m) = \begin{cases} 2^{\frac{m+1}{2}} + 1 & for\ m\ odd \\ 2^{\frac{m+2}{2}} + 1 & for\ m\ even \end{cases} \quad (5)$$

Gold codes have worse autocorrelation properties than m-sequences but have lower peak cross-correlations than m-sequences [7-8].

IV. Modulation Schemes

The mapping of data bits to signal waveforms for the transmission over an analog channel is known as Digital modulation [9]. Here modulation schemes are considered,

A. Binary Phase Shift Keying (BPSK)

In BPSK, the phase of a carrier signal is switched between two values according to the two possible signals m_1 and m_2 corresponding to binary 1 and 0, respectively. Normally, the two phases are separated by 180° [9]

B. Quadrature Phase Shift Keying (QPSK)

QPSK is a form of Phase Shift Keying in which two bits are modulated at once. In QPSK two bits are transmitted in each symbol so it's the bandwidth efficiency is double as compare to the BPSK [9]. The initial signal phases are 0, 90, 180 and 270 degrees.

V. Detection Techniques

We have considered four detection techniques namely, Equal Gain Combining (EGC), Maximum Ratio Combining (MRC), Zero Forcing (ZF) and Minimum Mean Square Error (MMSE).

1. In EGC multiple copies of same signal weighted equally regardless of the signal amplitude and summed to produce decision statistic [7].
2. In MRC scheme signals received from different path co-phased first, then weighted according to their individual SNR and summed. The output SNR of the combine signals is equal to the sum of the individual SNRs [7].
3. Zero Forcing is implementing by the inversion of the channel frequency response. Zero forcing is capable to retain the orthogonality between the spread data hence eliminate multiple access interference [7].
4. The MMSE equalizer works on the Mean Square Error (MSE) criteria. The main feature of MMSE equalizer is that it does not completely minimizes the total power of the noise [7].

VI. Simulation Results

In this section simulation results are presented to visualize the effect of various parameters such as: spreading codes, detection techniques, modulation schemes and number of users on the performance of MC-CDMA system. Comparative performance analysis of each case is done in terms of BER and SNR through MATLAB simulation. Parameters chosen for the simulation are mentioned in Table 1.

Table 1: Simulation Parameters

Parameters	Values
User data bits	**10^4**
No. of sub-carriers	**16**
No. of users	**2, 8, 16**
Channel taps	**4**
Spreading codes	**Walsh–Hadamard codes Gold Codes**
Channel coding	**Convolutional coding**
Modulation Schemes	**BPSK, QPSK**
Code Rate	**1/2**
Channel model	**Rayleigh**
Spreading code length L	**16**
Detection Techniques	**MRC, EGC, ZF, MMSE**

A. Effect of Spreading Sequence on the System Performance

Fig. 1 & 2 shows the comparative performance analysis of the two spreading sequences i.e. Walsh code and Gold code. Here ½ rate convolutional encoded data of 2 users are modulated using BPSK and QPSK modulation scheme. Link between the transmitter and receiver undergoes Rayleigh fading.

