Performance Evaluation of MC DS CDMA using Wireless Open Access Research Platform

Suwadi, Titiek Suryani, Devy Kuswidiastuti, Victor Hariadi and Dwi Anie Gunastut1
Departemen of Electrical Engineering, Faculty of Electrical Technology
Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111
E-mail: suwadi@ee.its.ac.id, titiks@ee.its.ac.id, devy@ee.its.ac.id, victor@if.its.ac.id, and dosen01653@unpam.ac.id

The need for reliable wireless communication systems has become an issue of communication technology development in the modern era. Multi Carrier Direct Sequence Code Division Multiple Access (MC-DS-CDMA) communication system offers superiority in efficient use of frequency spectrum through multicarrier principle as well as good information security level through direct sequence principle. WARP (Wireless Open Access Research Platform) is one type of SDR (Software Defined Radio) technology that can be programmed to create a prototype wireless communication system, one for MC DS CDMA communication system. Implementation of MC DS CDMA communication system using WARP device aims to evaluate the performance of MC DS CDMA communication system and to know how many users are able to be served simultaneously at the time of downlink compared to SC DS CDMA. The measurement results showed that the performance of BER will increase along with the increase of distance between nodes. At a distance of 3 meters the BER performance for gain 20 is 0, whereas at a distance of 5 meters for the same gain the BER performance is 0.0011. BER performance is also inversely proportional to the level of transmit power, where the greater the level of transmit power, the smaller the BER performance. At a distance of 5 meters for the transmit power level 10 obtained BER value 0.0125 and for the level of transmit power 20 obtained value BER 0.0016. In addition, MC DS CDMA communication system is more suitable for multiuser communication than SC DS CDMA with proven BER curves that are still smooth linear for data transmission of 20 users. BER performance is also the same linear down to the increase of transmit power value and Eb/No.

Key Words: BER, MC DS CDMA, WARP

I. INTRODUCTION

Wireless communication becomes a very important field to be developed, where several years we can see its development. The rapid development of video, voice and data communications over the internet is in line with the development of mobile telephony technology. Based on the development of this multimedia communication, the user wants high-speed communication system with adequate QoS (Quality of Service) and security or confidentiality of information sent in wireless technology [1,2].

MC-DS-CDMA communication system offers superiority in efficient use of frequency spectrum as well as good information security level. MC-DS-CDMA uses a multicarrier working principle where the information signal will be carried by multiple carrier waves simultaneously based on orthogonality principle, so it is permissible between carrier waves to overlap each other. In other words, this multicarrier technique is in line with the concept of bandwidth efficiency. MC-DS-CDMA technique also uses the principle of Direct Sequence (DS). One of the advantages of direct sequence is the level of security of information is good, this is because the direct sequence technique can transform signals with a certain frequency into a signal such as noise that has a wider bandwidth than the information signal multiplied by the code of a particular spreader will be returned to the original information signal using the same spreader code on the receiver [3]. MC-DS-CDMA has been implemented on WARP (Wireless Access Research Platform) to find out how many users can run. WARP is a scalable and extensible wireless platform that can be deprogrammed as a wireless network model. WARP itself was discovered by prof. Ashu Sabharwal from Rice University in 2006.

This paper is outlined as follows. Section 2 gives basic theory about the description of MC DS CDMA communication system and software defined radio. In Section 3 gives the description of system model. Performance analysis and measurement results are presented Section 4. It is followed by the conclusions of this paper in Section 5.

II. BASIC TEORY

A. Spread Spectrum

Spread spectrum is a signal transmission technique which use a chip-code for spreading the signal energy into a much wider spectrum signal bandwidth. Hence the transmission bandwidth becomes much wider than the information bandwidth. In spread spectrum transmission, pseudo – noise codes which are independent to the information are commonly used. A spread spectrum system must have the following requirements:

1. The signal is spread using an orthogonal code which is independent to the data.
2. The signal is occupying a wide spectrum bandwidth, which is much greater than the minimum bandwidth requirement for sending the information.
3. On the receiver side, the signal will be dispread using the same replica of the pseudo – noise code which is used as the spread code on the transmitter.

