JAVA Journal of Electrical and Electronics Engineering
Volume 13, Number 2, October 2015

Implementationand Performance Analysis of Multi Carrier-Direct Sequence-Code Division Multiple Accesson DSK TMS320C6416T

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***Abstract*—Wireless Digital Communication System nowadays must have the ability to provide a high data rate and highly reliable QoS. The application of multi carrier system offers a privilege in the spectrum efficiency aspect, because of the possibility of overlapping an orthogonal subcarrier. In MC-DS-CDMA system, some user sutilizing the same broadband frequency at the same time. Each user is distinguished by applying a unique spreading code. The problem is, the code sometimes becomes correlated with each other, hence affecting multi-user interference. This problem depends on the orthogonalities of the spreading codes that is used for each user. In this paper, implementation of MC-DS-CDMA system is done using DSK TMS320C6416T platform that is controlled via matlab simu link. Performance analysis of MC-DS-CDMA system is discussed from the aspect of resulting bit error rate (BER) parameter. Simulation and measurement are conducted to measure the real performance of the MC-DS-CDMA system prototype by giving a variation of the Eb/No value. From the measurement results, it shows a similarity with the expected theoretical result. The best result is obtained when the system operate with $E_b/N_0 \geq 12$dB. And the system failed to for $E_b/N_0 \leq 4$dB.**

Keywords—MC-DS-CDMA; BER; DSK TMS320C6416T; Matlab.

I. PENDAHULUAN

Wireless digital communication system nowadays must have the ability to provide a high speed data rate with a reliable QoS. The objective is to obtain a low bit error rate (BER) with minimum signal to noise ratio (SNR) requirement. The requirement of high data rate application leads to an increasing of bandwidth requirement whereas the bandwidth available now is very limited. So this could be a problem that needs to be solve. One of the possible solution is by applying a multicarrier CDMA system. This system offers a privilege in the aspect of spectrum efficiency. Because its ability to utilize orthogonal subcarriers which is overlapping between the successive subcarriers. A special case of multicarrier modulation system is *Orthogonal Frequency Division Multiplexing*(OFDM).

The idea of implementing MC-DS-CDMA technology in a Digital Signal Processing (DSP) processor is an effort to expand the communication networks. The DSP processor is commonly used in current modern electronic device including celluler phone, because it is available in market and can be buy easily, and the ability to used for high speed application and flexible to use in many applications.

In this paper, DSP processor is used as one of the component for implementation of MC-DS-CDMA system. Implementation is first done by simulation using Matlab simulink. And then by using *Code Composer Studio*, the simulink model can be translated in C language which is then uploaded on the DSK TMS320C6416T.

II. THEORY

A. MC-DS-CDMA

In *Direct Sequence* – CDMA modulation technique, the information signal is modulated directly with digital signal codes. Information signal can be analog or digital but nowadays, digital signal is the most commonly used. In digital signal, regardless the modulation type, the data signal is directly multiplied with a code, resulting a wideband carrier modulated signal.

Figure 1 shows binary signal that modulate an RF carrier. This modulated carrier is then modulated by a code consist of information bit code.

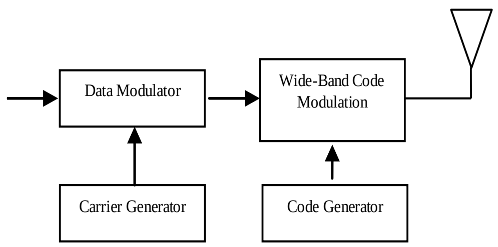

Figure 1. MC-DS-CDMA Transmitter block diagram

Regardless the modulation type, generally the transmitter and receiver of DS-CDMA system can be seen in Figure 2 and Figure 3. After transmitting process, the signal propagates and arraived at the receiver. And then the received signal is processed by a coherent demodulator to dispreading the signal using a local code sequence generator. In order to dispreading the received signal, the receiver does not have to know the code sequence that the transmitter used, as long as there is a synchronization between the transmitter and the receiver. So synchronization should be maintain from the starting point of receiving signal until the whole complete signal is received. Then after dispreading and demodulating the received signal, the original data that sent from the transmitter can be obtained.

