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Performance Analysis of MC-CDMA in Rayleigh Fading

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ABSTRACT
The technique of Spread Spectrum is used in 4G schemes and one of those techniques is Multi Carrier code Division Multiple Access "MC-CDMA". In this project MC-CDMA was simulated under Rayleigh fading and adaptive Gaussian White Noise. The simulation a huge difference for the signal in Rayleigh fading the bit error rate barely reached 10-3 dB with double the power used to reach 10-5 under Gaussian noise. MC-CDMA, Multi-Carrier Code-Division Multiple Access, Fading, 4G, 5G.

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I. INTRODUCTION

After the transmission from the analog mobile system known as 2G to 3G which is completely in digital form, several technologies have been innovated to fulfill the boosted demand on higher data rates and bandwidth. Moreover, the goals went far from that to be:

- Different multimedia other than audio such as images, video and different data.
- Bit rates up to 14.4 Mbit/s for hot spot applications. While in GSM the bit rate reached 171.2 Kbit/s with GPRS update.
- Flexibility in frequency, data rate and radio resource management.
- Different environment for operation.

Multiple access schemes were used to fulfill the new requirements. The common ones for 3G is time division multiple access "TDMA" and code division multiple access [1]. The principle of CDMA is the opposite to TDMA. In TDMA system, all users make use of the same band, but they are separated by allocating short and clearly defined time slots as shown in figure 1. in CDMA systems, all users transmit at the same to on the same carrier. Here a wider bandwidth is used. The users are defined by assigning different spreading codes with low cross correlation.

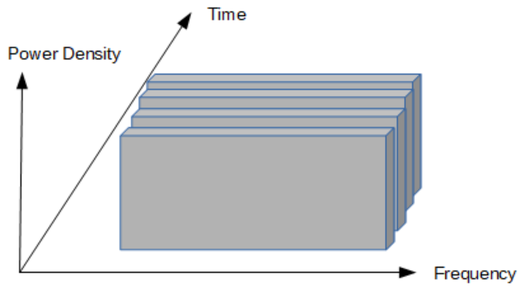

Fig 1 the basic principle of TDMA.

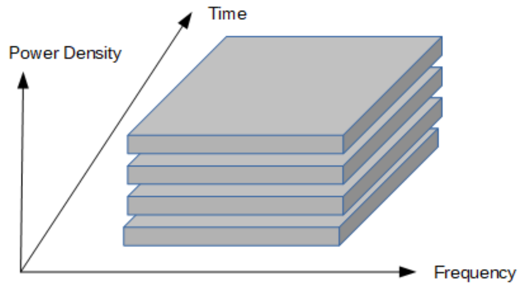

Fig 2: the basic principle of CDMA.

As the network generation went to 4G, new technology has presented in spread spectrum as well. The multiple access scheme is based on direct sequence code division multiple access "DS-CDMA". It depends on spreading the data stream using an assigned spreading code for each user in the time domain. The performance of such a system depends the number active users and the channel characteristics.

The technique of multi carrier transmission was introduced and it interested organizations in the field of wireless communications. The basic principle of such a system relies on the transmission of data by dividing high-rate data stream into several low rate sub-streams. And these are modulated on different sub-carriers [2] [3] [4]. this scheme requires more filters and oscillators. To overcome this issue a new digital technique called Orthogonal Frequency Division Multiplexing "OFDM" was introduced. OFDM can be given by Discrete Fourier Transform [4].

There are two multiple access schemes that excites researchers to test. Those two are MC-CDMA and MC-DS-CDMA. In this project we are concentrating on MC-CDMA and see its performance.

MC-CDMA is based on on a serial concatenation of direct sequence spreading with multi carrier modulation [5]. The main characteristics of MC-CDMA is shown in table 1.

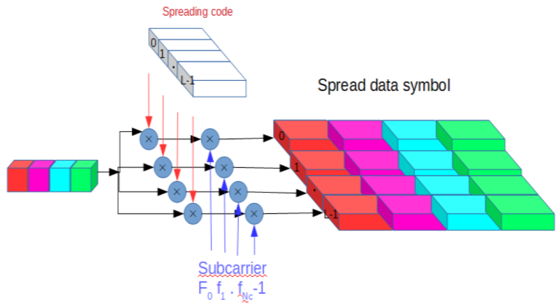

Fig 3 principle of MC-CDMA [1].