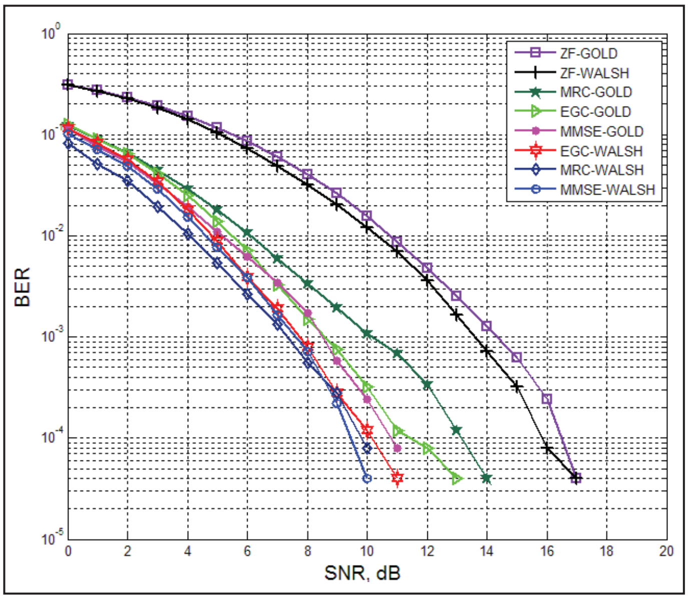

Fig. 1: System Performance Comparisons for Walsh Code and Gold Code

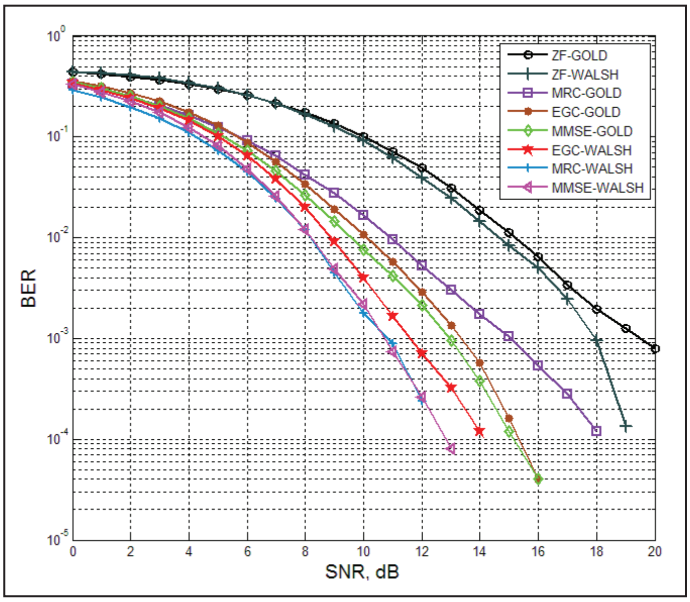

Fig. 2: System Performance Comparisons for Walsh Code and Gold Code

B. Effect of Modulation Schemes and Detection Techniques on the System Performance

Comparative performance analysis of the MC-CDMA system different modulation schemes and detection techniques is shown in fig. 3. Simulation is carried out with 2 active users which are employing Walsh code for spreading their sequences.

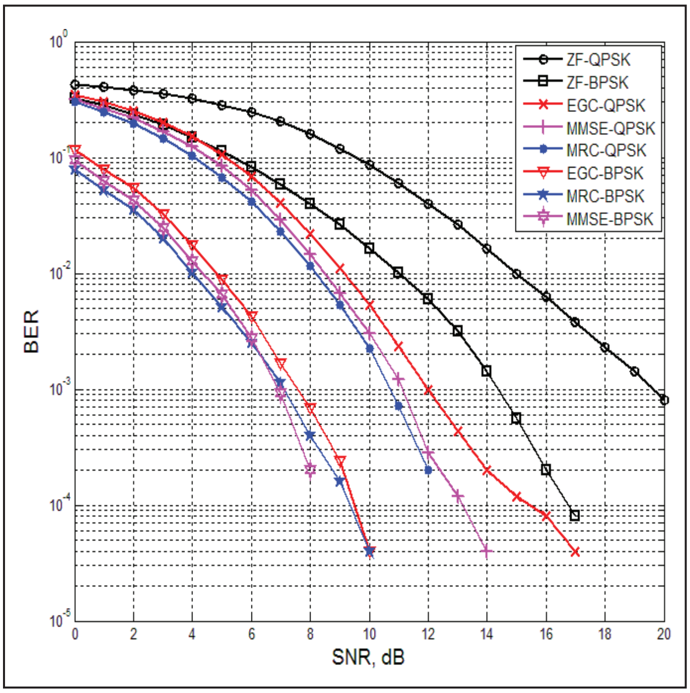

Fig. 3: System Performance Comparisons for BPSK and QPSK Modulation Scheme

C. Effect of Number of users on the System Performance

Simulation results are presented to visualize the effect of number of active users on the performance of MC-CDMA system. Simulation has carried out for different detection technique while the users are employing Walsh code for spreading of the data sequence and BPSK scheme for modulation.

