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Performance Analysis and Simulation Result of MC-CDMA for AWGN Channel and Rayleigh Based on SNR/BER

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Abstract

For any electronic communication system bandwidth utilization and BER performance under different channel conditions are major aspect of consideration, to cope up with these conditions different modulation technique are used one of them is MC-CDMA (Multicarrier Code Division Multiple Access) which outperforms other techniques for bandwidth utilization and performs well under noisy and fading channels, as theoretical derivation states. This paper presents a comprehensive analysis of MC-CDMA system over the AWGN (Additive White Gaussian Noise) and Rayleigh channel for different number of subcarrier and different number of users, system analysis is performed by simulating the MC-CDMA using MATLAB program, and finally the paper also presents a comparison between simulated and theoretical results.

Keywords

MC-CDMA, AWGN, SNR, BER.

1. Introduction

Multi Carrier Code Division Multiple Access (MC-CDMA) is a relatively new concept. Its development aimed at improved performance over multipath links. MC-CDMA is a modulation method that uses multi-carrier transmission (more precisely OFDM) of DS-CDMA-type signals [1].

This scheme was first proposed at PIMRC '93 in Yokohama by Linnartz, Yee (U. of California at Berkeley) and Fettweis (Teknekron, Berkeley, currently at U. of Dresden, Germany). Independently, Fazal and Papke proposed a similar system. Linnartz and Yee showed that MC-CDMA signals can also be detected with fairly simple receiver structures, using an FFT and a variable gain diversity combiner, in which the gain of each branch is controlled only by the channel attenuation at that subcarrier. Results showed that a fully loaded MC-CDMA system, i.e., one in which the number of users equals the spread factor, can operate in a highly time dispersive channel with satisfactory bit error rate. These results appeared in contrast to the behavior of a fully loaded DS-CDMA link that typically does not work satisfactorily with large time dispersion [1]. Since 1993, MC-CDMA rapidly has become a topic of research. At the keynote address of the ISSSTA conference 1996, Prof. Hamid Aghvami predicted that the hottest topic in spread-spectrum, viz. multi-carrier CDMA, would attract 80% of the research by 1997. Around 2000, we see that MC-CDMA has attracted tremendous attention, with entire conference sessions devoted to this. Mc-CDMA is praised as a modulation solution that merges the insights due to Shannon (particularly those relating to CDMA) with insights due to Fourier (particularly those explaining why OFDM has advantages in a dispersive channel) [1].

2. MC-CDMA

Multi-carrier CDMA is an enabling technology for future mobile phones. Future mobile phone services are likely to be endowed with crystal-clear integrated digital TV, digital Hi-Fi radio, high-speed internet browsing as well as the video phone capabilities. All these services require efficient transmission of multimedia traffic. Multi-carrier CDMA is likely to be the transmission method of future mobiles due to its bandwidth efficiency and inherent diversity over fading channel. However, the multi-carrier signals show highly varying envelope power waveforms, which hinder the popular employment of multi-carrier CDMA. Our research focus is to study this phenomenon and to provide some practical solutions for it. Another important topic is to use adaptive modulation, exploiting the channel quality fluctuations, so that more multimedia traffic can be exchanged using the same bandwidth.

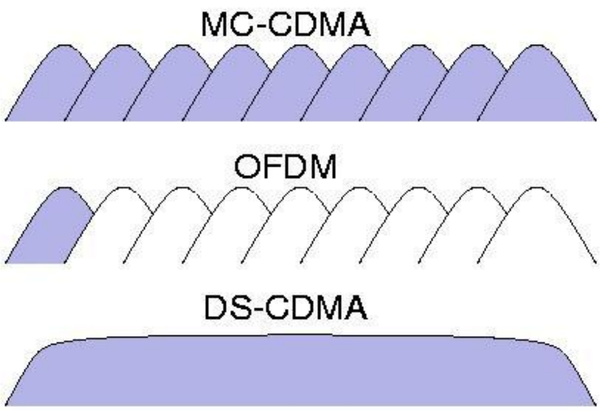

Fig 1. MC-CDMA and DS-CDMA

Since the introduction of OFDM, there are many researches that have been focus to fully exploit the benefits of OFDM either in improving the data rate, the capacity or achieve better spectrum efficiency with the technique. Many researchers have proposed the merger of OFDM [2] [3] and CDMA systems to achieve better spectrum efficiency and also increase the system capacity. This section takes a look at a scheme widely proposed by researchers in this field called the OFDM-CDMA system. This system is also known as the MC-CDMA (Multi-carrier CDMA) system. MCCDMA system achieves comparable performance of DS-CDMA, however, the benefits of the MC-CDMA system lies within its flexibility and the relatively simple receiver design.