Table 1 Main Characters in MC-CDMA.

Spreading	Frequency direction
Sub carrier spacing	
Detection algorithm	MRC, EGC, ZF, MMSE equalization, IC, MLD
Specific characteristics	Very efficient for the synchronous downlink by using orthogonal codes.
Applications	Synchronous uplink and downloink

K. Fazel and S. Kaiser have illustrated this technique in their book [1]. The performance of MC-CDMA was analyzed as well under Rayleigh fading. Single user detection techniques were used. QPSK was used in band-pass modulation. Orthogonal Walsh-Hadamard codes were used for spreading with a code length of eight. Figure 4 is the result from the reference [1].

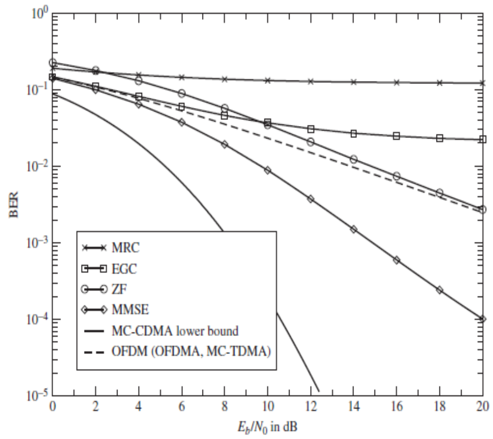

Figure 2-14 BER versus SNR for MC-CDMA with different single-user detection techniques: fully loaded system; no FEC coding; QPSK; Rayleigh fading

Fig 4 BER versus SNR for MC-CDMA for a single user with various detection techniques [1].

A published paper by Fan Lingtau, Li Gaozhi and Chen jian [6] is aimed to measure the BER of MC-CDMA over Rayleigh fading channels. The spreading technique used is Walsh-Hadamard codes as well. The number of users varies from one to 34 users with a fixed SNR of 13 dB. Figure 5 is taken from from the reference [6] as a result.

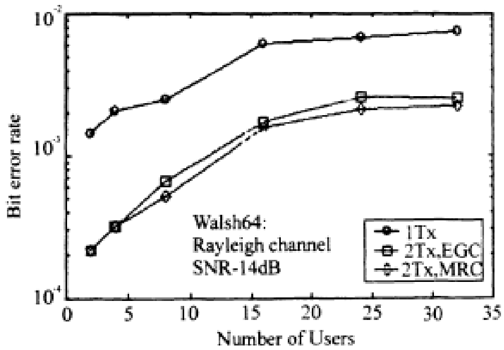

Fig.3 Performance of MC-CDMA with and without OTD over Rayleigh channel

Fig 5 BER at different users number with SNR=14 dB [6].

As seen of past works in this area. The aim here is to measure the BER for MC-CDMA at Rayleigh fading and white nose. This is a step ahead to understand the concept of codes spreading, Fading channels and MC_CDMA.

As for Rayleigh fading. There are several ways to make a fast simulation of the channel as described Matthias Patzold in his book [7]. The table system is one way to make a channel simulator. Here the design should store some portions of the data in into at table that is read afterword cyclically. Figure 6 below shows the main concept of table system.

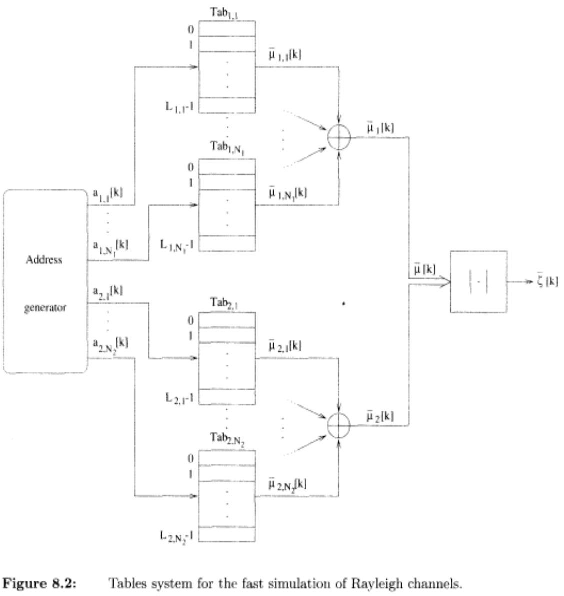

Fig 6 table system for fast Rayleigh channels [7].