B. Direct Sequence

Nowadays, direct sequence spread spectrum is the most commonly used technique because it is easy to be implemented and it delivers a high data transmission rate. Direct sequence spread spectrum uses a unique code for spreading the signal directly to the baseband information signal and then digitally modulated by the modulator before transmitted to the channel [2].

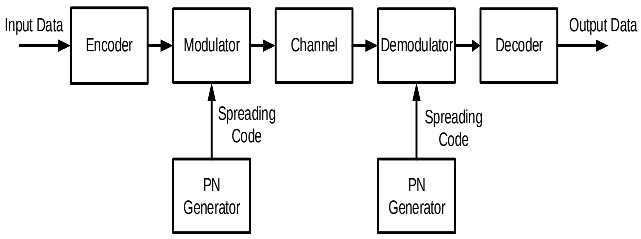

Figure 2.1 DSSS System

In Figure 2.1, it can be seen that direct sequence spread spectrum (DSSS) on the transmitter side, the information signal is multiplied by a higher data rate sequence, known as the chipping code. The information signals is spread by pseudo random generated signal. Hence, the generated signal will have the same signal period as a pseudo noise signal. Then the signal is modulated before later on being transmitted through the antenna. In the signal spreading process that occurs at the transmitter, the binary data is directly multiplied by PN sequences that are independent to the binary data. The effect of this multiplication is to change the signal bandwidth, Rb, to a baseband bandwidth, Rc.

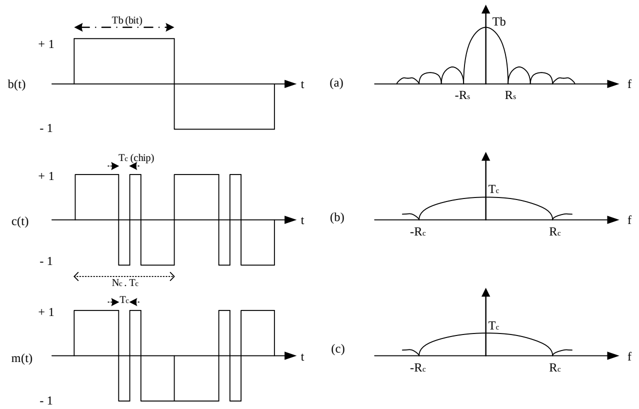

Figure 2.2 Signal spread
(a) Signal and power spectral density.
(b) Chip signal (PN-sequence) and power spectral density.
(c) Spreading signal and power spectral density[1].

C. Pseudo Noise (PN)

Pseudo random sequence is a binary sequence which has a similar autocorrelations within one period. In the DSSS system, pseudorandom sequences hold a very important role in the signal spreading and dispreading process of the baseband signal. The PN code has chips unit, which are signals that can increase the data rate.

PN code is not completely a random signal, it is actually a periodic signal that is known both by the transmitter and the receiver. There are 3 basic criteria which can be applied to each of the binary sequence to check the randomness of the generated signal [3], namely:

a. Balance property. It is needed in each period of the sequence, where the difference between the number of binary 0 and binary 1 is at most one digit.
b. Run property. Defined as a sequence of one single type of binary digit. Alternative digit display in one sequence runs as a new run. The length of a run is the number of digits in the run.
c. Correlation property. If each period of a sequence is compared in each level, it is very good if the ratio of the error and the received sequence is not more than 1.

One way to generate PN signals is by using Maximum Length Sequences (MLS), which applied the polynomial concept. An MLS is a combination of shift registers and a set of logic circuits in its feedback system. The clock sets the period of chip generation on the bit sequences [1].

