ANALYSIS THE PERFORMANCE OF MULTI-CARRIER CDMA SYSTEM WITH FADING AND INTERFERENCE

Bobby Barua*

ABSTRACT

Users moving at vehicular speed communicate over a wireless channel that exhibits time-variant frequency-selective characteristics due to multipath propagation and doppler effects. Multi Carrier Code Division Multiple Access (MC-CDMA) is a relatively new concept to improve the performance over multipath links. MC-CDMA is a modulation method that uses multi carrier transmission of DS-CDMA type signals and an MC-CDMA transmitter spreads the original data stream in the frequency domain over different sub carriers using a given spreading code. The MC-CDMA offers better frequency diversity to combat frequency selective fading. In this paper we evaluate the performance results of MC-CDMA in terms of bit error rate, power, length, code length and no. of subscriber.

Keywords: *Bit Error Rate (BER), Code Division Multiple Access (CDMA), Multi Carrier Code Division Multiple Access (MC-CDMA), Multipath propagation.*

*Assistant Professor, Department of EEE, Ahsanullah University of Science and Technology, Dhaka, Bangladesh

1. INTRODUCTION

Mobile communications are rapidly becoming more and more necessary for everyday activities. With so many more users to accommodate, more efficient use of bandwidth is a priority among cellular phone system operators [1]. Again the security and reliability of these calls are equally important. One solution that has been offered to mitigate the situation is a Code Division Multiple Access system [2]. Multiple Access is a technique where many subscribers or local stations can share the use of a communication channel at the same time or nearly so despite the fact originate from widely different locations [3].

A multicarrier system is a system where several subcarriers are used for parallel transmission of data packets. A new multicarrier mechanism is applied to a Code Division Multiple Access (*CDMA*) network [4]. In a CDMA network each data symbol is spread over a larger bandwidth, larger than the bandwidth needed for transmission. This allows to transmit with a spectral energy that is lower than in a non spread spectrum system, a fact that allows the use of parallel transmission channels, at the same time in the same frequency band. Each symbol of the data stream of one user is multiplied by each element of the same spreading code and is thus placed in several narrow band subcarriers. Multiple chips are not sequential, but transmitted in parallel on different subcarriers [5].

In the field of wireless communications, the combinations of Multi-Carrier (MC) modulation [6] and Code Division Multiple Access (CDMA) [7] have gained considerable interest due to their excellent performance. According to the spreading approach used, these techniques can be classified into two different schemes [8]. In the former, referred to as Multi-Carrier Direct Sequence CDMA (MC-DS-CDMA), spreading is performed in the time-domain, whereas in the latter, named Multi- Carrier CDMA (MC-CDMA), spreading is performed in the frequency-domain [9-10].

Again MC-CDMA based communication system has some limitation. Bandwidth, Noise and Fading are some major limitation of the system.

Bandwidth is the measurement of a particular frequency range. When we fixed a bandwidth for a channel then we transmit that amount of data in one second of time. So if the frequency range is very high then we can transmit or receive more data for a period of time. In a communications system lack of bandwidth means lack of throughput of intelligible data. So that Bandwidth limitation means restricting the quantity of information transmitted from sender to receiver per second. This either means the information arrives slower, or the information contains less detail.

Noise will also affect intelligibility. The noise is additive, i.e., the received signal equals the transmit signal plus some noise, where the noise is statistically independent of the signal.
Fading is a fluctuation in the received signal strength at the receiver or a random variation in the received signal is known as fading. Fading of radio waves is the undesired variation in the intensity or loudness f the waves received at the receiver. There are two types of fading limitations. Frequency-selective fading & Time selective fading.
In this paper we try to investigate the performance of MC CDMA system with fading and interference. Here different schemes of MC-CDMA are considered to evaluate the performance results in terms of bit error rate code length, no. of subscriber etc.

2. SYSTEM MODEL FOR MULTI CARRIER CODE DIVISION MULTIPLE ACCESS

MC-CDMA is a modulation method that uses multi carrier transmission of DS-CDMA type signals. An MC-CDMA transmitter spreads the original data stream in the frequency domain over different sub carriers using a given spreading code. In this system the sub carriers convey the same information at one time. The MC-CDMA offers better frequency diversity to combat frequency selective fading.

