PERFORMANCE ANALYSIS OF MCCDMA SYSTEM IN RAYLEIGH CHANNEL AND AWGN CHANNEL USING BPSK MODULATION TECHNIQUE

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Abstract

Multi-carrier code division multiple access (MCCDMA) is an attractive choice for high speed wireless communication as it avoids the problem of inter symbol interference (lSI) and also exploits frequency diversity. In order to support multiple users with high speed data communications, the MC-CDMA technique is used to address these challenges. In this paper working of Transmitter and Receiver model of MCCDMA system is presented. This work also derives simulation through MA TLAB of average bit error rate (BER) versus bit energy to noise ratio (Eb/No) of Multi Carrier Code Division Multiple Access (MC-CDMA) systems over Rayleigh channel using BPSK modulation and Additive White Gaussian Noise, which shows the reduction in BER performance. In this paper the performance of MCCDMA in Rayleigh and awgn channel is compared.

Key words: MCCDMA, BPSK Modulation Rayleigh channel, AWGN.

Introduction

With a surging increase in demand for personal wireless radio communications within the past decade, there is a growing need for technological innovations to satisfy theses demands. Future technology must be able to allow users to efficiently share common resources, whether it involves the frequency spectrum, computing facilities, databases, or storage facilities.[l]The multicarrier (MC) technique has grown an important alternative for wireless indoor communications. One large advantage of this technology is its robustness in case of multipath propagation. MC-CDMA is one representative of the MC technique. It has emerged as another feasible option for forward-looking MC communications systems by exploiting the flexibility and potential offered by the combination of OFDM and CDMA.

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Multi-carrier CDMA (MC-CDMA)

Two main variations of the MC spread spectrum systems are the MC-CDMA (frequency domain spreading) and MC direct sequence CDMA (MC-DS-CDMA) (time domain spreading). One way of looking at MC-CDMA is as a combination of CDMA and OFDM, resulting in better frequency diversity and higher data rates. In MC-CDMA, each symbol is spread using code chips and transmitted on several subcarriers. There is no necessity for the number of carriers to be equal to the code length; thus offering a degree of flexibility in our design.MC-DS-CDMA differs in the fact that the data is spread in time domain rather than in frequency; with each sub channel representing a regular DSCDMA system. The principle of MCCDMA is that a single data symbol is transmitted on multiple narrow band subcarriers. Indeed, in MCCDMA systems, spreading codes are applied in frequency domain transmitted over independent subcarriers. The eminent advantage of MC-CDMA is the increase in bandwidth efficiency; the reason being the multiple access made possible through proper systems design using orthogonal codes.

System Model

In this section, we describe the transmitter and receiver model of MCCDMA system. Here, symbols are modulated on many subcarriers to introduce frequency diversity instead of using only one carrier like in CDMA. Thus, MC-CDMA is robust against deep frequency selective fading compared to DS-CDMA [10]. Each user data is first spread using a given high rate spreading code in the frequency domain. A fraction of the symbol corresponding to a chip of the spreading code is transmitted through different subcarriers [8].