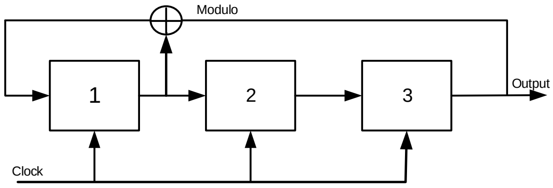

Figure 2. 3 MLS PN Generator [1]

A type of PN sequence that has a good correlation value is gold PN sequence or commonly called the gold code. A set of n Gold sequences is obtained from a particular pair of m-sequences with a length of $L = 2^{n-1}$ by taking the modulo-2 summation of a certain m-sequences, then by changing the value of n through cyclic m-sequence shifts. The Gold Code has 3 values, namely {-1, -t (m), t (m) -2} where:

$$L(m) = \begin{cases} 2^{(m+1)/2} + 1 & \text{for } m \text{ odd} \\ 2^{(m+2)/2} + 1 & \text{for } m \text{ even} \end{cases}$$

The Gold code basically works with the same concept as the m sequence. The only difference is that the Gold code is obtained from a pair of two m sequences with a certain shift register length. XOR operation of the two m sequences will produce a Gold code sequence.

D. Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is Multi-Carrier Modulation (MCM) which achieved by dividing a single transmission channel into several sub-channels or subcarriers that are perpendicular (orthogonal) to each other, in order to optimize the efficiency of data transmission [5]. Mathematically, the orthogonalities of the OFDM signal can be explained as follows:

- Suppose the function $X_m(t)$ and $X_n(t)$ are the m[th] and n[th] subcarrier signal. Both of these subcarriers are said to be orthogonal to each other at intervals a <t <b if they meet the following conditions [1]:

$$\int_a^b \mathbf{X_m(t) * X_n(t) dt = 0} \qquad (1)$$

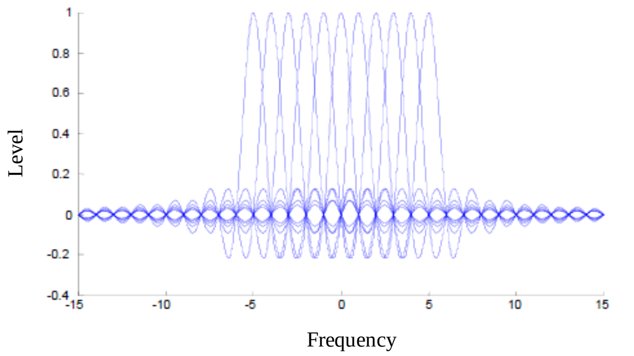

Figure 2.4 OFDM signal spectrum [1]

There are some of the OFDM superiority compared to single carrier modulation systems:

a. Resistant to spreading delay due to multipath; because the symbol duration is made longer.
b. Resistant to frequency selective fading channels; because the available channel bandwidth is converted into several narrow band subcarriers. Hence, it can be assumed that subcarriers only experience a flat fading channel.
c. Efficient in terms of modulation and demodulation; Modulation and demodulation of each subcarrier only uses a simple IFFT and FFT methods. Using this method makes possible of the spectrum efficiency by overlapping the spectrum between successive subcarriers.
d. High bit rate transmission
e. Simple equalizer; The OFDM symbol is greater than the maximum delay spread resulting in a flat fading channel that can be equalized easily.
f. A large spectral efficiency

E. Multi Carrier Direct Sequence Code Division Multiple Access (MC DS CDMA).

MC DS CDMA system is a combination of CDMA, DSSS and OFDM schemes. On the MC DS CDMA transmitter, the data sequence is generated and the serial to parallel process is carried out, giving the data sequence which are divided into subcarriers with a lower bit-rate. Then each of these subcarrier signal will be spread by a spreading code so that each chip in the same symbol for each user will occupy the same subcarrier. This spreading technique is called time domain spreading system.

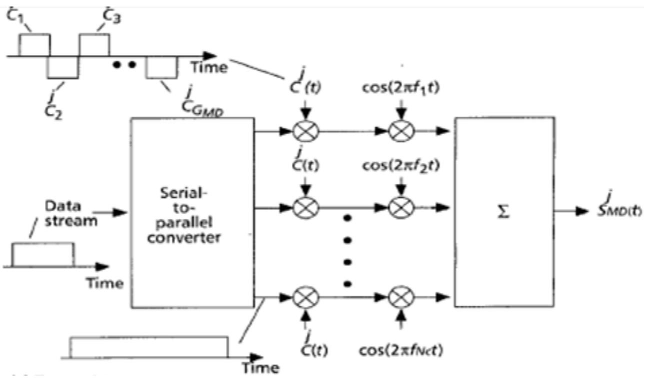

Figure 2.5 MC DS CDMA Transmitter [7]