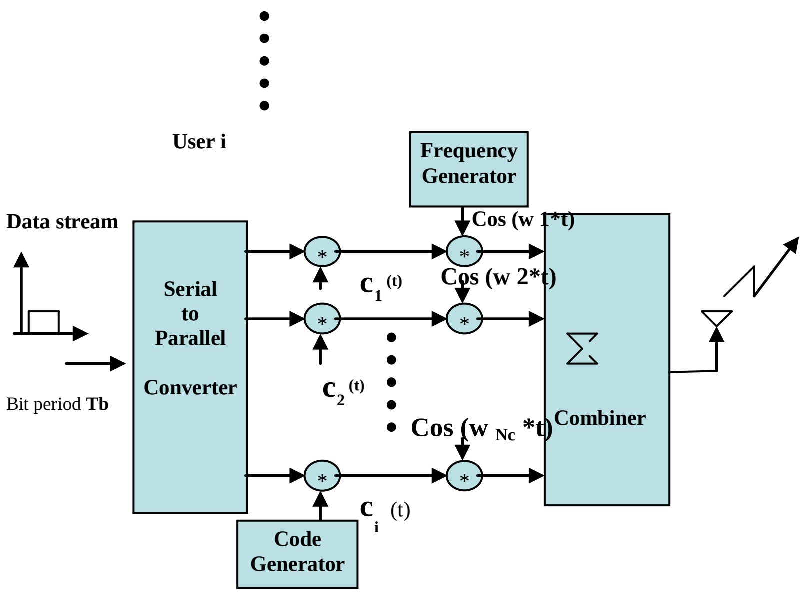

Figure 1 MC-CDMA transmitters

In figure 1 we see the transmitter MC-CDMA system for *i* number of user. The MC-CDMA transmitter spreads the original data stream using a given spreading code in the frequency domain. The code generator creates different unique codes for each different user and then combines together. Then the frequency generator combines different carrier frequency to the data signal and then combines the entire signal together by a combiner. After combining all the signals the CDMA antenna transmits the signals over the wireless media.

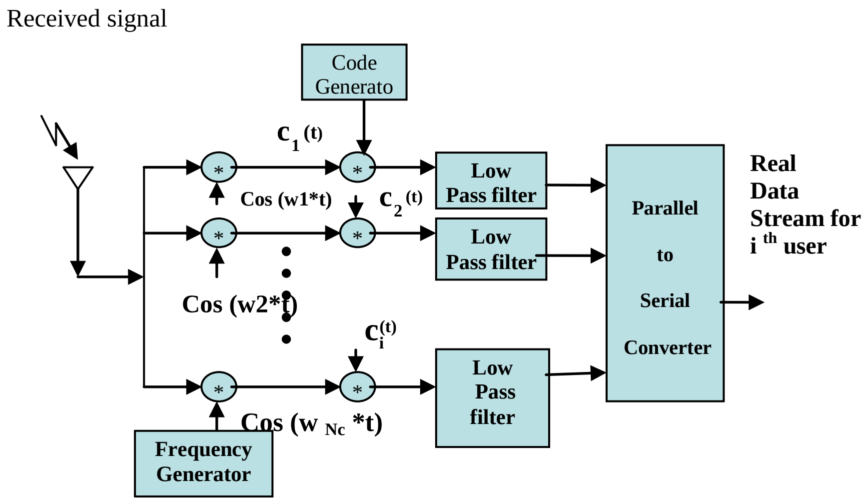

Figure 2 MC-CDMA receiver

In figure 2 the MC-CDMA receiver is designed by the capacity of *i* number of user. MC-CDMA receiver also receives the transmitted signal as a summation of i number of users. At first demodulates the received signal by the same career frequency of each signal and then the signals multiply with the specific codes given by the receiver code generator. Then we get the signal of i^{th} user which is same for transmitter and receiver. After that low pass filter remove the high frequencies portion of the signal. Finally, the P/S converter presents the actual digital data signal.

In receiver side we get the all combing signal with some unexpected signal which are MUI, ICI and Noise signal. So in the receiver side after combining all sub-carrier signals we get the received signal is

$$x = x_0 + x_{MUI} + x_{ICI} + x_{noise} \quad [1]$$

Where,

x_0 = wanted signal;

x_{MUI} = multi-user interference (due to imperfect restoration of the sub-carrier amplitudes);

x_{ICI} = inter-carrier interference (due to crosstalk $\beta_{m,n}$ between a_n and y_m);

x_{noise} = noise;

We can write the wanted signal as,

$$x_0 = b_0 \frac{T_s}{N}\left[\sum_{n=0}^{N-1}\beta_{n,n}\omega_{n,n} + \sum_{m\neq 0}\sum_{n=0}^{N-1}\beta_{m,n}\omega_{n,n}c_0[n]c_0[n-m]\right] \quad [2]$$

Where,

N = number of subscriber,

n = subscriber number,

$\beta_{n,n}$ = crosstalk between the user.

