Performance Analysis of MC-CDMA for Rayleigh fading Channel

[1]Vikas Gupta
[1]Assistant Professor, TIT Bhopal
[2]Ruby Tiwari
[2]Student (M.E.), TIT Bhopal
EWS-49 North T.T.Nagar, Bhopal. MP- 462003
rubytiwari2007@gmail.com
Contact No- +919993369723

Abstract*:* For wireless communication system multipath fading is a common problem specially in urban areas where a large number of buildings reflects the radio signals which results in interference amongst the reflected signals which causes the multipath fading effect since its selective by nature some spectrum at some specific location cancels out hence the receive signal losses some part of their information this abruptly increases the BER of communication system in slight movement of receiver, this paper specially analyzes the BER performance under Rayleigh fading channel conditions of MC-CDMA (Multicarrier Code Division Multiple Access) in presence of AWGN (Additive White Gaussian Noise) for different number of subcarrier, different number of users, and different path gains system analysis is performed by simulating the MC-CDMA using MATLAB program, and finally the paper also presents a comparison between simulated results.

Keywords*:* MC-CDMA (Multicarrier Code Division Multiple Access), AWGN (Additive White Gaussian Noise), Rayleigh fading.

1. **Introduction**

Multipath fading is not a new problem for wireless communication but recent growth in mobile communication system; attracts the designer to seriously think about the problem because it is difficult to avoid such problem under moving conditions. Because the device is continuously moving we can’t impose the restrictions on it and it could travel to many points which fall under selective fading.

In wireless communication multipath fading could occur by reflection of radio signals from different objects, (causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings) which cause the reception of signals at different phase angles on receiver. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading. The standard statistical model of this gives a distribution known as the Rayleigh distribution. Rayleigh fading with strong line of sight content is said to have a Rician distribution, or to be Rician fading. In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications. The errors are due to inter-symbol interference (ISI). Equalizers are often used to correct the ISI. Alternatively, techniques such as orthogonal frequency division modulation (OFDM) and rake receivers may be used.

2. MC-CDMA

There are many ways to describe the MC-CDMA, but generally it is described as DS-CDMA again modulated by an OFDM carrier, the number of sub-carriers depends upon the length of spreading code used with DS-CDMA. One major difference between MC-CDMA and OFDM is the subcarriers in MC-CDMA at any instant transmits the one symbol but in OFDM each sub carrier transmit separate symbol, the efficiency of MC-CDMA is hidden in orthogonal sub carrier by which the overlapping spectrum of successive subcarriers can be separated other advantage comes from a wideband coverage of carriers and slower transmission time or larger transmission duration for each bit.

MC-CDMA technique has some unique advantages over its root techniques (OFDM, DS-CDMA) Compared to Direct Sequence (DS) CDMA.

Comparison to DS-CDMA: DS-CDMA is a method to share spectrum among multiple simultaneous users. Moreover, it can exploit frequency diversity, using RAKE receivers. However, in a dispersive multipath channel, DS-CDMA with a spread factor N can accommodate N simultaneous users only if highly complex interference cancellation techniques are used. In practice this is difficult to implement. MC-CDMA can handle N simultaneous users with good BER, using standard receiver techniques.

Comparison to OFDM: To avoid excessive bit errors on subcarriers that are in a deep fade, OFDM typically applies coding. Hence, the number of subcarriers needed is larger than the number of bits or symbols transmitted simultaneously. MC-CDMA replaces this encoder by an NxN matrix operation [2].

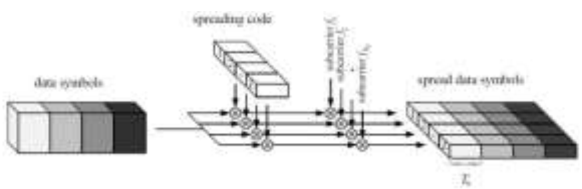

Figure 2.1: MC-CDMA System

From the fig 2.1 it is clear that each symbol of input data is firstly spread by spreading code then each then these spreaded signals are parallel transmitted by orthogonal sub-carriers.

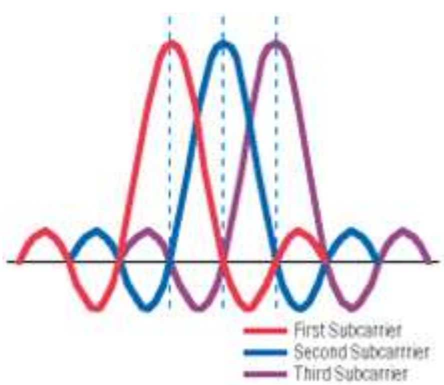

Figure 2.2: Three subcarriers in MC-CDMA

OFDM subcarriers can overlap to make use of the spectrum, but at the peak of each subcarrier spectrum, the power in all the other subcarriers is zero. OFDM therefore offers higher data capacity in a given spectrum while allowing a simpler system design. Creating orthogonal subcarriers in the transmitter is easy using an inverse FFT [3].