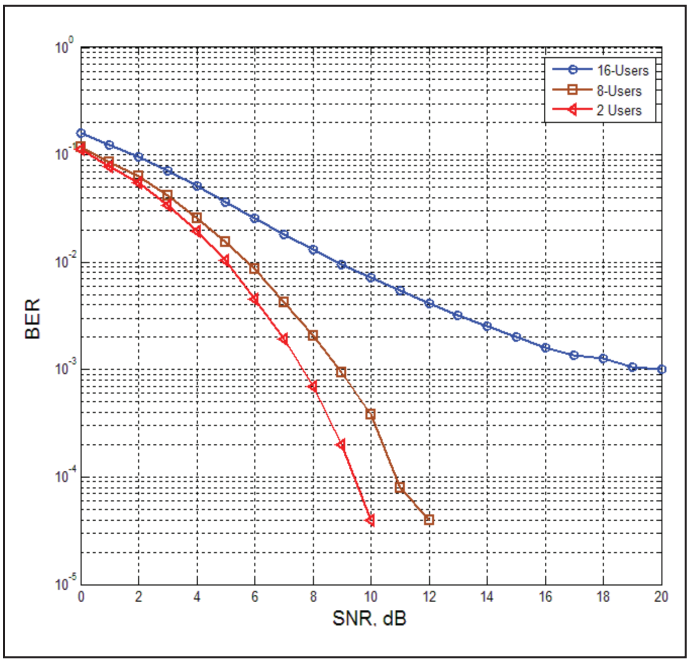

Fig. 4: System Performances with EGC Detection Technique

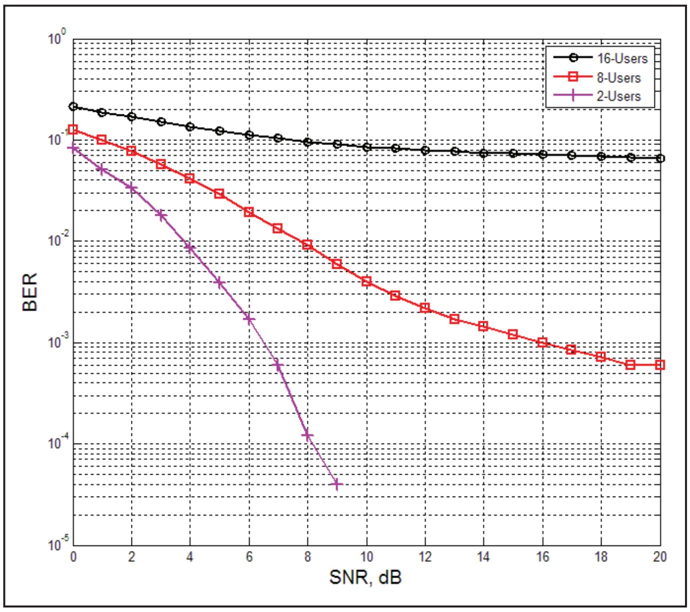

Fig. 5: System Performances with MRC Detection Technique

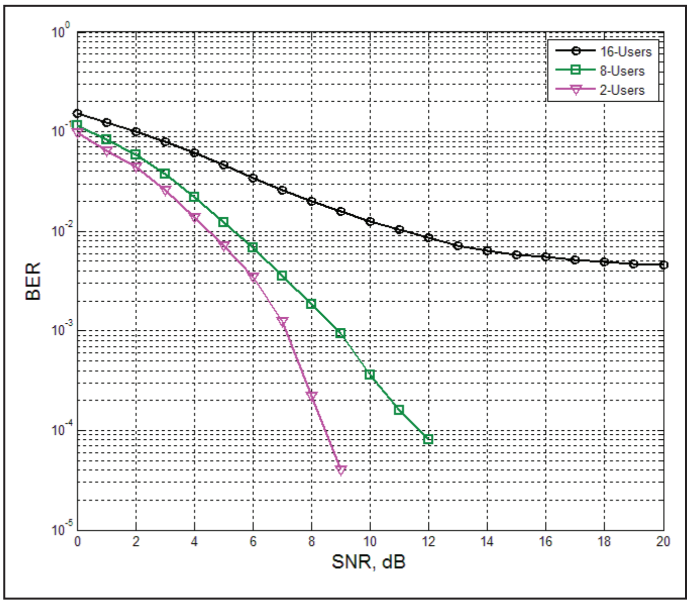

Fig. 6: System Performances with MMSE Detection Technique

VII. Conclusion

In this paper effect of various parameters such as: Spreading sequence, Modulation schemes, Number of users and Detection technique on the performance of the MC-CDMA system is evaluated through MATLAB simulation. Based on the simulation results we conclude walsh code provides better gain in terms of SNR performance as compare to the gold code. Analysis of the simulation results is also done to investigate the effect of modulation schemes and detection techniques on the system performance. Simulation results shows that BPSK modulation scheme improves system performance by more than 4 dB as compare to the QPSK and MMSE is an optimum detection technique among four considered detection techniques. Performance of the system is also affected by the number of active users and it degrades as the number of users is increasing.

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