Performance Analysis of MC-CDMA in Rayleigh Channel Using Walsh Code with BPSK Modulation

S. Kuzhaloli and K.S. Shaji

Abstract High Speed data rate communication is possible with the help of the Multi Carrier Code Division Multiple Access (MC-CDMA). Inter symbol Interference (ISI) and frequency diversity problems are resolved by MC-CDMA. This paper analyzes the performance of MC-CDMA in the presence of Additive White Gaussian noise using a BPSK modulator in Rayleigh fading channel. The results based on various combining techniques for different users are simulated and compared using MATLAB software.

Keywords MC-CDMA · AWGN · BPSK · MRC · ZF

1 Introduction

Conventional CDMA multiplexing technique involves many number of users where each user is assigned with a specific code dedicated to it and this is encoded and decoded by the transmitter and the receiver respectively. On the other hand, Orthogonal Frequency Division Multiplexing (OFDMA) also plays a major role in transmission of signal at increased data rates. MC-CDMA referred to as a Frequency domain spreading technique. In this technique each code is transmitted simultaneously with number of subcarriers multiplied by their own spreading code. It is a combination of OFDMA and CDMA and has the benefits of CDMA along with the frequency selectivity of OFDMA. The main contribution of this paper is based on the equalization techniques or the combining techniques like Maximal-

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Ratio Combining and the Zero Forcing is the estimation of the Bit Error Rate (BER) performance using a Binary Phase Shift Keying modulation technique with ordered Hadamard sequence or the Walsh sequence as the spreading codes. This is analyzed for a Rayleigh fading channel conditions of MC-CDMA in the presence of Additive White Gaussian noise (AWGN).

2 MC-CDMA System

The main difference between the MC-CDMA and MC-DS CDMA system is that the MC-CDMA is a frequency domain spreading technique and MC-DS-CDMA is a time domain spreading technique. MC-CDMA system is often looked as a combination of CDMA and OFDMA which helps in higher data rates and results is better frequency diversity and has the added advantage of increasing the bandwidth efficiency. It can also be defined as DS-CDMA modulated again by an OFDMA subcarrier. In this MC-CDMA system a single data symbol is transmitted over number of narrow band sub-carriers. The spreading technique is carried out in the frequency domain. Both the MC_CDMA transmitter and receiver works with the orthogonal codes.

3 Spreading Codes

The spreading codes that are used in CDMA system are Pseudo noise sequence or m-sequence, Gold codes, Walsh codes, Hadamard codes etc. This MC-CDMA is implemented using Walsh Codes [1]. Walsh matrix is a square matrix, derived from Hadamard matrix, where every row is orthogonal to all other rows in the matrix and every column is orthogonal to all other column in the matrix. User 1 is assigned with code 1 representing the 2nd row of the Walsh code matrix. Similarly User 2 is assigned with the 15th row of the Walsh code matrix. The number of data sub carriers N_c is considered to be 16.

The general Hadamard matrix is given by

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & \overline{H_N} \end{bmatrix}$$

The Walsh matrix is obtained from Hadamard matrix with ordered sequencing and the matrix for 16 subcarriers is represented by the H_{16} matrix.

4 BPSK Modulation

Various modulation techniques are involved in modulating the spreaded signal by the carrier signal. But normally some form of Phase shift Keying (PSK) techniques like Binary Phase shift Keying (BPSK), Differential Phase shift Keying (DPSK), Quadrature Phase shift Keying (QPSK) and Minimum Shift Keying (MSK) are involved. Here the modulation technique used is BPSK modulation [2]. Constellation diagram is the most convenient way to represent PSK schemes. Points are plotted in the complex plane wherein the real axis is called the in-phase axes and the imaginary axis is known as the quadrature axes as both the axes are separated by 90°. These constellation points are placed on a circle with uniform angular spacing. Good immunity is achieved by placing the points with maximum plane separation. Any number of phases can be used for the modulation scheme. Here Binary phase Shift keying (BPSK) scheme is considered which uses only two phases separated by 180°. The BPSK equation takes the form $s_n(t) = \surd(2E_b/T_b) * \cos(2\pi f_c t + \pi(1 - n))$ yields two phases 0 and π.

5 System Channel

The medium which is physically present between the transmitter and the receiver is known as the channel. Noise is present in this physical channel in all the communication systems. Major sources of noises that are generated in the channel are thermal Noise, electrical Noise, Inter-cellular Interference etc. Apart from these noises there are noises that are developed internally like Inter symbol Interference, Inter carrier Interference, Inter Modulation distortion etc. The two channels that are considered in this paper are the Additive White Gaussian Noise (AWGN) and the Rayleigh Channel [3, 4].