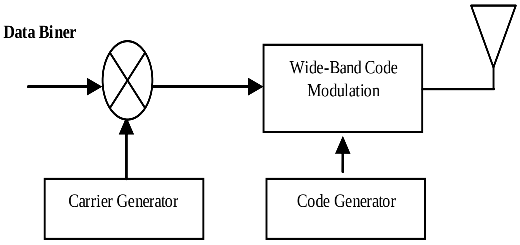

Figure 2. Modified MC-DS-CDMA Transmitter Block Diagram

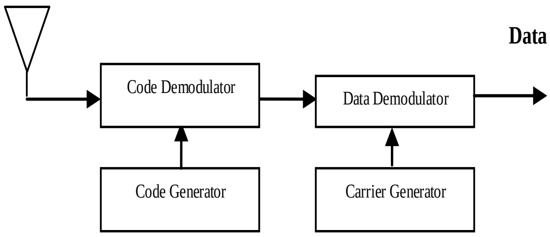

Figure 3. MC-DS-CDMA Receiver

B. *BPSK Modulation and Demodulation*

Modulation is mixing between information signal and the carrier signal. Digital modulation is used for mapping the information signal which consist of binary sequence into a certain waveform signal that traveled through the channel. After the signal arrived at the receiver, to obtain the original baseband signal, first the received signal must be demodulated. Phase shift Keying modulation commonly said as the efficient modulation technique, because it has a small error probability at each received signal levels. PSK modulation can be mapped into a two dimentional constellation diagram as seen in Figure 4. It is an example of Binary PSK constellation diagram.

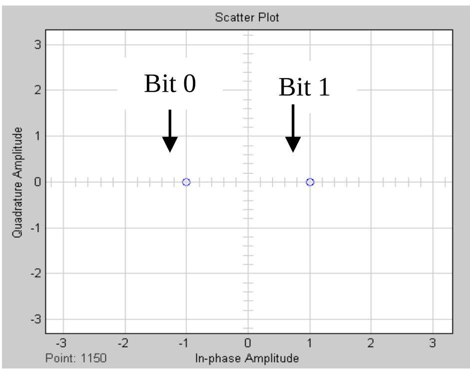

Figure 4. BPSK modulation constellation mapping

C. *Rayleigh Fading channel*

In cellular communication system, the signals that arrived at the receiver antenna usually is not only came from the line of sight path but also from its reflection path. So the received signals will be consist of accumulation of multipath signals. Because each path has different propagation length, the signal would also experience a different variation of delay. So the information signal would suffer a delay spread. Typically in an urban area, the delay spread is about 2-5 ms, and this delay can caused the signal would experience an inter symbol interference (ISI).

Multipath fading inican cause a large variation of received signal, because the signal can be either strengthening or attenuating each other. This signal variation is said as a *Rayleigh fading*, because its randomness follow the Rayleigh distribution. Statistically, the received signal would be 10 dB below the local mean in 10% of the location and 20 dB below the local mean for 1% of the location. This can cause damaged of most part of the information. Another caused of the multipath is arise from the mobile station movement which results in a shifting frequency of the received signal (Doppler effects). The Doppler frequency is a function of movement vector and velocity of the mobile station.

Rayleigh distribution is commonly used for modeling the changing of flat fading channel of a multipath component from time to time. Based on the statistic theory that the summation of two Gaussian Noise signal would generate a random variable with has Rayleigh distribution. The probability density function of Rayleigh distribution is as follow:

$$p(r_a) = \begin{cases} \frac{r_a}{\sigma^2} \exp\left(-\frac{r_a^2}{2\sigma^2}\right) & (0 \leq r_a \leq \infty) \\ 0 & (r_a \leq 0) \end{cases} \quad (1)$$

Where:

σ = rmsof the received signal level

σ^2 = average power of the received signals

$r_{a\ median}$ = 1,177σ

D. *DSP Starter Kit TMS320C6416T*

Texas Instruments DSK TMS320C6416T is a low cost development platform for real time digital signal processing application. It consists of a small circuit board of DSP TMS320C6416 fixed-point and analog circuit interface (codec) TLV320AIC23 which connected to the PC controller through a USB port. *Digital Signal Processor* has been commonly used for many kinds of application, for example in communication field, for speech control and image processing. This DSP works for application which in the frequency range of 0-96 kHz. Those frequency range is a standard range for speech communication. It is suitable for sampling speech in 8 kHz or one sample per 0,125 ms).

