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PERFORMANCE ANALYSIS OF MC-CDMA OVER DIFFERENT FADING CHANNELS

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Abstract - ***In this paper Multi-Code Multi-Carrier Code Division Multiple Access system is presented, which will be used as a wireless communication system for future generation. In this system, advantages of MC-CDMA are used for rejection of interference and in clashing of multiple paths. On receiving the information about the channel, improvements in potent data rate and all over capacity of the system can be done. As in wireless communication system multipath fading is a common problem as signals are reflected by large towers, buildings, houses etc. and it ultimately results in interference of signals, so solution to this problem is provided by MC-CDMA. Therefore, the MC-CDMA based approach is a promising wireless access scheme in the forward link because the orthogonality among code-multiplexed channels is maintained by applying an orthogonal code such as the Walsh-Hadamard code (Devikarani et al. 2014) associated with the synchronous transmission from a base station.***

Key Words: *MC-CDMA, OFDM, Rayleigh Fading, Rician Fading, Walsh Code.*

1. INTRODUCTION

Multicarrier Code Division Multiple Access (MC-CDMA) is a recent technology that support many users at the same time to provide high data rates with high quality of service. In this technology two techniques are intercrossed i.e OFDM (orthogonal frequency division multiplexing) and CDMA (code division multiple access). This mixing of two technologies results in high spectral efficiency, robustness to multipath propagation, high flexibility[3]. MC-CDMA provides a solution to problems such as sensitivity to multipath conditions, poor bandwidth efficiency, narrowband interference. MC-CDMA is the technology that has come forward to overcome the drawbacks of the individual phenomena i.e OFDM and CDMA. In MC-CDMA input data symbols are spread with spreading codes such as, PN sequence and Walsh codes, in frequency domain. Then parallel multi subcarriers are used for carrying data symbols over it.

Its advantages include efficiency in dealing with multipath and protection against narrowband interference. Its disadvantages are sensitivity to frequency offset and phase noise.

CDMA is a multiple access technique where many transmitters send message simultaneously over a single communication channel.

This paper contains following sections-section 2 discusses the MC-CDMA system followed by section 3 which describes the OFDM and then section 4 is about the types of fading channels used here. Section 5 contains the explanation of Walsh code spreading sequence and Section 6 is about results and discussions. Section 7 gives the conclusions.

2. MC-CDMA SYSTEM

In MC-CDMA, data symbols are modulated with many subcarriers instead of only one carrier like in CDMA. Each one of the data symbol is spread with spreading code. In MC-CDMA, application of spreading code is done in frequency domain instead of time domain. Parts of symbol are transmitted through different subcarriers.

2.1 MC-CDMA transmitter

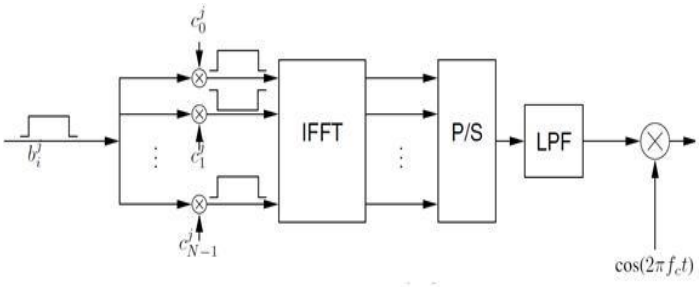


FIG 1- MC-CDMA TRANSMITTER

The signal which is transmitted [1] at the transmitter side is given by the formulae-

$$s(t) = \sum_{k=0}^{N-1} b_i^j \, c_j^k e^{2\pi(f_0 + kf_d)t} p(t - iT) \quad \text{....1}$$

Where,
N = no. of subcarriers
b_i^j= *ith* message symbol of *jth* user
c_k=*kth* chip, *k*=0,.....,N-1
f_o=lowest subcarrier frequency
f_d=subcarrier separation
p(t)=rectangular pulse