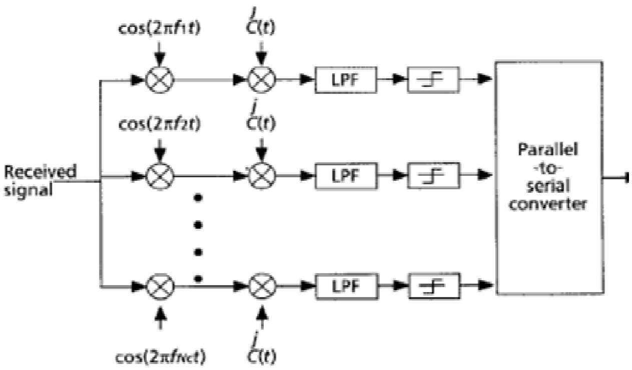

Figure 2.6 MC DS CDMA Receiver [7]

III. SYSTEM DESIGN AND IMPLEMENTATION

This section discuss about the design and implementation procedure of MC DS CDMA system using a WARP device. The system parameter which will be implemented in this paper is depicted in Table 1.

Table 1 MC DS CDMA communication system parameter

Parameter	
Number of Information bits	10000
Modulation	BPSK
Channel	Wireless
Measurement set	Indoor
PN sequence	Gold
Measurement scheme	Performance comparison between MC DS CDMA and SC DS CDMA in terms of the BER value.

The steps of MC DS CDMA system modeling are as follows:

1. Modeling of MC DS CDMA transmitter system
2. Modeling of MC DS CDMA receiver system
3. Design and implementation MC DS CDMA in SDR platform (WARP) module
4. Design of the system frame buffer

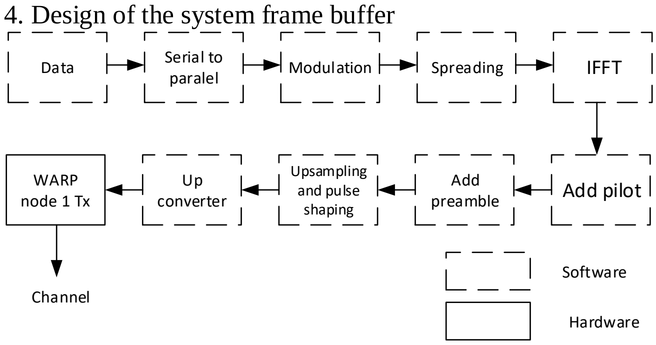

Figure 3.1 MC DS CDMA transmitter block diagram

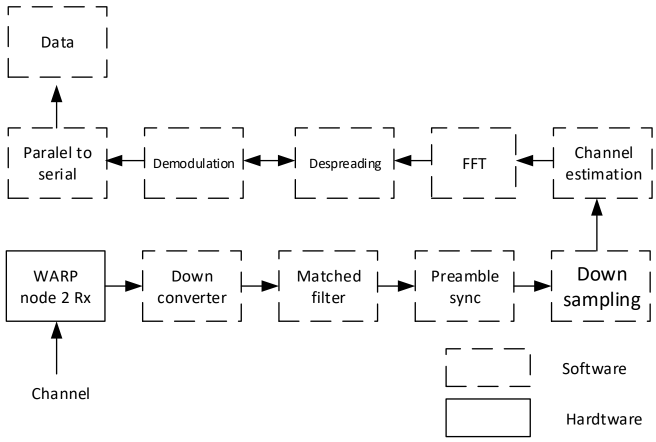

Figure 3.2 MC DS CDMA receiver block diagram

PC controller and WARP module are connected and integrated through an ethernet switch using LAN cables. And the system configuration is shown in Figure 3.3.