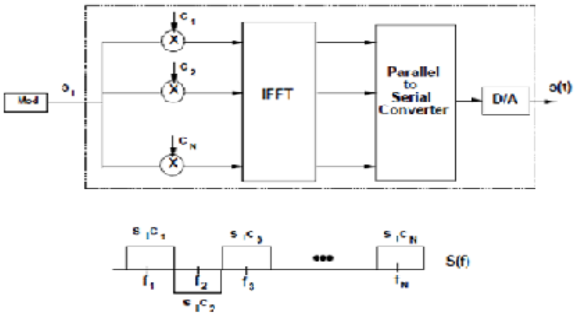


Fig 1: MCCDMA Transmitter model

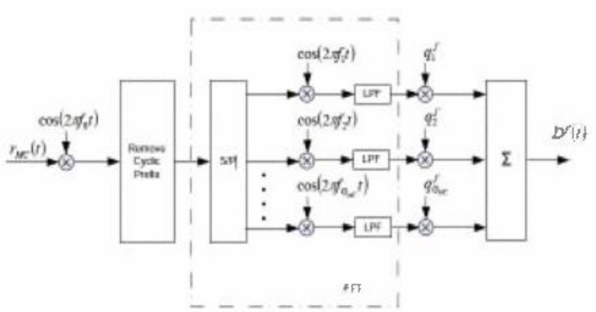
In this figure, the main difference between MCCDMA & OFDM is that the MC-CDMA scheme transmits the same symbol in parallel through several subcarriers whereas the OFDM scheme transmits different symbols. $c^j_{(j)} = [c^j_1, c^j_2, \ldots, c^j_{G_{MC}}]$ Is the spreading code of the Jth user in the frequency domain, G_{MC} denotes the processing gain, sometimes called the spreading factor. The input data stream is multiplied by the spreading code of length G_{MC} Each chip of the code modulates one sub carrier. The number of subcarriers is $N=G_{MC}$ the users are separated by different codes. All data corresponding to the total number of sub carriers are modulated in baseband by an inverse fast Fourier transform (IFFT) and converted back into serial data. Then, a cyclic prefix is inserted between the symbols which is a repeat of the end of the symbols at beginning, to combat the inter-symbol interference (ISI) and the inter-carrier interference (ICI) caused by multipath fading. And hence the cyclic prefix length is chosen such that it is greater than the delay spread of the channel, so that the effects of multipath are mitigated effectively. Finally, the signal is digital to analog converted and up converted for transmission.

In MC-CDMA transmission, it is essential to have frequency nonselective fading over each sub carrier. Therefore, if the original symbol rate is high enough to become subject to frequency selective fading [8], the input data have to be serial to parallel (S/P) converted into P parallel data sequences $[a^j_1, a^j_2, \ldots, c^j_P]$ and each SIP output is multiplied with the spreading code of length $G_{MC.}$ Then, each sequence is modulated using G_{MC} subcarriers. Thus, all sub carriers $N = PXG_{MC}$ are also modulated in baseband by the IFFT.

The MCCDMA receiver configuration for the Jth user is shown in Figure 2. The received signal is first down converted. Then, the cyclic prefix is removed and the remaining samples are serial to parallel converted to obtain the m-subcarriers components (corresponding to the aj_p data), where m=1,2. . . , G_{MC} . The m-subcarriers are first demodulated by a fast Fourier transform (FFT) (OFDM demodulation) and then multiplied by the gain q_{jm} to combine the received signal energy scattered in the frequency domain. In [8], the decision variable is given by:

$$\bar{D}^j = \sum_{G_{MC}}^{m-1} q_m y_m \tag{1}$$

$$y_m = \sum_j^{j-1} z^j_m a^j c^j_m + n_m \tag{2}$$



Where, Y_m and n_m are the complex baseband component of the received signal and the complex Gaussian noise at the mth subcarrier, respectively. Z_{jm} and a_j are the complex envelope of the mth sub carrier and the transmitted symbol of Jth user, respectively. J is the number of active users.

Simulation of MCCDMA

Here we discuss BER for BPSK in a Rayleigh multipath channel. In discussion on Rayleigh channel, a circularly symmetric complex Gaussian random variable is considered, which is of the form, $h=h_{re}+h_{im}$ where, real and imaginary parts are zero mean independent and identically distributed (iid) Gaussian random variables with mean 0 and variance σ^2. The magnitude |h| which has a probability density,

$$p(h) = \frac{h}{\sigma^2} e^{\frac{h^2}{2\sigma^2}},$$

Where h≥0 is called a Rayleigh random variable. This model, called Rayleigh fading channel model, is reasonable for an environment where there are large numbers of reflectors. [12].

The received signal in Rayleigh fading channel is of the form, Y = hx+ n ,where ' Y' is the received symbol, ‘h ‘ is complex scaling factor corresponding to Rayleigh multipath channel, 'x' is the transmitted symbol (taking values +1' s and -1' s)and 'n' is the Additive White Gaussian Noise(AWGN) Assumptions:

I. The channel is flat fading - means that the multipath channels has only one tap. So, the convolution operation reduces to a simple multiplication.