Firstly an OFDM system is used to provide a number of orthogonal carriers, free from ISI. Each carrier is then modulated by an individual code chip to provide a spread spectrum system. In MC-CDMA the spreading code is based on the Walsh-Hadamard coding which ensures that the users do not clash, as the rows are mutually orthogonal. The core difference between MC-CDMA and DS-CDMA is that the codes that identify different users are modulated in the frequency domain instead of in the time domain. Since the codes are introduced in the frequency domain, there is no need for a rake receiver that complicates the whole system. Therefore, this method greatly simplifies the receiver design.

Although MC-CDMA system transmits the signal over different sub-carriers, the overall bandwidth of MC-CDMA is exactly the same as in DS-CDMA as shown in Fig 2. Therefore, there is not any extra cost in term of bandwidth expansion between both the systems.

The combination of OFDM signaling and CDMA scheme has one major advantage that it can lower.

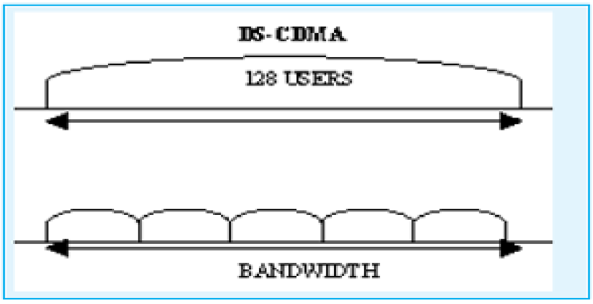

Fig 2. Bandwidth allocation in the DS and MC-CDMA system

This scheme relies on spreading the original data stream over different subcarriers using a given spreading code in the frequency domain. Therefore, each subcarrier carries a fraction of the symbol corresponding to a chip of the spreading code. The Walsh Hadamard codes may be used as it presents an orthogonal set thereby taking care of the autocorrelation characteristic of the spreading code [4].Figure 3 shows the power spectrum of the MCCDMA scheme. Here GMC is the Gain Margin.

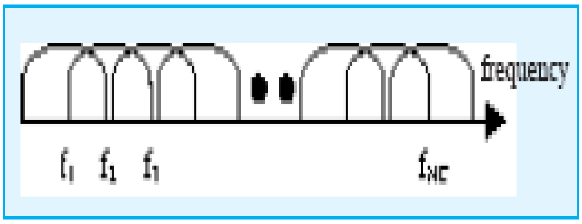

Fig 3. Power Spectrum of the MC-CDMA scheme

3. The AWGN and Rayleigh Channel

We discuss the BER for BPSK in a Rayleigh multipath [5] channel. Rayleigh channel, wherein we stated that a circularly symmetric complex Gaussian random variable is of the form,

$h = h_{re} + jh_{im}$,

where real and imaginary parts are zero mean independent and identically distributed (iid) Gaussian random[6] variables with mean 0 and variance σ^2. The magnitude $|h|$ which has a probability density,

$$p(h) = \frac{h}{\sigma^2} e^{\frac{-h^2}{2\sigma^2}}, \quad z \geq 0$$

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. System model 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

1. The channel is flat fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication.
2. 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 andvariance 1/2.
3. The noise n has the Gaussian probability density function with

$$p(n) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(n-\mu)^2}{2\sigma^2}}$$ with $\mu = 0$

and $\sigma^2 = \frac{N_0}{2}$.

4. The channel h is known at the receiver. Equalization is performed at the receiver by dividing the received symbol y by the apriori known h i.e.

$$\widetilde{y} = \frac{y}{h} = \frac{hx+n}{h} = x + \widetilde{n}$$

where

$\widetilde{n} = \frac{n}{h}$ is the additive noise scaled by the channel coefficient.

Bit Error Rate

BER[7][8] computation in AWGN, 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 $\frac{E_b}{N_0}$. The bit error rate is,

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

However in the presence of channel h, the effective bit energy to noise ratio is $\frac{|h|^2 E_b}{N_0}$. So the bit error probability for a given value of h is,

$$P_{b|h} = \frac{1}{2} erfc\left(\sqrt{\frac{|h|^2 E_b}{N_0}}\right) = \frac{1}{2} erfc(\sqrt{\gamma}),$$

Where $\gamma = \frac{|h|^2 E_b}{N_0}$.