Figure 5 above shows a DSK TMS320C6416 circuit board diagram. It is a multi-layer boardwith a dimension of 8.75 x 4.5 inch (210 x 115 mm), with an external supply of +5 volt. This DSK consist of a 1 GHz DSK TMS320C6416 fixed-point digital signal processor and 16-bit *stereo codec* TLV 320AIC23 for analog input and output. Codec AIC23 provides ADC and DAC using 12 MHx clock and could provide a sampling rate of 8–96 kHz. The DSK has 16 MB Synchronous Dynamic Random (SDRAM) and 512 kBflash memory. It also equipped with card expansion facility and two 80-pin connectors for providing external peripheral and external memory interfaces. JTAG emulation can be done on-board using JTAG emulator or using an external emulator via USB host interface.

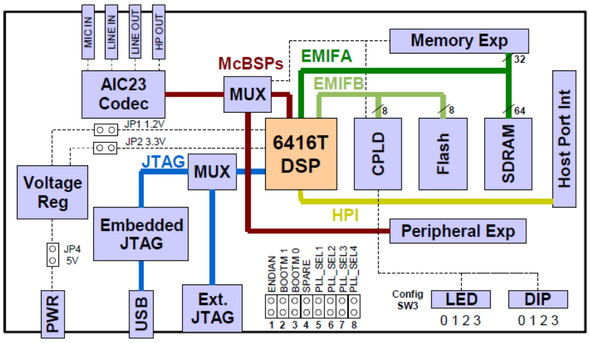

Figure 5. DSK TMS320C6416T

There are four connectors for input and output of the DSK:

- MIC IN for *input* from the *microphone*.
- LINE IN for *input* from the *function generator*.
- LINE OUT for *output*.
- HEADPHONE for *output* on the *headphone*.

Dip switch in DSK can be functionised according to the program and provide a control function. There are a voltage regulator that supply a 1,26V for processor and 3,3V for memory system and other features.

E. *Code Composer Studio v3.3*

CCS is an Integrated Development Environment (IDE) for Texas Instruments (TI) embedded processor. CCS provides IDE for real time digital signal processing under C language. CCS deliver an assembler code, C compiler and linker for DSK Texas Instrument output.

CCS has a graphic ability and support for a real time debugging. *C compiler* compiled a program in C language with an extension of **.c*,for producing an assembly file with **.asm*. *Assembler* will process the **.asm* file to produce a machine language file with an extension of **.obj*. Then *linker* will gathering those files become an executable file with an extension of **.out*. This file is then will be feed as an input of the C6714 processor. For a real-time time analysis, a real-time data exchange (RTDX) facility can be used. It is possible to do the data exchange between PC and DSK

In Matlab, there has been a function provided for communicating to DSK TMS320C6x with the assist of CCS. Then CCS would integrate the simulation that has been build in Matlab Simulink the convert it into a C or assembly language.

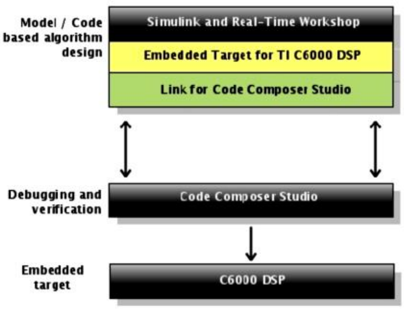

Figure 6. Processing Diagram between Simulink, CCS, dan C6000 DSP

III. SYSTEM DESIGN AND IMPLEMENTATION

System simulation and implementation is based on the processing block diagram that can be seen in Figure 7.