T_s = Sampling time.

$\omega_{n,n}$ = weight factors which is constant.

$c_0[n]c_0[n-m]$ = orthogonal spreading codes

The variance of x_0 became zero for large number of N, i.e., the system working like non fading channel.

3. THEORETICAL ANALYSIS OF MC-CDMA

The multi-user interference signal is

$$x_{MUI} = T_s \sum_{k=1}^{N-1} b_k \left[\sum_{n=0}^{N-1}\beta_{n,n}\omega_{n,n}c_0[n]c_k[n]\right] \quad [3]$$

We can write the x_{MUI} as,

$$x_{MUI} = T_s \sum_{k=1}^{N-1} b_k \left[\sum_{n\in A_+}\beta_{n,n}\omega_{n,n} - \sum_{n\in A_-}\beta_{n,n}\omega_{n,n}\right] \quad [4]$$

Where,

$A_- = \{n : c_j[n]c_k[n] = -1/N\}$ is the sets of orthogonal code of the sub career index n

$A_+ = \{n : c_j[n]c_k[n] = 1/N\}$ is the sets of orthogonal code of the sub career index n

And $A_+ \cup A_- = A$ is the value of $\sum_{A_+ \cup A_-} c_j[n]c_k[n] = 0$.

So the variance of MUI,

$$\sigma^2_{MUI} = E_{ch} E x_{MUI} x^*_{MUI}$$

$$= \frac{(N-1)T_s}{N^2}\left[E_{ch}\left(\sum_{n\in A_+}\beta_{n,n}\omega_n\right)^2 + E_{ch}\left(\sum_{n\in A_-}\beta_{n,n}\omega_n\right)^2 - 2E_{ch}\left(\sum_{n\in A_+}\beta_{n,n}\omega_n\right)\times\left(\sum_{n\in A_-}\beta_{n,n}\omega_n\right)\right] \quad [5]$$

If we may assume that fading of the sub-carriers is independent, we can write

$$E_{ch}\left(\sum_{n\in A_+}\beta_{n,n}\omega_n\right)^2 = \frac{N}{2}M_{22} + \frac{N}{2}\left(\frac{N}{2}-1\right)M_{11}^2 \quad [6]$$

and,

$$E_{ch}\left(\sum_{n\in A_+}\beta_{n,n}\omega_n\right)\times\left(\sum_{n\in A_-}\beta_{n,n}\omega_n\right) = \left(\frac{N}{2}\right)^2 M_{11}^2 \quad [7]$$

Where

$$M_{11} = E\beta_{n,n}^2 / N_0 = P_0 / N_0$$
$$M_{22} = E\beta_{n,n}^4 / N_0^2 = 2P_0^2 / N_0^2$$

P_0 = power of the signal.

N_0 = power of the noise signal.

After simplify all the equation we get the variance,

$$\sigma_{MUI}^2 = \frac{(N-1)T_s^2}{N}\left(M_{22} + M_{11}^2\right) \quad [8]$$

The ICI comes from the crosstalk between sub carriers. Inter-carrier interference signal is,

$$x_{ICI} = T_s \sum_{n=0}^{N-1} a_n \sum_{\Delta\neq 0}\beta_{n+\Delta,n}\omega_{n+\Delta,n+\Delta}c_0[n+\Delta] \quad [9]$$

Here,

Δ = distance of signal between two subscriber,

Now after putting $a_n = \sum_k c_k[n]b_k$ in the equation,

$$x_{ICI} = \sum_{\Delta\neq 0}\sum_{n=0}^{N-1}\sum_{k=0}^{N-1} b_k c_k[n]\beta_{n+\Delta,n}\times\omega_{n+\Delta,n+\Delta}c_0[n+\Delta] \quad [10]$$

So the variance of ICI,

$$\sigma_{ICI}^2 = E_{ch}Ex_{ICI}x_{ICI}^*$$

$$= T_s^2 E_{ch} E\left[\sum_{m=1}^{N-1}\sum_{k=1}^{N-1} b_k \sum_{n=0}^{N-1}\beta_{mn}\omega_n c_0(n)c_k(n-m)\right]^2 \quad [11]$$

After simplify the equation we get the variance

$$\sigma_{ICI}^2 = \sum_{\Delta \neq 0} p_\Delta M_{02} T_s^2 \qquad [12]$$

Where $M_{02} = E\beta_{n,n}^2 / N_0^2 = P_0 / N_0^2$

p_Δ = variation of the signal power between of any two subscriber.