5.1 AWGN Channel

The very simple environment considered is the Additive white Gaussian Noise (AWGN) channel. The major source is the thermal noise and due to its simplicity manmade noise model as well as multiuser interference is also considered. The general expression to describe an AWGN channel is given by $g(t) = s(t) + v(t)$. In the above expression d(t) is the transmitted input signal and v(t) is the additive white noise or disturbance. Spectral density is uniform for this random noise and the amplitude follows Gaussian distribution.

5.2 Rayleigh Channel

There is large delay in transmitting the signal as there is too much of dispersion when obstacles lie between the transmitting end and receiving end, that is, when they do not lie in the Line-of-sight (LOS). Hence there are several number of transmission paths which leads to superposition. When more number of paths are available they are analyzed using the central limit theorem and they follow the statistical characteristics of the Rayleigh distribution.

6 Combining Techniques

The combining techniques are also referred to as equalizing techniques in which an equalizer is introduced in a network to recover the signal that is badly affected by the Inter symbol Interference and helps in improving the Signal-to-Noise Ratio (SNR) by improving the BER characteristics [5, 6]. The equalizers involved in these techniques are:

6.1 Maximal Ratio Combining (MRC)

This Maximal-Ratio Combining is also called as ratio-squared or pre detection combining. In this technique every signal is multiplied by a weight factor which is proportional to the signal amplitude. Here signals from every channel is combined together and gain of every channel is made to be inversely proportional to the mean square noise level of that channel and is directly proportional to the root-mean-square value of the signal.

6.2 Zero Forcing (ZF)

Zero forcing Equalizer is a linear form of equalization algorithm, applies inverse of the frequency channel response to the received signal and hence restores the signal. This zero forcing forces the Inter Symbol Interference to zero. If the channel frequency response is given by F(f), the zero forcing equalization E(f) is given by E(f) = 1/F(f). Hence by combining the channel and the equalizer, the flat frequency response and the linear phase is equal to one i.e., E(f) F(f) = 1. The Zero forcing detector has the constraint given by $W = [H^H \; H]^{-1} \; H^H$, where W is the Equalization matrix and H is the channel matrix. This is known as the pseudo inverse matrix of the general matrix.

7 Simulation Results

Simulation is done using MATLAB software. First a random Binary sequence of +1 and −1 is generated and the symbols are multiplied with the channels. Then an Additive White Gaussian noise is added. Finally an equalization procedure is carried out at the receiver and the BER is calculated [7]. Number of users and number of subcarriers considered are 2 and 16 respectively. The modulation technique used is BPSK modulation. Both the sequences are spreaded and IFFT operation is carried out. A cyclic prefix is appended for the users. The number of tappings considered in the Rayleigh channel is 4. Finally Bit Error Rate is calculated for both MRC and ZF Equalization techniques for both the users. The outputs are obtained as shown in Figs. 1, 2, 3 and 4 respectively.