II. The channel is randomly varying in time – meaning each transmitted symbol gets multiplied by a randomly varying complex number 'h'. Since 'h' is modeling a Rayleigh channel, the real and imaginary parts are Gaussian distributed having mean 0 and variance 1/2.

III. The noise 'n' has the Gaussian probability density function with

$$p(n) = (1/\sqrt{2\pi\sigma^2})e^{-(n-\mu)^2/2\sigma^2}$$

μ=0 and $\sigma^2 = N_0/2$.

IV. The channel ' h ' is known at the receiver. Equalization is performed at the receiver by dividing the received symbol ‘y’ by the ‘h’ $\tilde{Y}$=Y/h=(hx+n)/h=x+n_1, where n_1=n/h,where n_1 is the additive noise scaled by the channel coefficient.

Bit Error Rate

BER computation in A WGN, the probability of error for transmission of either + 1 or -1 is computed by integrating the tail of the Gaussian probability density function for a given value of bit energy to noise ratio Eb/No. The bit error rate is

$$P_b = \frac{1}{2} erfc(\sqrt{E_b/N_o})$$

however in the presence of channel ‘ h ' , the effective bit energy to noise ratio is $|h|^2$ Eb/No . So the bit error probability for a given value of ‘h' is,

$$P_{b/h} = \frac{1}{2} erfc\left(\sqrt{\frac{|h|^2 E_b}{N_o}}\right) = \frac{1}{2} erfc(\sqrt{\gamma}),$$

Where

$$\gamma = \frac{|h|^2 E_b}{N_o}$$

To find the error probability over all random values of $|h|^2$, one must evaluate the conditional probability density function $P_{b/h}$ over the probability density function of γ Probability density function of γ the probability density function of γ is,

$$P(\gamma) = \frac{1}{E_b/N_o} e^{\frac{\gamma}{E_b/N_o}} \quad \gamma \geq o$$

So the error probability is

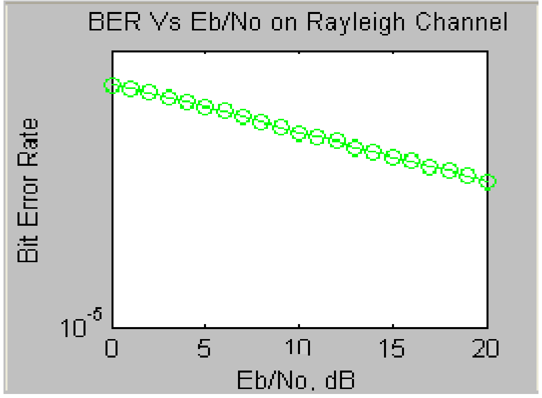
$$P_b = \int_0^\infty \frac{1}{2} erfc(\sqrt{\gamma})\, p(\gamma) d\gamma$$

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{(E_b/N_o)}{(E_b/N_o)+1}}\right)$$

Simulation Model

Procedure for Matlab simulation of a BPSK transmission and reception in Rayleigh channel is as follows:-

First we generate random binary sequence of + 1’s and l's, then multiply the symbols with the channel and then add AWGN. At the receiver, we equalize (divide) the received symbols with the known channel & perform hard decision decoding and count the bit errors. Finally we repeat for multiple values of Eb/No and plot the simulation results



Channel Model:

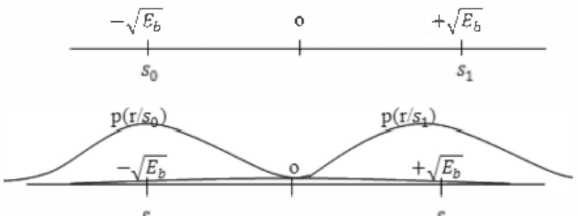
The transmitted waveform gets corrupted by noise 'n' typically referred to as Additive White Gaussian Noise (AWGN). Additive: As the noise gets ' added ' (and not multiplied) to the received signal White: The spectrum of the noise if flat for all frequencies. Gaussian: The value of the noise n follows the Gaussian probability distribution function,

$$p(x) = (1/\sqrt{2\pi\sigma^2})\, e^{\frac{-(x-\mu)^2}{2\sigma^2}} \quad \text{with } \mu = 0 \text{ and } \sigma^2 = \frac{N_o}{2}$$