The variance of the noise collected over all sub-carriers weighted by $\omega_{n,n}$ becomes,

$$\sigma_{noise}^2 = N M_{02} N_0 T_s \qquad [13]$$

Now

$$\frac{E_N}{N_0} = \frac{M_{11}^2 T_s^2}{\sigma_{ICI}^2 + \sigma_{MUI}^2 + \sigma_{noise}^2} = \frac{M_{11}^2}{\left(M_{22} + M_{11}^2\right) + M_{02}\left[\sum_{\Delta \neq 0} p_\Delta + \frac{N_0}{T_s}\right]} \qquad [14]$$

Since we consider many different channels, x_{MUI}, x_{ICI} and x_{noise} are zero-mean complex Gaussian. So BER is,

$$B = \frac{1}{2} erfc \sqrt{\frac{E_N}{N_0}} \qquad [15]$$

4.RESULTS AND DISCUSSION

The system described above is simulated using Matlab. For the convenience of the readers the parameters used for computation in this paper are shown in table 1.

TABLE 1

Parameter	**Value**
Max. TxPower	10dBm
Spreading Factor	4
CWmin	4 slots
Cwmax	255 slots
Code Length	8, 16 and 32
Number of Subcarriers	12

Channel Bandwidth	20 MHz
Carrier Frequency	5.25 GHz
Noise Level	-93dBm
Path loss Factor	3.5
TxRate Data	12Mbps
TxRate Control	12 Mbps
Data Packet Length	1024 Byte

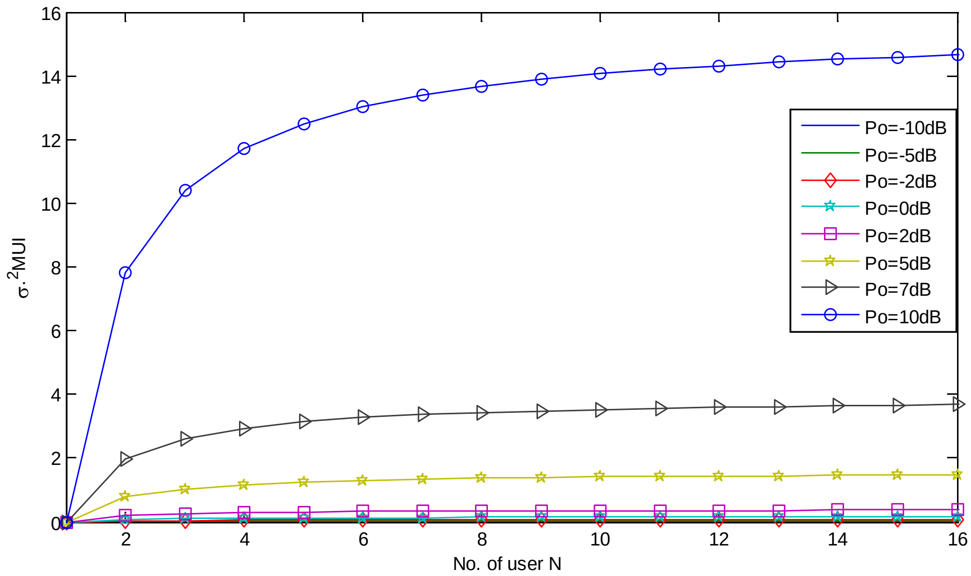

Figure 3: Plots of σ_{MUI}^2 versus number of user in MC-CDMA system

Figure 3 shows the plots of σ_{MUI}^2 versus number of user in MC-CDMA system. This figure comes from equation 8. We see that if we increase the number of user then the interference between different user increases. The variance of the multi user interference depends on signal power. If we increase the power then the interference increases gradually. For example, in this graph variance of MUI for 10dB power is very high and it is more than 14. Whereas for low power like 5dB variance of MUI is less than 2. and it is close to zero for very low power like -10dB.