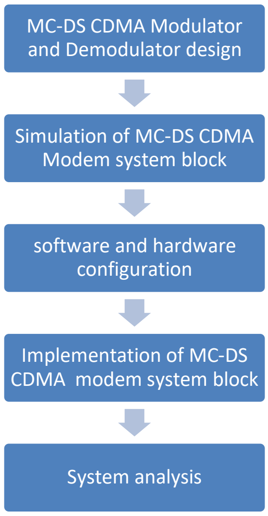

Figure 7.Methodology

Simulation modeling of MC-DS-CDMA modulator and demodulator is made using Matlab Simulink. The purpose is to simplify the implementation process procesure on DSK TMS320C6416T which later will be also programmed using Matlab Simulink.

Generally there are 6 process that is done by the simulation. They consist of code spreading process, modulation, Rayleigh fading channel, demodulation, dispreading process, and at last the analysis of the system specifically in the resulting bit error rate (BER). Description of each of the process is explained as follow:

1. *Code Spreading*, in this process, the information signal would be multiply with a PN sequence in order to produce a new signal which has a lower bit rate.
2. Modulation, the information signal would modulate the carrier information.
3. Demodulation, it is a reversed process of the modulation, which is to extract the information signal apart from its carrier. The resulting signal is then mixed with a cosinus wave to obtain the information signal which is a speech signal in this case.
4. *Code Dispreading*, it is a reversed process of the code *spreading*. After the received information signal is obtained, the signal would be remultiply with the same PN *code* that is used in the spreadingprocess. So in the end the original signal with the same bit rate as the information signal that is sent can be obtained.
5. Rayleigh fading channel, the modulated signal will propagate through a noisy channel where the channel noise coefficient is following the Rayleigh distribution.
6. BER analysis, is done by calculating the resulting BER of the MC-DS CDMA system using a variation of the E_b/N_0value. A comparison of the received data form output

of the detection process with the original data is done after naking sure there is a delay synchronization between the starting of data transfer with the starting of data received.

Figure 8 is the complete block diagram of MC-DS-CDMA system. Each detailed process is explained in the following section.

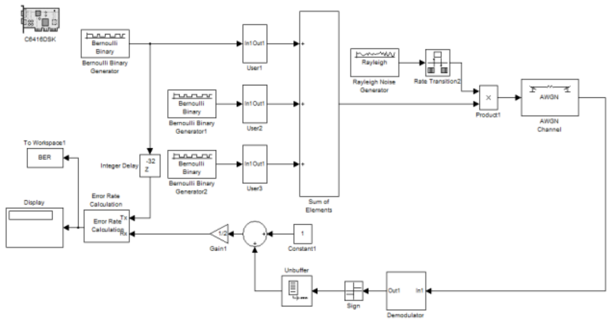

Figure 8. MC-DS-CDMA Modulation and Demodulation block diagram

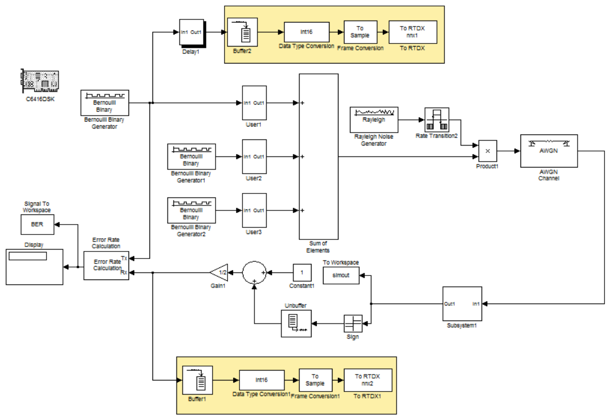

Figure 9. Implementation of MC-DS-CDMA system

IV. System Measurement and Analysis

In this chapter, analysis of the simulation result and also a brief comparison with the implementation result of *Multicarrier Direct Sequence Code Division Multiple Access* modulation and demodulation using DSK TMS302C6416T will be explained. The simulation will be done for different E_b/N_0 value. And the results will be shown as a graphic of BER vsE_b/N_0. The MC-DS-CDMA result analysis can be described in 5 part, they are:

A. Theoretical BER Analisisof BPSK in Rayleigh FadingChannel

To measure the performance of a communication system, it is common to use the resulting bit error rate as a performance parameter. In communication, there are always be error that occurs because of the phenomena that the signal experience on its propagation way from transmitter to the receiver. And from the error received at the receiver side, it can be used to calculate the bit error rate of the system.