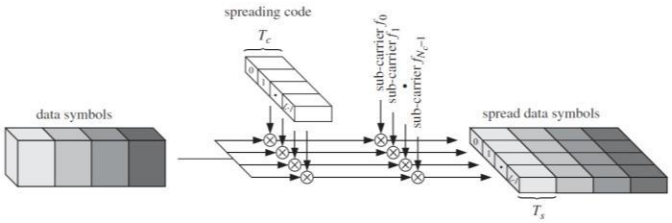


FIG 2- MC-CDMA signal generation for 1 user

The data symbols of the multiple users are transmitted on the sub channels and then multiplied by the chips of spreading codes. Here the length of the spreading code need not to be equal to the number of subcarriers, so complexities of receiver design are reduced.

The major advantage of MC-CDMA, that has many subcarriers over CDMA , that has only single carrier is that the symbol rate is less than the chip rate, so transmission can be quasi-synchronised easily. If the symbol rate is high then the system is affected by frequency selective fading. For this data has to be converted from serial data to parallel data.

2.2 MC-CDMA receiver

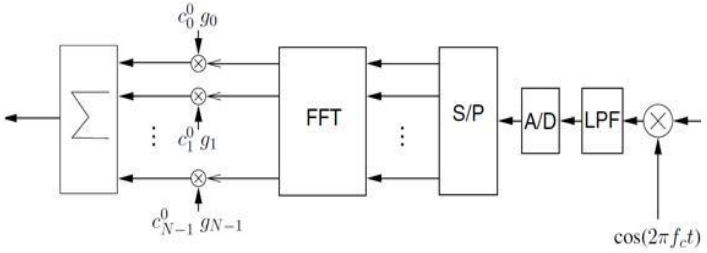


FIG 3- MC-CDMA Receiver

In above figure, structure of MC-CDMA receiver is shown. At the receiver side, the chip code of a specific user can be recovered back using Fast Fourier transform (FFT) and hence the original data of the user can be recaptured back.

The received signal at the receiver is given by[1]-

$$r = \sum_{j=0}^{j-1} H_k b_i^j c_k^j + n \quad \text{....2}$$

Where,
J = no. of users
H_k = freq. response of *kth* subcarrier n= noise sample

This received signal of a specific user is multiplied by its corresponding chip sequence and the gain also and then this is summed up to get the decision variable:

$$d_i^j = \sum_{k=0}^{N-1} c_k^j g_k r$$

3. OFDM

The problem in case of CDMA is that the designing of receiver is complex. Also it is affected by self jamming problem because of bad synchronisation. With the advent of OFDM (orthogonal frequency division multiplexing) which is robust against the frequency selective fading[8].

OFDM is a suitable scheme to provide services of multimedia with high speed transmission and bandwidth efficiency. In this phenomenon the entire bandwidth is subdivided into subcarriers and they are orthogonal to each other.

Some of the advantages of OFDM includes-
- Spectral efficiency is high.
- Receiver complexity is reduced.
- High flexibility.

Drawbacks of OFDM are-
- Low symbol rate due to limited bandwidth.
- More sensitive to carrier frequency offset than, with the system having single carrier only.
- Peak to average ratio (PAR) of transmitted signal power is large.

4. FADING CHANNELS

Fading is a common problem in wireless communication system which is due to multipath propagation. Multipath propagation takes place when a signal transmitted by the transmitter is reflected by large buildings and its takes multiple paths before being received by the receiver.

4.1 Rayleigh fading model

This type of fading channel is applied in the cases where there is no line of sight (LOS) between the transmitting and receiving antenna. This model is effective when many scatterers are present in the passage and which scatters the radio signal before being received by the receiving

antenna[7].

The assumption made for Rayleigh fading model is that the magnitude of the signal, that has passed through the environment that scatters the radio signal, will vary randomly according to the Rayleigh distribution[3].