Another system can be driven from the table system which is the matrix system. Here all the tables are combined into a channel matrix. The number of rows represents the number of tables used to store the data.

II. METHOD

The block diagram from the proposal is updated to the structure given in figure 7. the block is done for two users. The band pass modulation used is binary phase shift keying for a better signal to noise performance at white noise. The design parameters is shown in table 2.

Table 2 Design Parameters.

Number of users	2, 4
Data generation	Random binary
Data length	10000 bits
Modulation technique	BPSK
Spreading technique	Walsh-hadamard
Number of sub carriers	4, 8, 16
SNR	Up to 20 dB

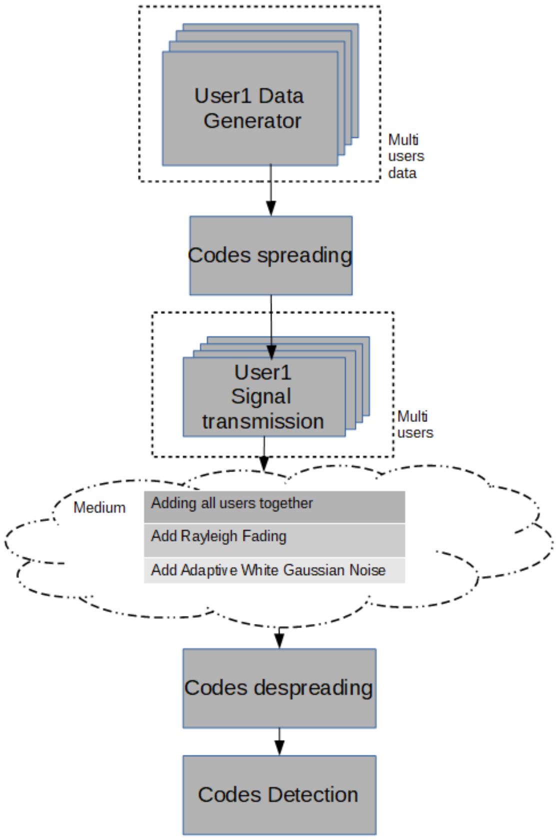

Fig 7 design block diagram.

Band pass modulation used is to grant the highly BER can be provided with a modulation technique. Recall that the probability of errors in BPSK is given as:

$$P_e = Q(\sqrt{\frac{2E_b}{N_0}}) \quad (1)$$

The BER of BPSK under flat fading [8] is given by:

$$P_b = \frac{1}{2}(1 - \sqrt{\frac{E\_b/N_0}{E\_b/N_0 + 1}}) \quad (2)$$

Wash-Hadamard is widely used as seen from several papers. The peak to average power ratio PAPR is less than or equals to double the number of sub carriers [1]. While the others provide less PAPR.

III. RESULTS

Figure 8 shows the BER of two users compared with the theoretical BER of BPSK under white noise and under flat fading channel [8]. Figure 9 is for two users and eight sub carriers.

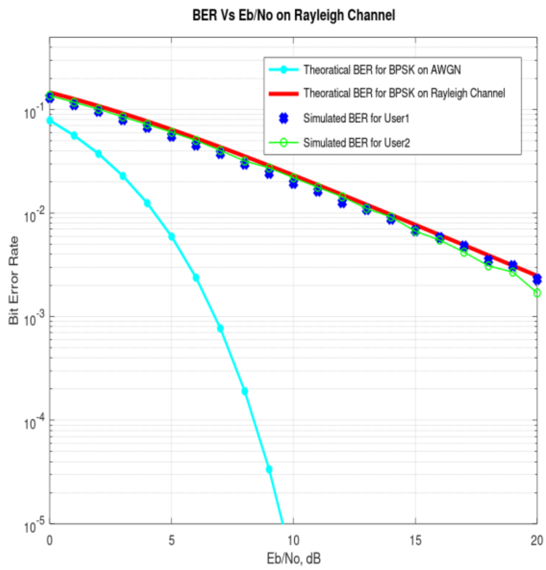

Fig 8 bit error rate against Signal to noise ratio for two users and four sub-carriers.