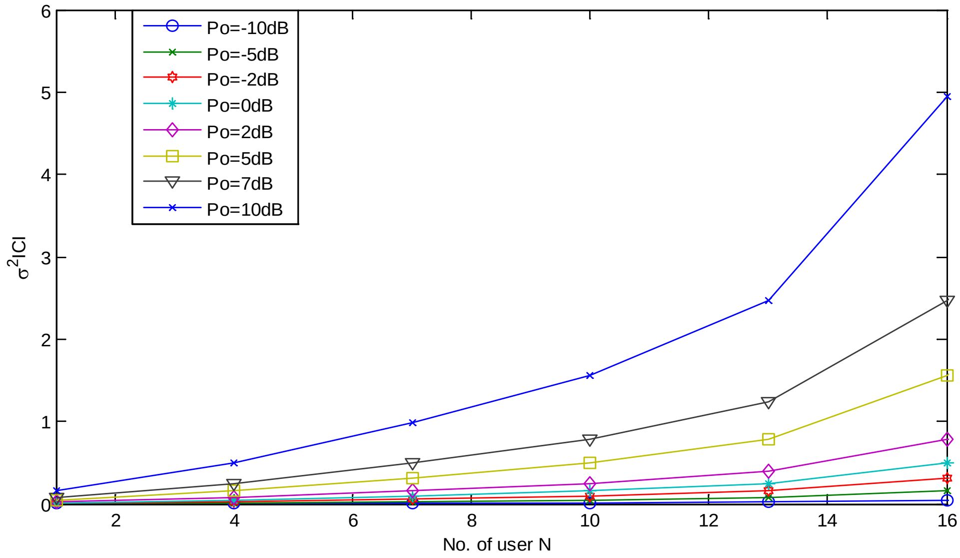

Figure 4: Plots of σ_{ICI}^2 versus number of user in MC-CDMA system

Figure 4 shows the plots of σ_{ICI}^2 versus number of user in MC-CDMA system. This figure comes from equation 12. We see that if we increase the number of user then the variance of ICI increase. The variance of the ICI also depends on the signal power. If power is low then the interference between the carrier is very low but when we increase the power then the inter carrier interference also increase and that case the crosstalk between the sub carrier occurs very rapidly.

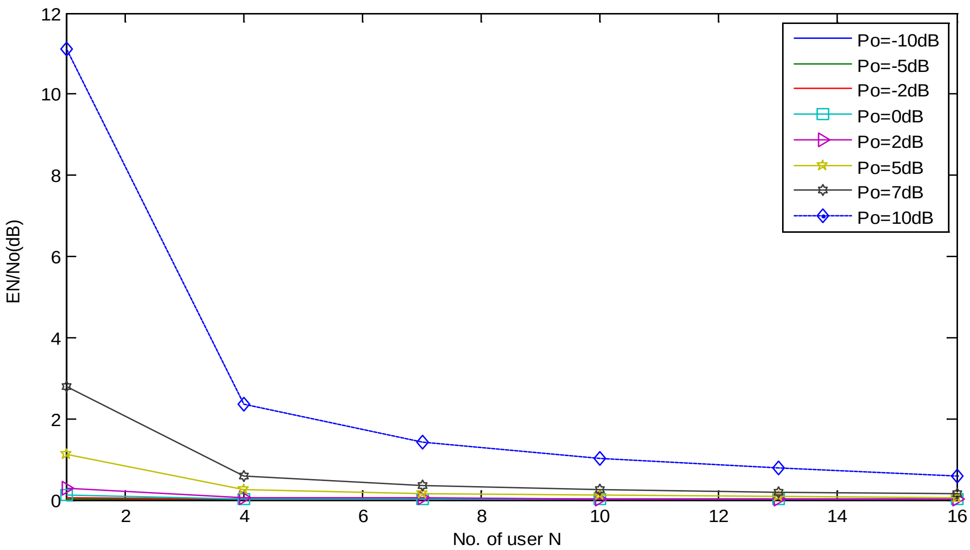

Figure 5: Plots of E_N/N_0 versus number of user in MC-CDMA system

Figure 5 shows the plots of E_N/N_0 versus number of user in MC-CDMA system. This figure comes from equation 14. E_N/N_0 have an inverse relationship with no of subscriber. If we increase number of user then E_N/N_0 decreases.