4.2 AWGN channel model

Additive White Gaussian Noise is a channel model in which the only flaw is due to addition of white noise and the message signal is converted to noise. The parameters that are not considered here are scattering and fading. This model is used for studying behavior of a system before the other phenomena are considered[6].

4.3 Rician fading channel

This model is used when a LOS component is presentin the channel. There are two types of components discussed here- Specular component and Random or Scatter component. The LOS component is the specular component and the multipath component is the random component. The Rician factor ‗K' is ratio of power of specular component to the power of random component[2].

$$k = \frac{m}{2\sigma^2}$$

m is mean

σ^2 is variance

$$m = \sqrt{\frac{k}{k+1}} \qquad \sigma = \sqrt{\frac{1}{2*(k+1)}}$$

5. WALSH CODES SPREADING SEQUENCES

Walsh codes is achieved on application of Hadamard transform to a 1×1 dimensional zero matrix continously.

The Hadamard transform is given by –

$$H_1 = [0]$$
$$H_{2n} = \begin{bmatrix} H_n & H_n \\ H_n & \overline{H_n} \end{bmatrix}$$

where $n = 2^i$, and i is an integer.

Hadamard matrix is a square shaped matrix. Every row or column is written with a Walsh code of length n[7]. For instance let us take the case of n=4.

The resultant matrix is as follows:

$$H_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

6. RESULTS AND DISCUSSIONS

The MC-CDMA system discussed in section II is implemented in various simulation parameters used for analysis given in table 1.

TABLE 1. SIMULATION PARAMETERS

Contents	Parameters
Channel type	AWGN, Rayleigh, Rician
No. of users	2
Modulation	BPSK
Spreading	Walsh-Hadamard

6.1 MC-CDMA in Rayleigh channel

This simulation gives the performance analysis for wireless environment in Rayleigh fading channel. Figure 4 shows theoretical performance of MC-CDMA in 4 tap Rayleigh channel.[4]

Figure 5 shows MC-CDMA in Rayleigh channel for user 1. Figure6 shows MC-CDMA in Rayleigh channel for user2.

6.2 MC-CDMA in AWGN channel

Figure 7 shows performance of MC-CDMA system in AWGN channel for 4 users[4].

6.3 MC-CDMA in Rician channel

MC-CDMA system is then analysed for fading in Rician channel and for different users in figure 8 and figure 9[4].

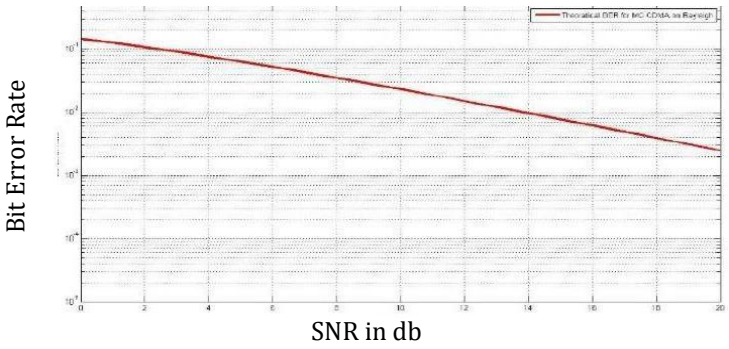
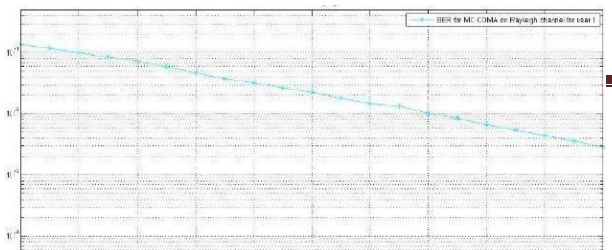