Computing Probability Of Error:

The received signal, $y = S_1 + n$ when bit 1 is transmitted and $y = S_o + n$ when bit 0 is transmitted. The conditional probability distribution function (PDF) of y for the two cases

$$p(y/s_1) = \frac{1}{\sqrt{\pi N_0}} e^{\frac{-(y-\sqrt{E_b})^2}{N_0}} \quad \& \quad p(y/s_0) = \frac{1}{\sqrt{\pi N_0}} e^{\frac{-(y+\sqrt{E_b})^2}{N_0}}$$



Assuming that $p(r/S_o)$ and $p(r/S_1)$ are equally probable i.e. $+\sqrt{E_b}$ & $-\sqrt{E_b}$ have equal probability, the threshold 0 forms the optimal decision boundary. If the received signal is $+\sqrt{E_b}$, which is greater than 0, then the receiver assumes $p(r/S_1)$ of S_1 was transmitted. If the received signal is $-\sqrt{E_b}$which is less than or equal to 0, then the receiver assumes $p(r/S_o)$ of S_0 was transmitted. i.e. $y>0 \Rightarrow S_1$ and $y>0 \Rightarrow S_0$

- Probability of error given S_1 transmitted was with this threshold, the probability of error given S_1 is transmitted

$$p(e/s_1) = \frac{1}{\sqrt{\pi N_0}} \int_{-\infty}^{0} e^{\frac{-(y-\sqrt{E_b})^2}{N_0}} dy = \frac{1}{\sqrt{\pi}} \int_{\sqrt{\frac{E_b}{N_0}}}^{\infty} e^{-z^2} dz$$

$$= \frac{1}{2} erfc(\sqrt{\frac{E_b}{N_o}} \text{ where, } \quad erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{x^2} dx$$

Above equation is the complementary error function

- Probability of error given S_0 was transmitted similarly the probability of error given S_0 is transmitted is

$$p(e/s_0) = \frac{1}{\sqrt{\pi N_0}} \int_0^{\infty} e^{\frac{-(y+\sqrt{E_b})^2}{N_0}} dy = \frac{1}{\sqrt{\pi}} \int_{\sqrt{E_b/N_0}}^{\infty} e^{-z^2} dz$$

$$= \frac{1}{2} \operatorname{erfc}\left(\sqrt{E_b/N_0}\right)$$

Above equation is the complementary error function

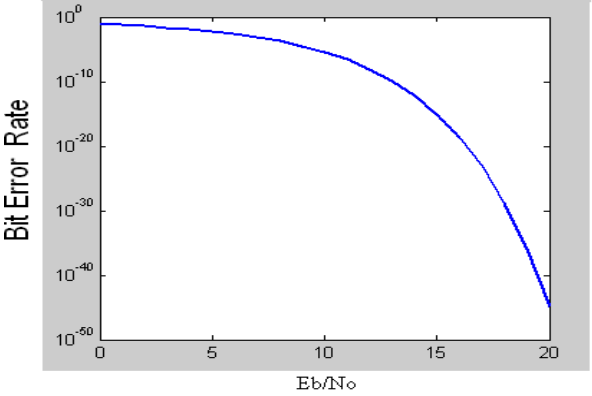
Total Probability of error:

$$P_b = p(s_1)p(e/s_1) + p(s_0)p(e/s_0)$$

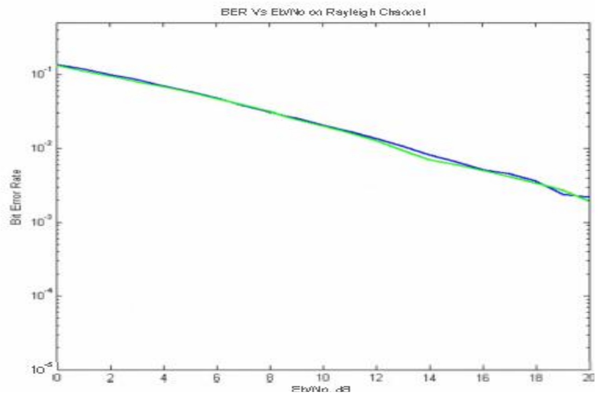
Given that we assumed that S_1 and S_0 are equally probable i.e. $p(S_0)=P(S_1)=1/2$, the probability of error is $P_b = \frac{1}{2} erfc(\sqrt{Eb/N_o})$

Simulation Using BPSK Modulation In AWGN Channel:

Initially, we generate random BPSK modulated symbols +1's and -l's, then we pass them through AWGN channel after that we demodulate the received symbol based on the location in the constellation, then we count the number of errors finally repeat the same for multiple Eb/No values.



BER Vs Eb/No on Rayleigh Channel



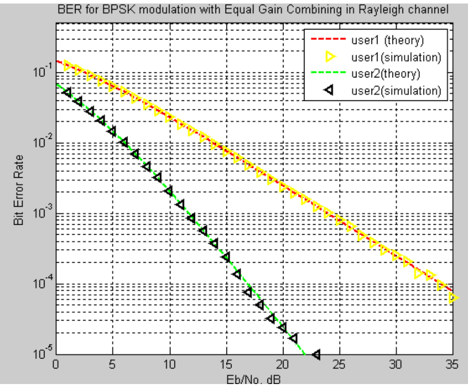
In the above graph, Blue & Green line shows: Simulated BER for BPSK for user-1&2 with AWGN on Rayleigh Channel.

11. Combining Techniques:

At the receiver the signal received from all the various paths is combined by using combing techniques like Orthogonality Restoring Combining (ORC), Controlled Equalization (CE), Minimum Mean Square Error Combining (MMSEC), Equal Gain Combining (EGC) and Maximal Ratio Combining (MRC). In this work EGC and MRC techniques are presented.

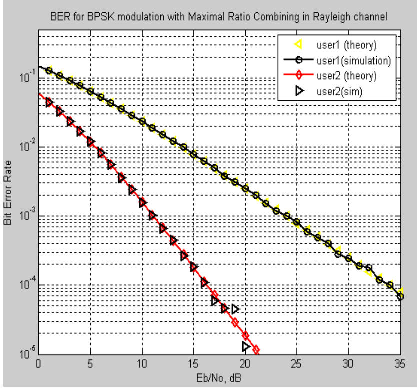
EGC: With two receive antennas, the BER with EGC is, $P_e = \frac{1}{2}\left[1 - \frac{\sqrt{E_b/N_0(E_b/N_0+2)}}{E_b/N_0+1}\right]$

.We perform the following procedure for simulation: Initially, we generate random binary sequence of +l's and -l's then we multiply the symbols with the channel & add AWGN, after that we equalize each receive path by compensating with the known channel phase at the receiver & then we accumulate the equalized symbols from all receive paths, then we perform hard decision coding & count the bit errors. Finally, we repeat it for multiple values of Eb/No & plot the simulation results.



MRC: Error rate with Maximal Ratio Combining (MRC): From the discussion on chi-square random variable, we know that, if hi is a Rayleigh distributed random variable, and then h_i is a chi-squared random variable with two degrees of freedom. The probability of error is defined as

$$p=\frac{1}{2}-\frac{1}{2}\left(1+\frac{1}{E_b/N_0}\right)^{-1/2}$$



Conclusion:

In this paper we try to present the performance of mccdma in AWGN channel and Rayleigh channel Using BPSK modulation technique. As from graph it is evident that as Eb/No increases the BER decreases. In this system it provides faster speeds because here message is transmitted using different subcarriers unlike other techniques. In this system the interference between channels is also eliminated of using orthogonal subcarriers.

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