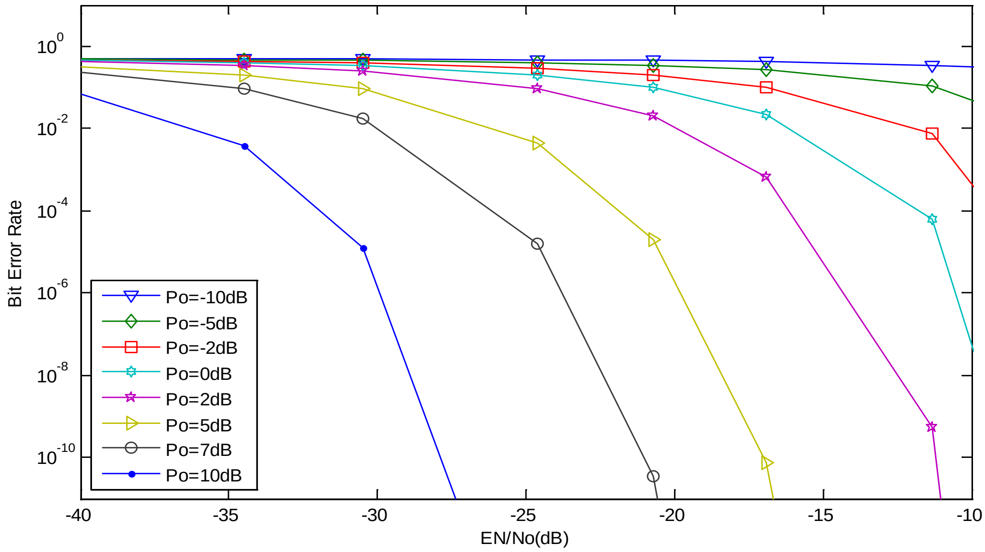

Figure 6: Plots of Bit Error Rate versus E_N/N_0 in MC-CDMA system

Figure 6 shows the Plots of Bit Error Rate versus E_N/N_0 in MC-CDMA system. This figure comes from equation 15. It is found that BER decreases with respect to E_N/N_0 for a particular signal power. I signal power is very high than BER decrease rapidly with respect to E_N/N_0. But if signal power is very low then BER decreases very slowly with respect to E_N/N_0. We prefer lower BER in Wireless communication system and that's why we should use high signal power.