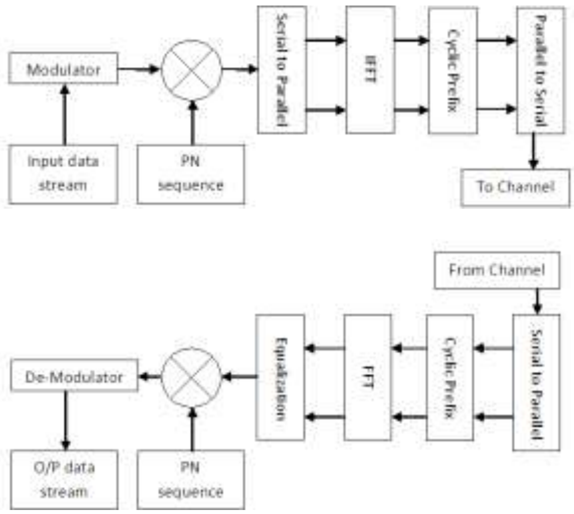

Figure 2.3: Implemented model of Multi-Carrier spread-spectrum transmitter and receiver.

Each bit is transmitted over N different subcarriers. Each subcarrier has its own phase offset, determined by the spreading code. Note that the code is fixed over time, but only varies with subcarrier frequency.

Fig.2.2 shows the block diagram of the MC-CDMA system. At the transmitter, each user's modulated signal is spread by a pre-assigned spreading code. The frequency domain spread signal is interleaved and then converted into time domain by IFFT. Here the interleaving operation is used to map the chips of each symbol onto equally-spaced subcarriers. At the receiver, after removing the CP, the time domain signal is converted into frequency domain by FFT and a frequency domain MMSE equalizer is implemented to recover the orthognality of the spreading codes. Then the equalized signal is despread directly to obtain the desired user's signal.

3. The Rayleigh Fading

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver.

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modelled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function:

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0$$

where $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes [9].

4. Performance Simulation

Computer simulations are done to simulate SNR vs. BER performance of MC-CDMA for different fading channels and 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

All results are calculated for 10^3 bits of transmission, the length of spreading code is same as number of sub-carriers and results are collected for each SNR step changing from 0 to 20 dB with a step size of 1 dB. For the Rayleigh channel four paths are considered, the delay for each path is taken as multiple of λ/2 and the gain of each path are selected during simulation also mentioned on the figure description.

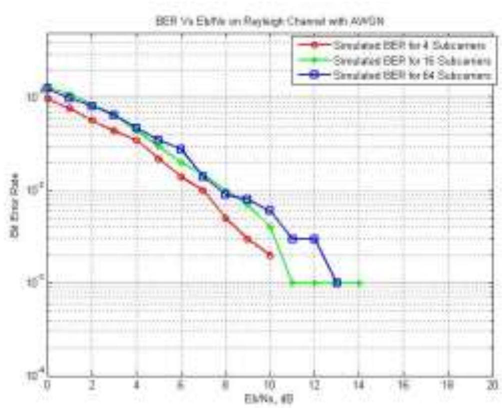

Figure 5.1: SNR/BER for single user 4, 16 and 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.1, p3 = 0.1, p3 = 0.1.

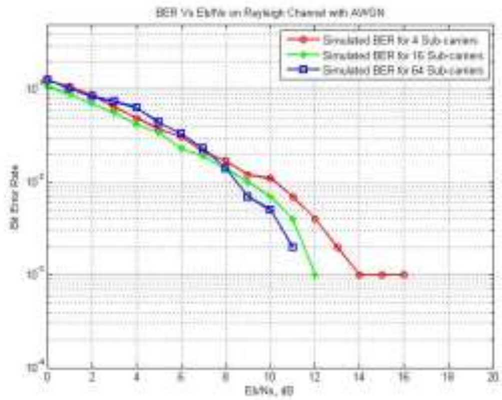

Figure 5.2: SNR/BER for single user 4, 16 and 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.3, p3 = 0.0, p3 = 0.0.

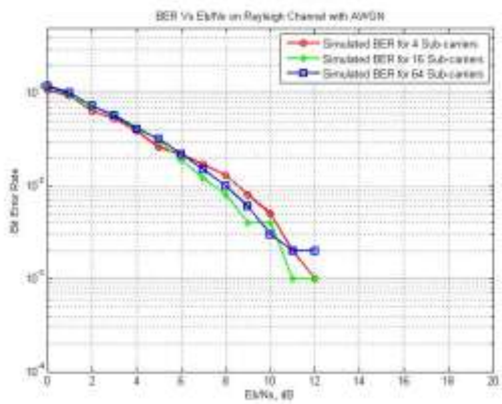

Figure 5.3: SNR/BER for 2,8 & 32 users for corresponding 4,16 & 64 sub-carriers, path gains are p1 = 0.7, p2 = 0.1, p3 = 0.1, p3 = 0.1.

6. Conclusion

Simulation results shows that the increase in sub-carriers decreases the effects of multipath fading, as the comparison in figure 5.1 results significant reduction on BER curve with higher sub-carriers (from 4 to 64), the effect of larger number of reflecting path can also be analyzed by comparing the graphs in figure 5.2 the final conclusion in figure 5.3 shows the case of multiuser (50 percent of capacity) which shows almost same BER performance irrespective number of sub carriers.

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