FIG. 4- MC-CDMA in theoretical in Rayleigh channel



SNR in db

FIG. 5- MC-CDMA in theoretical in Rayleigh channel for user 1

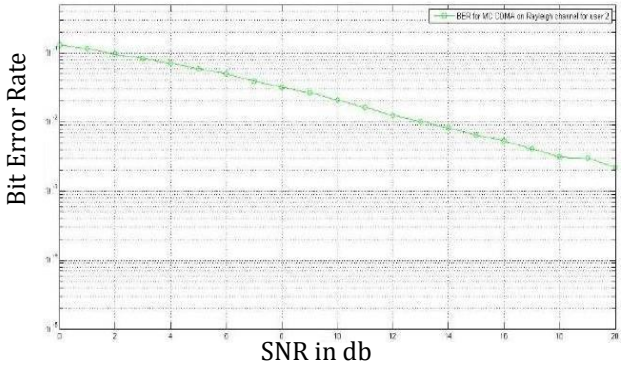


FIG. 6- MC-CDMA in theoretical in Rayleigh channel for user 2

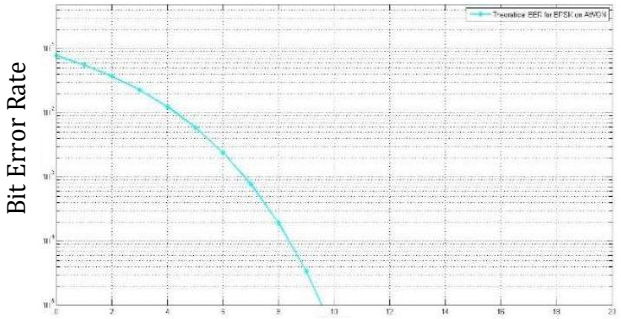


FIG. 7- MC-CDMA in AWGN channel

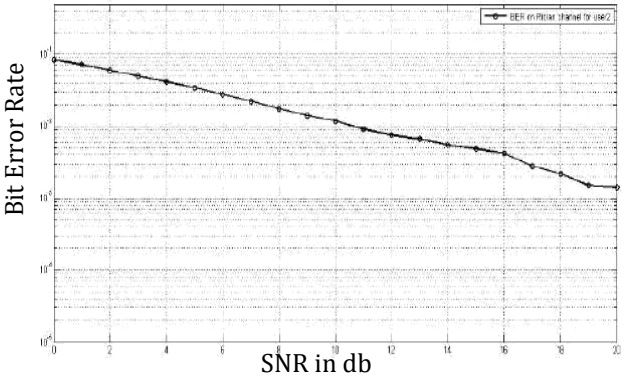


FIG. 8 MC-CDMA performance in Rician channel for user 1

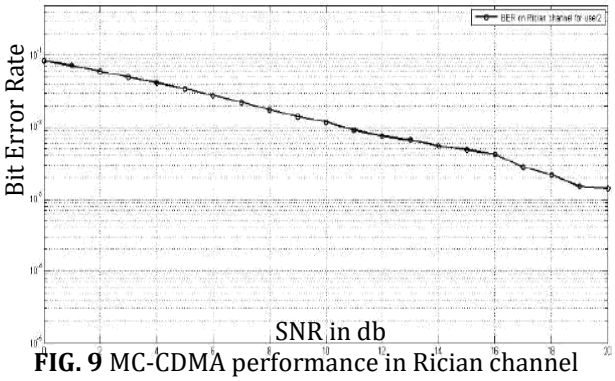


FIG. 9 MC-CDMA performance in Rician channel for user 2

7. CONCLUSIONS

We have analysed the performance of MC-CDMA over Rayleigh fading channel, AWGN channel and Rician fading channel.

The following are the observations that are made on the basis of results shown above-

- BER performance is higher for Rayleigh fading channel in comparison to Rician fading channel.
- This lower BER performance shows that MC-CDMA has reduced the problem of frequency selective fading in CDMA.

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