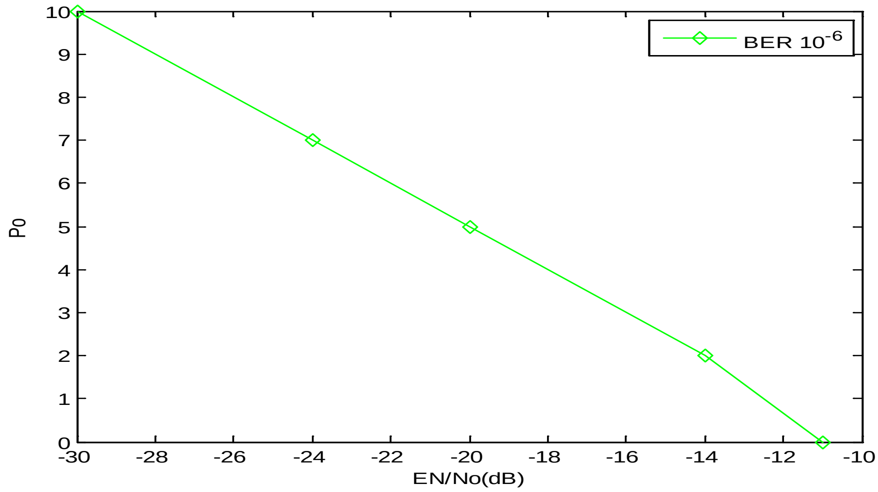

Figure 7: Plots of Signal Power versus E_N/N_0 in MC-CDMA system

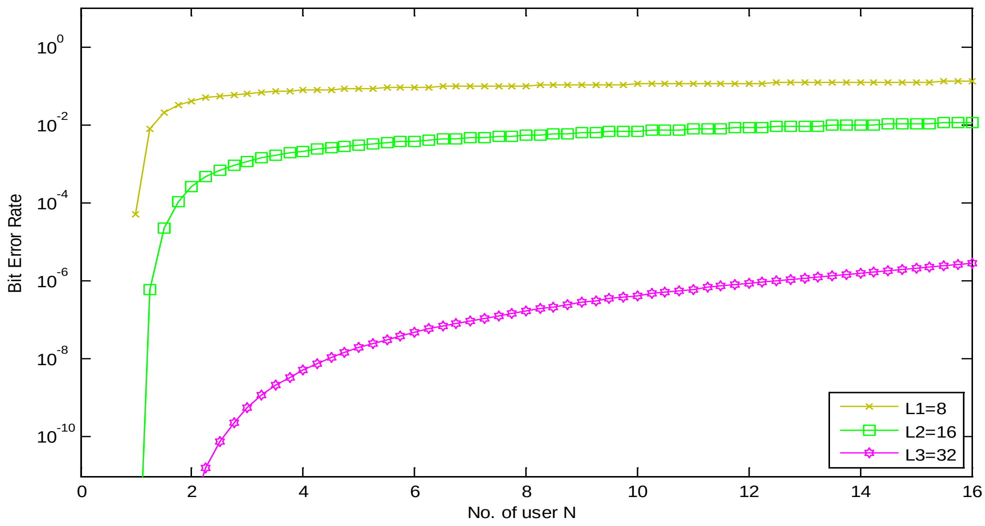

Figure 8: Plots of bit error rate versus number of user in MC-CDMA system

Figure 8 shows the plots Bit Error Rate versus number of user in MC-CDMA system. Here we three different code length which is 8bit , 16bit and 32 bit. It is show that the number of user increases and at the same time BER also increases. Since grater BER is not accepted in wireless communication system and it is essential to reduce higher BER. We can easily do that by increasing the number of chips per bit. When we increase the code length the BER decreases and at the same time we can easily give service more number of user.

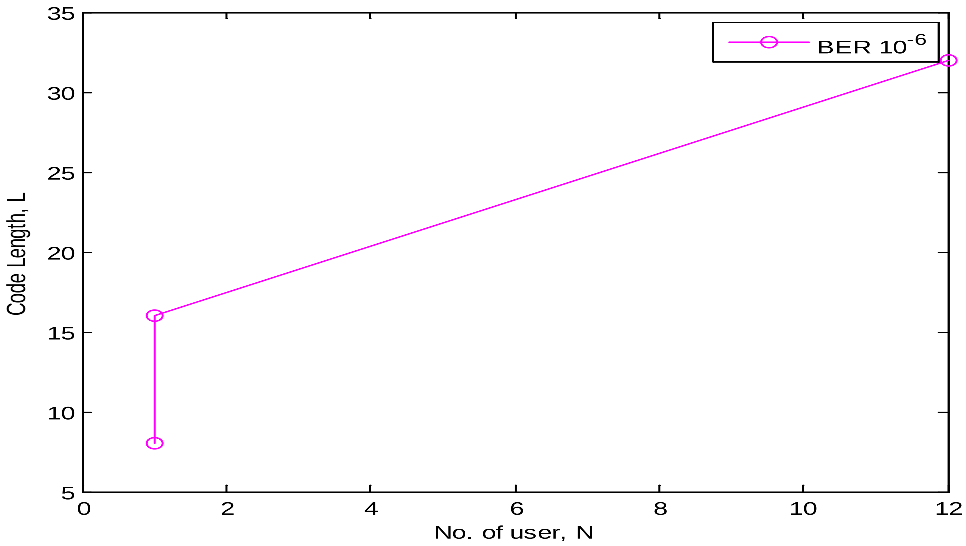

Figure 9: Plots of Code Length versus number of user in MC-CDMA system

The graph for Code length versus Number of user for related BER 10^{-6} which we see in

Figure 9. Here we see that for a particular BER if we increase the Code length then we can easily give support to the more number of users. For more number of users that particular BER may be low and that is acceptable in our system. But if user is less and this reason that particular BER became high for system and that is not acceptable.

5.CONCLUSION

In this paper we used some basic equation to find out our expected results. From the overall analysis we found that the performance result for Multi-user interference and Inter carrier interference for certain number of user. If we increase the user then the MUI and ICI occurs more and more. By BER versus ratio of Energy of bit and Noise density analysis we saw that if we increase the value of E_N/N_0 then the BER became low. In communication system we can not prefer high BER. If BER is low then the channel can transfer the signal more perfectly .We also saw that how can the Code length effect the user capacity in the system. For a particular accepted BER we can easily serve more number of users if the code length is high. The major problem of MC-CDMA is Multi carrier interference and inter carrier interference occur. Near far problem and Multi-path fading also another disadvantage of this system. We saw that in CDMA system due to code difference between the users they can easily share the same frequency.

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