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.

Simulation Model

It will be useful to provide a simple Matlab/Octave example simulating a BPSK transmission and reception in Rayleigh channel. The script performs the following (a) Generate random binary sequence of +1's and -1's.(b) Multiply the symbols with the channel and then add white Gaussian noise.
(c) At the receiver, equalize (divide) the received symbols with the known channel.(d) Perform hard decision decoding and count the bit errors.(e) Repeat for multiple values of $\frac{E_b}{N_0}$ and plot the simulation and theoretical results.

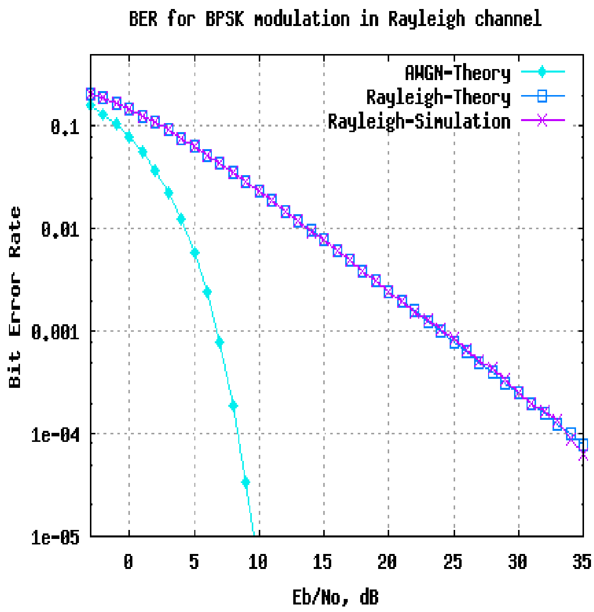

Fig 4. BER for BPSK

4. Performance Simulation

Computer simulations are done to simulate SNR vs. BER performance of MC-CDMA for different channel noise conditions, different number of subcarriers and to analyze the effect of number of users in BER. To make the results more useful, the results are generated for varying number of users and for different number of subcarriers. Throughout the simulation, the information symbol is BPSK modulated at the transmitters and detected by using the maximum likelihood method in the demodulation at the receiver. A cyclic prefix is added to protect the symbol. Walsh codes are chosen as the spreading codes of the system. The simulation codes are written for MATLAB, and simulated on Pentium class processor.