Theoritical BER of BPSK modulation with *Rayleigh fading channel* is shown in Figure 10.From Figure10,can be conclude that the BER is getting better with the increasing of E_b/N_0value.

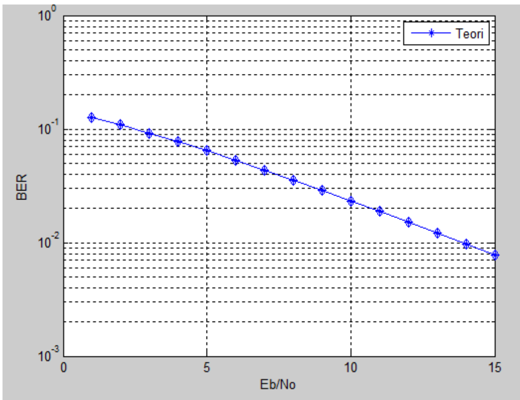

Figure10. Theoritical BER of BPSK Modulation system in *Rayleigh Fading channel*

B. BER of Single User MC-DS-CDMA system

The test is done by doing the measurement 5 times and then an averaging is done to get the BER result in Figure 11. BER result based on theory, simulation and implementation are compared in a single graphic.

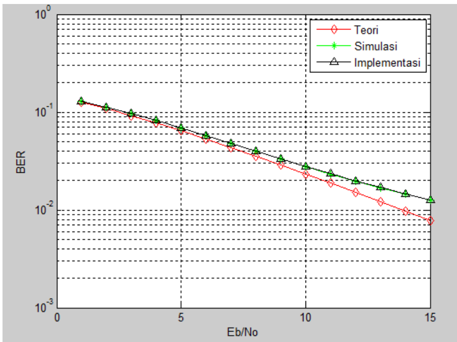

Figure 11.BER of *Single User* MC-DS-CDMA

In Figure 11, it can be seen that the BER vsEb/N0 of a single user MC-DS CDMA systembased on simulation and implementation is slightly worse than the theory. It is mainly caused by a hardware limitation. Detail comparison of single user MC-DS CDMA based on theory, simulation and measurement are described in Table 1.

C. BER analysis of Multi User MC-DS-CDMA system

In this simulation, the system performance is analysed for a multi user scenario. There are 3 users that is using the system, and the BER result can be seen in Figure 12.

From Figure12, a comparison of multi-user MC-DS CDMA modulation and demodulation system is described.The BER result of the simulation and the implementation is relatively the same. A detailed comparison can be seen from table 2 in the appendix.

D. BER analysis of Single User and Multi User MC-DS-CDMA system

In this section, BER Analysis of simulation and measurement results of MC-DS CDMA system for single user and multi-user is compared. From Figure 13, it can be seen that because of multiple access interference (MAI) the performance of multi-user MC-DS CDMA is decreased compared to the single user one. It is shown with an increasing BER until approximately 0.01 higher than single user performance for Eb/No 5-15 dB.