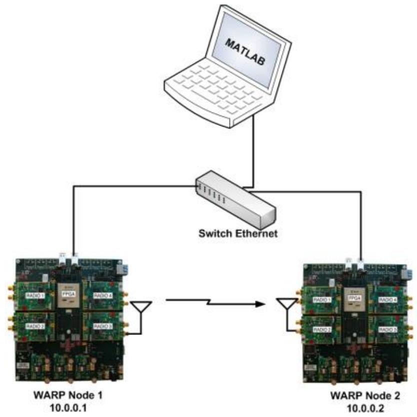

Figure 3.3 PC controller and WARP module configuration scheme

WARP module has a limited IQ buffer, which is around 2^{14} or equivalent to 16384 samples, then there must be frame buffers in order to guaranteed that all the generated bits, can be transmitted. The frame buffer design is shown in the following Figure 3.5.

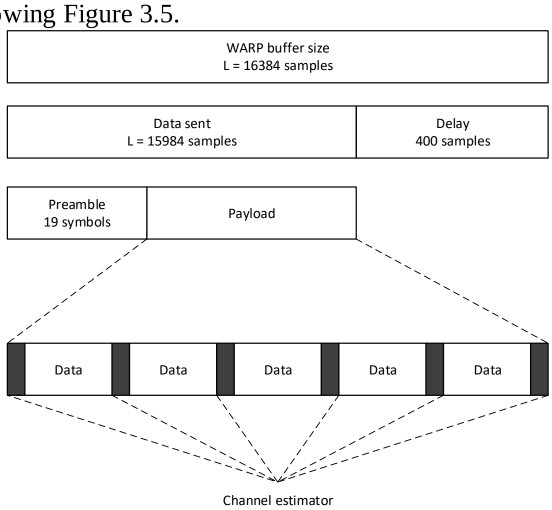

Figure 3.5. Data frame and buffer architecture

Measurements were carried out in an indoor environment which was located in the B.304 lab in a line-of-sight (LOS) condition. The purpose of this measurement is to measure performance of multiple users that can be served simultaneously by MC DS CDMA compared to the CDMA SC DS system. The performance is measured in terms of its BER value.

IV. MEASUREMENT RESULTS AND ANALYSIS

Analysis of MC DS CDMA system which is implemented based on the design procedures in section 3 using WARP modules. The block diagram configurates the MC DS CDMA communication system process starting with bit generation, then the bits are sent through WARP, until the bits are received at the receiving side and bits comparison are made between the information bits sent and the estimation of the received bits.

A. BER performance analysis with distance variation

This part of the paper discussed about the BER performance comparison between single carrier and multi carrier DS CDMA with the distance of 3 and 5 meter. Based on the measurement results shown in Figure 4.1 and Figure 4.2. It turns out that from the measurement results, both systems have an increasing BER value following the increasing of the distance between the transmitting and receiving nodes.

Table 4. 1 BER performance of SC DS CDMA at 3m and 5m distance

SC DS CDMA	BER (Bit Error Rate)	
Gain	5m distance	3m distance
0	0,094	0,0082
5	0.0498	0,0043
10	0.0172	0,0003
15	0.0058	0
20	0.0016	0
25	0.0008	0
30	0.0002	0
35	0	0
40	0	0
45	0	0
55	0	0
60	0	0

Table 4.2 BER performance of MC DS CDMA at 3 m and 5 m distance

MC DS CDMA	BER (Bit Error Rate)	
Gain	5 m	3 m
0	0,0721	0,0053
5	0.0376	0,0025
10	0.0125	0,0011
15	0.0046	0,0001
20	0.0011	0
25	0.0006	0
30	0.0001	0
35	0	0
40	0	0
45	0	0
55	0	0
60	0	0

Hence, it can be concluded that the larger the distance, the higher the BER value obtained with the same power gain. This is due to the increasing of noise along with the increasing of distance with a fixed gain value. From Table 4.2, it can be seen that the BER value of MC DS CDMA is lower than the value of the SC DS CDMA of the same distance.

B. BER performance analysis with variation of transmit power level (Tx_Rf)

This part of the paper analyzed the effect of changing the power level of the transmitter from 0 to 60 dBm with a step of 5 dB for the same distance of 5 meters. The measurement result is shown in Table 4.3.