5. Simulated Results

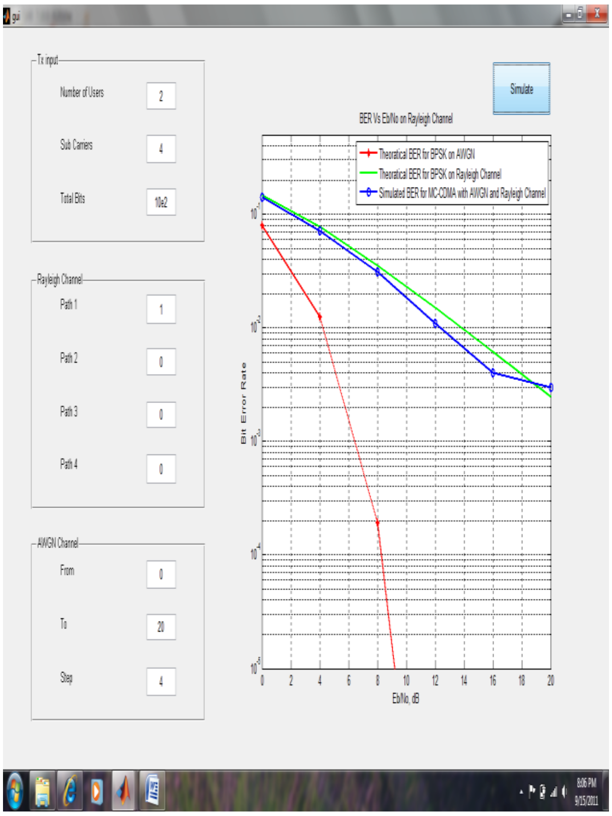

Fig 5 SNR for single path, with no of users 2, subcarriers

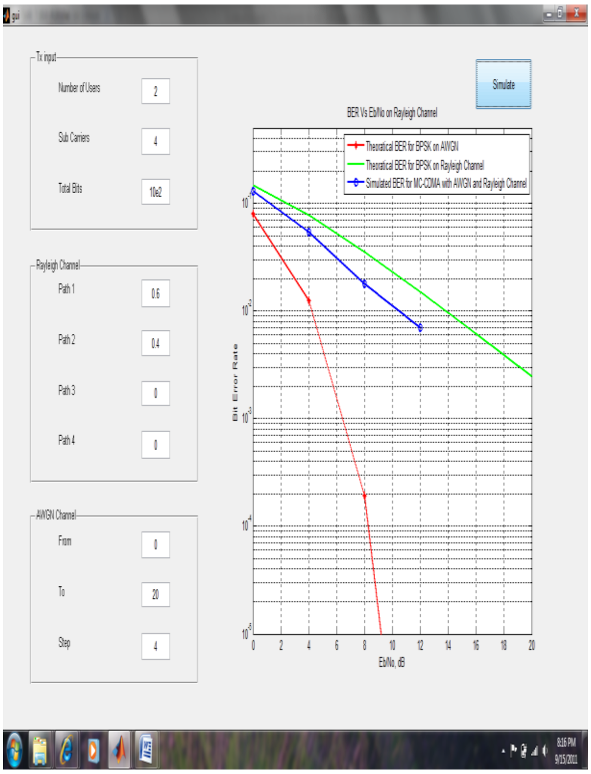

Fig 6 SNR for two different path gains, with no of users 2, subcarriers

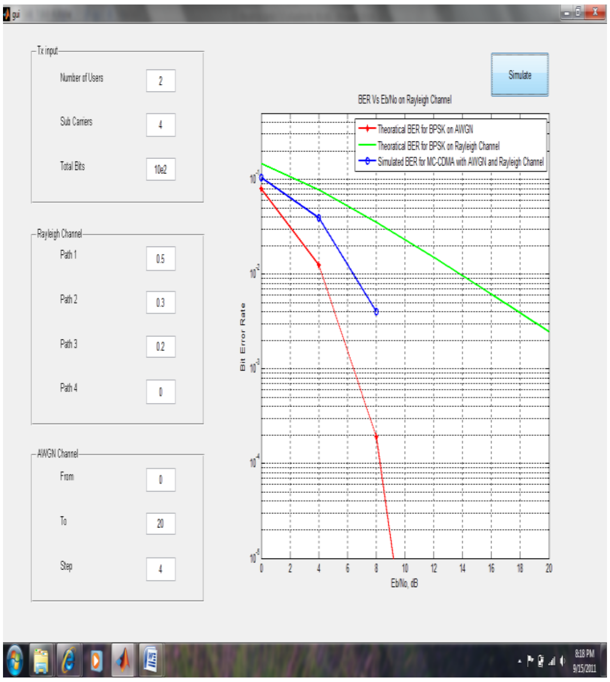

Fig 7 SNR for three different path gain, with no of users 2, subcarriers

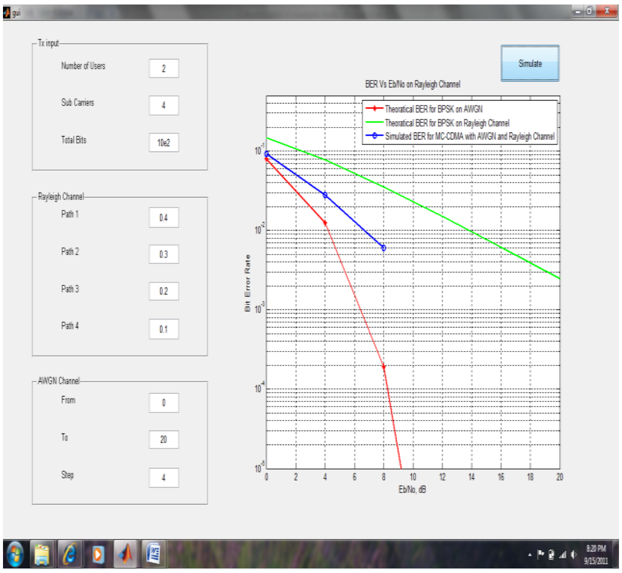

Fig 8. SNR for four different path gain, with no of users 2, subcarriers

6. Conclusion

Analysis of the figures from 5.1 to 5.9 shows that BER values for MC-CDMA that number of sub-carriers decrease the BER about 10 (.01 to 0.001) times, when sub-carriers varies from 4 to 64. It also shows that the crowdedness of channel does not affect the performance of the system very much until the number of users remains within the system capacity.

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