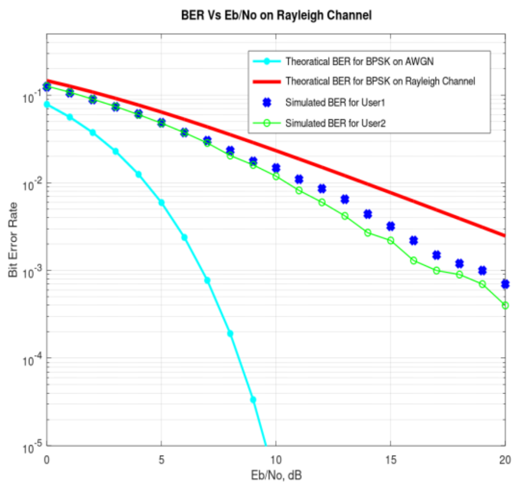

Fig 9 bit error rate for two users with eight sub carriers.

The results after increasing the number of users to four with sub carriers gave the result shown in figure 10. increasing the sub carriers yielded to the result shown in figure 11.

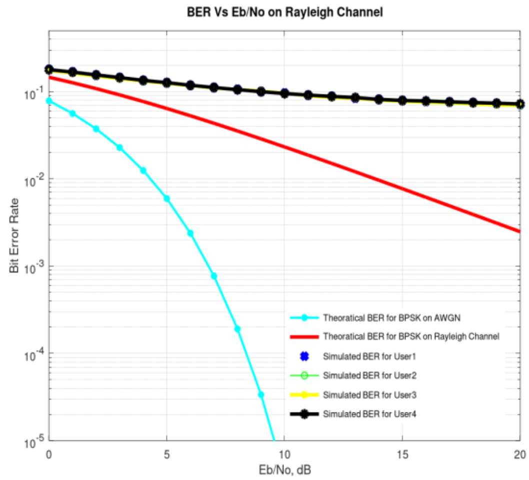

Fig 10 BER for four users and sub-carriers.

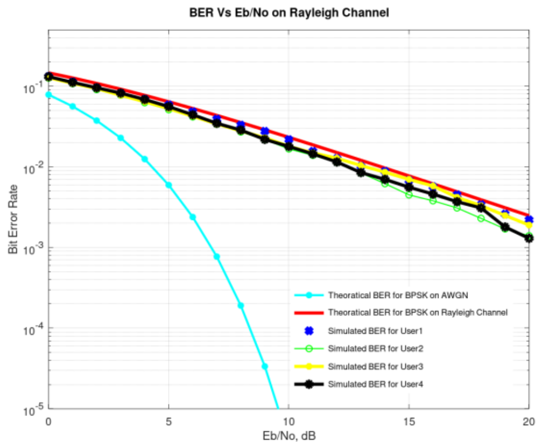

Fig 11 BER for four users and eight sub carriers.

IV. DISCUSSION:

Rayleigh fading hugely affects the Bit Error Rate of the transmitted information. When the signal to noise ratio approaches 10 dB the bit error rate is around 0.5*10-1 while if the medium is fading free it can go to 10-5. The simulation for the two users is almost like the theoretical. The detection technique used is equalization. Increasing signal to noise ratio does not have a huge change on the bit error rate unlike fading free signal.

Increasing the sub carriers using Wlash Hadamard code decreased the bit error rate. If more users have shared the channel the errors increase.

V. CONCLUSION:

The performance of MC-CDMA was simulated under Rayleigh fading. The code was randomly generated and modulated with BPSK. It was then spread using Walsh-Hadamard technique. The performance is then compared with the theoretical bit error rate. Other work that might be done is to change the detection technique and see the result compared to the one found here. Other suggested technique is Maximum liklihood sequence estimator MLSE.

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