From Table 4.3 and followed by Figure 4.1, it can be concluded that by increasing the value of the transmitted power gain, the BER value will be decreasing. The higher the power transmitted then the effect of the noise will be smaller, then it will lead to a smaller BER value. Using the same transmitted power gain, the BER value of MC DS CDMA system is lower than SC DS CDMA system.

Table 4. 3 BER performance comparison between SC DS CDMA and MC DS CDMA with 5 dB increment on the transmit power level for 5 meters distance

Level Tx_Rf	BER (Bit Error Rate)	
	SC DS CDMA	MC DS CDMA
0	0,094	0.0721
5	0.0498	0.0376
10	0.0172	0.0125
15	0.0058	0.0046
20	0.0011	0.0016
25	0.0008	0.0006
30	0.0002	0.0001
35	0	0
40	0	0
45	0	0
50	0	0
55	0	0
60	0	0

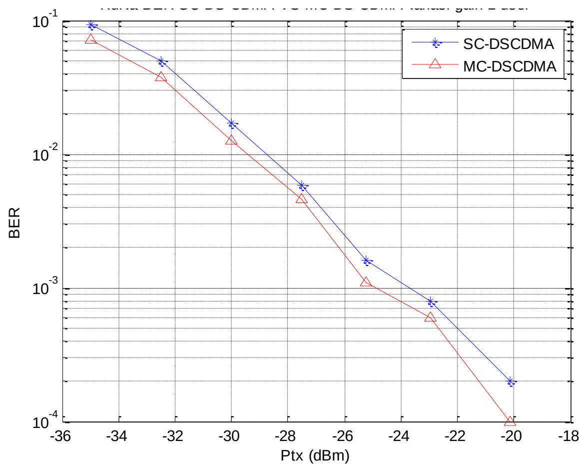

Figure 4.1 BER of single user of SC DS CDMA and MC DS CDMA systems with variation of transmit power gain value Tx_Rf, at 5 meter distance

C. BER performance analysis for multi user scenario

From both Figures shown in Figure 4.2 and Figure 4.3, it can be seen that the BER performance of MC DS CDMA system is better than the SC DS CDMA. This is shown by how the BER curve of the MC DS CDMA system which is linearly decreasing more smoothly towards the increasing of the transmit power gain (Tx_Rf) compared to the SC DS CDMA.

The BER performance for 20 users shown by the purple curve for both systems. The BER curve of SC DS CDMA starts to rise when the transmit power gain is -11dBm. Whereas on the MC DS CDMA, the BER curve still decreases linearly. In addition, the BER value of MC DS CDMA system are less than SC DS CDMA.

Then it can be concluded, with the same number of users, the performance of MC DS CDMA is better than SC DS CDMA. It can also be concluded that the MC DS CDMA is more resistant to noise and small fading multipath.