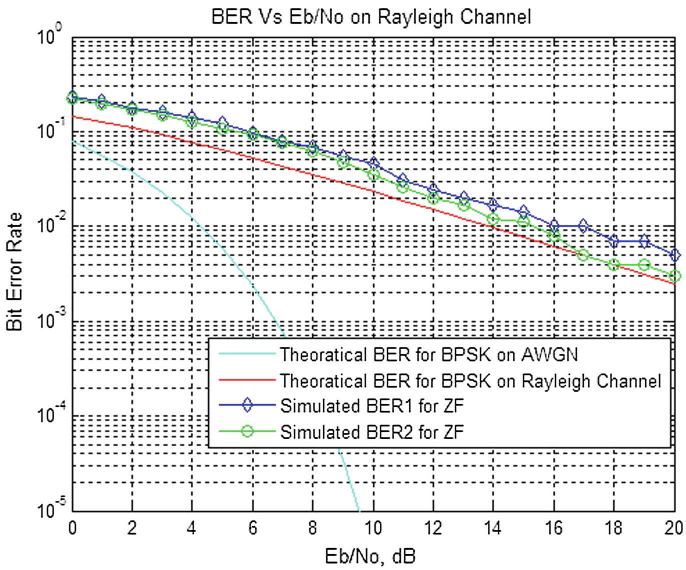

Fig. 1 BER/No for ZF technique for user 1 & 2

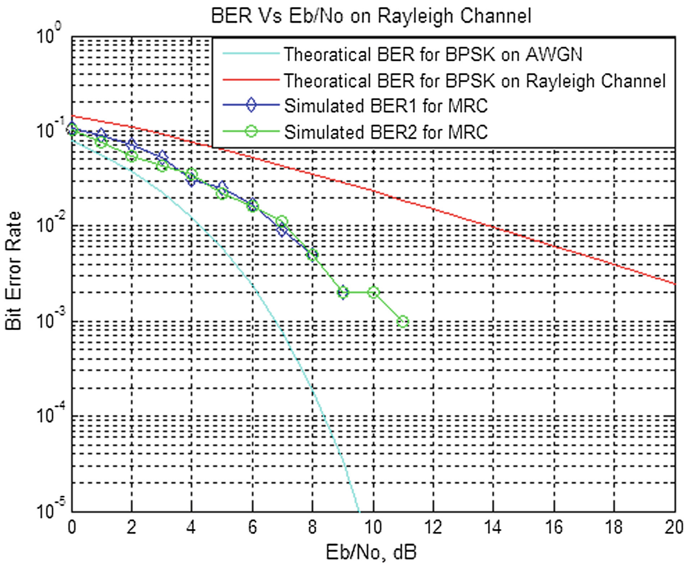

Fig. 2 BER/No for MRC technique for user 1 & 2

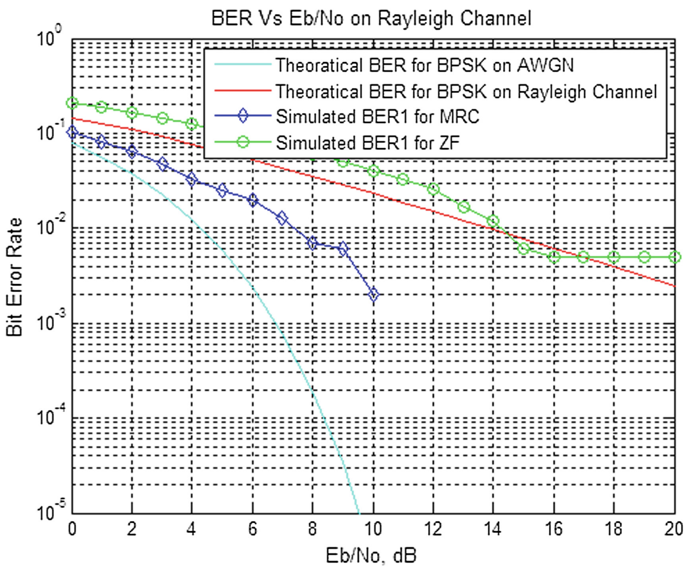

Fig. 3 BER/No for MRC & ZF technique for user 1

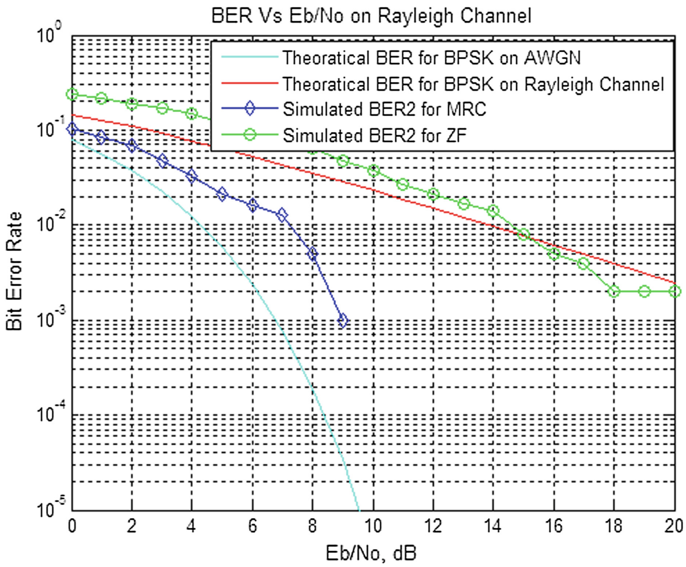

Fig. 4 BER/No for MRC & ZF technique for user 2

8 Conclusion

In this paper, the two combining techniques MRC and ZF are implemented on an MC-CDMA system. Performance of an MC-CDMA system using a Rayleigh channel is analyzed with BPSK modulation and Walsh codes for spreading the users. The number of users considered is two. The ratio of Eb/No increases as the value of BER decreases.

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