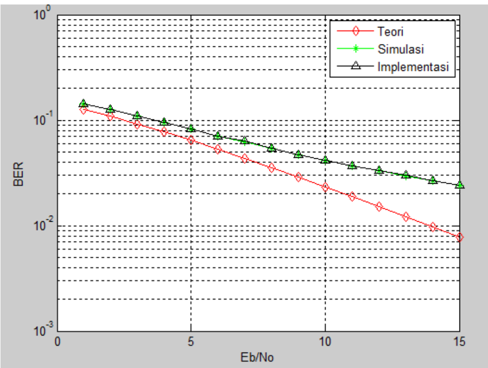

Figure12. BER of *Multi User* MC-DS-CDMA

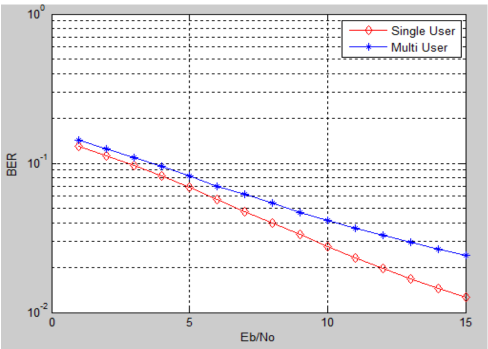

Figure 13. BER comparison of simulation result of *Single User* and *Multi User*MC-DS-CDMA

E. BER in Single User andMulti User MC-DS-CDMA

In this section the measurement result of MC-DS CDMA system implementation is analyzed for single and multi user scenario.

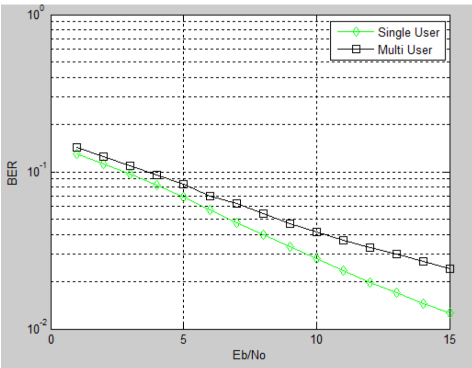

Figure 14. BER comparison of measurement result of *Single User* and *Multi User*MC-DS-CDMA

Figure 14 shows the consistent result with the simulation result, that the resulting BER value of multi user MC-DS CDMA is approximately 0.01 higher for Eb/No 5-15 dB. This is mainly caused by the multiple access interference(MAI) that occurs in multi user MC-DS-CDMA sytem.

V. Conclusion

Based on the simulation and analysis, of MC-DS-CDMA system implementation on DSK TMS302C6416T there are several conclusion that can be made:

1. The performance of MC-DS CDMA system both of single and multi user scenario will increase as the increasing value of the E_b/N_0.
2. Based on simulation and implementation result for Eb/No value of 5-15 dB, the BER performance of MC-DS CDMA system for multiuser scenario where 3 user is accessing the system at the same time, are approximately 0.01 higher than single user scenario. The increasing of BER valueis mainly caused by the multiple access interference(MAI) that occurs in multi user MC-DS-CDMAs ytem.

Appendix

Table1 BER of Single *User* MC-DS-CDMA

E_b/N_0	**Theory**	**Simulation**	**Measurement**
1	0.126733462	0.1295	0.129588
2	0.108484732	0.11271	0.112784
3	0.091913176	0.096534	0.09678
4	0.077136916	0.082024	0.082134
5	0.064182685	0.069056	0.069274
6	0.052998884	0.057436	0.057506
7	0.043474407	0.047376	0.047438
8	0.035459068	0.03965	0.039706
9	0.028782367	0.03338	0.033474
10	0.023268705	0.027782	0.027846
11	0.018748391	0.023304	0.023386
12	0.01506468	0.019784	0.019846
13	0.012077547	0.016828	0.016912
14	0.009665039	0.01439	0.014466
15	0.007723002	0.012628	0.01274

Table2 BER of *Multi User* MC-DS-CDMA

E_b/N_0	Theory	Simulation	Measurement
1	0.126733462	0.142442	0.142576
2	0.108484732	0.125412	0.125666
3	0.091913176	0.109562	0.109818
4	0.077136916	0.095194	0.095344
5	0.064182685	0.082676	0.082846
6	0.052998884	0.070068	0.0704182
7	0.043474407	0.062268	0.063082
8	0.035459068	0.053902	0.054104
9	0.028782367	0.046916	0.047022
10	0.023268705	0.041332	0.041454
11	0.018748391	0.036602	0.036688
12	0.01506468	0.03294	0.033036
13	0.012077547	0.029702	0.02984
14	0.009665039	0.026722	0.02685
15	0.007723002	0.024152	0.024286

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