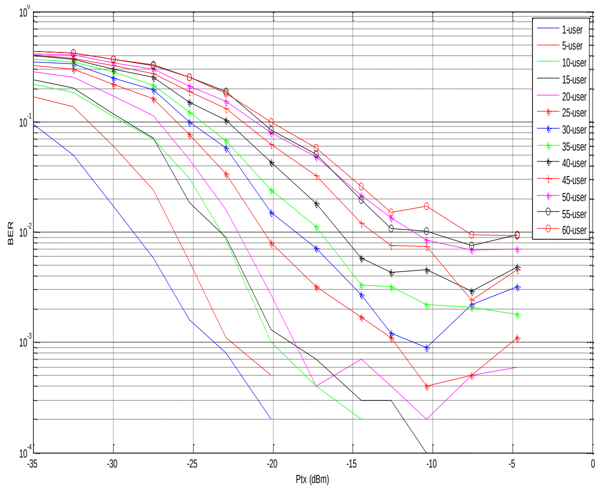

Figure 4.2 BER of SC DS CDMA for 1-60 user

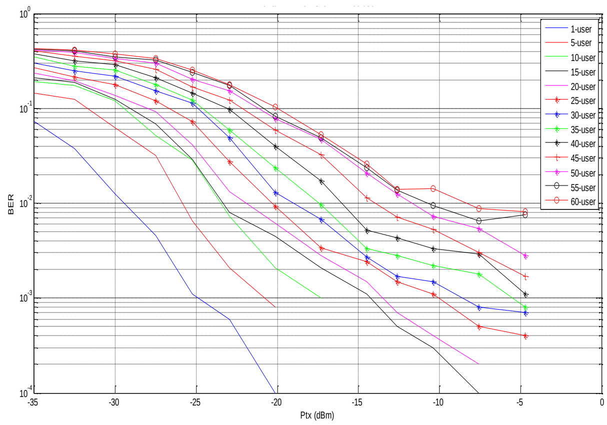

Figure 4.3 BER of MC DS CDMA for 1-60 user

It is indicated by the form of the BER curve which is more smoothly linear decreasing than SC DS CDMA.

D. Power Analysis of MC DS CDMA system

This section explain about the power analysis of MC DS CDMA system. The performance is analyzed in term of the bit error rate which can be achieved using a certain transmit power level. The experiment is done for single user scenario using a variation of power level value

Table 4.4 Eb/No of MC DS CDMA for single user scenario

PTx	Eb/No (dbm)	BER
0	7,002	0,0721
5	8,34	0,0376
10	12,223	0,0125
15	13,778	0,0046
20	19,21	0,0011
25	21,73	0,0006
30	23,88	0,0001
35	25,76	0
40	25,97	0
45	26,001	0
50	27,67	0

55	29,13	0
60	29,43	0

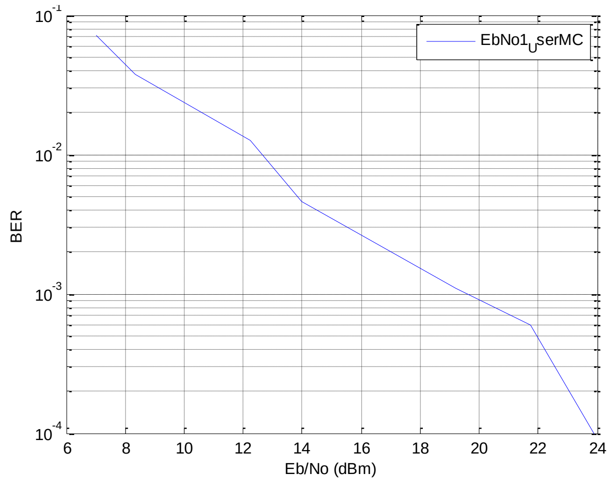

Figure 4.4 BER of MC-DS CDMA for single user scenario

From the data shown in Table 4.4 and plots in Figure 4.4, it can be seen that the Eb / No value will get higher along with the increasing of the gain. And the BER value will also decrease along with the increasing of Eb / No and PTx values. Then it can be concluded that the BER value will be linearly decreasing along to the increasing value of PTx (dbm) or the Eb / No (dbm).

V. CONCLUSION

Based on the experiment results and analysis which has been done in the previous section, it can be concluded that The bit error rate (BER) value is linear to the distance. The greater the distance between the transmitter and the receiver node will give a higher BER. It can be validated by the experiment result of MC CDMA system for difference Tx-Rx distance scenario. By using the gain value of 20, the system achieved zero BER for 3 meter and 0,0011 for 5 meter distance. The decreasing of the performance is mainly caused by the noise and attenuation which grow larger with the distance.

The transmit power level is inversely proportional to the BER value. A higher transmit power will give a better performance of the system. It can be seen that when the power level is 5 and 20 result in BER value of 0,0376 and 0.0011 respectively.

Using the same transmit power level, the MC-DS CDMA system performance is better than SC-DS CDMA system. It can be seen from the experiment results that the BER values of MC DS CDMA system are consistently lower than SC DS CDMA one in single user nor in multi user scenario.

In related to multi user scheme, MC DS CDMA system performs better than the SC DS CDMA system. It is more robust to the multipath and flat fading effect. It can be seen that until 20 users, the BER curves are decreasing but in a smoothly linear order.

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