Analysis Effect of Discrete Wavelet Transform in Multi Carrier Code Division Multiple Access

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***Abstract*—Multi Carrier Code Division Multiple Access (MC-CDMA) has become options for high data rate systems in high mobility without reducing the interference robustness. Discrete Fourier Transform (DFT) MC-CDMA still has usual problem of Multi Carrier Modulation (MCM) that is high Peak to Average Power Ratio (PAPR), but this problem can be reduced by replacing fourier transform with wavelet transform. This paper will analyze the result of Discrete Wavelet Transform (DWT) MC-CDMA compared with DFT MC-CDMA. The simulation results showed that DWT MC-CDMA system has better quality than DFT MC-CDMA but DWT MC-CDMA has higher complexity than DFT MC-CDMA.**

Keywords—MC-CDMA, OFDM, wavelet, fourier, cyclic prefix, PAPR.

I. Introduction

Nowadays multicarrier modulation technique (MCM) has been popular for high speed data access. One of method in MCM Orthogonal Frequency Division Multiplexing (OFDM). This method, has advantage which is robust to frequency selective fading and narrowband interference. CDMA have higher user capacity than TDMA and FDMA. CDMA system offer better robustness to multiple access interference (MAI) [3]. Combining OFDM with the Code Division Multiple Access (CDMA) can obtain the advantage of both systems. The combination of OFDM and CDMA called Multicarrier Code Division Multiple Access (MC-CDMA). MC-CDMA is the system that efficient and mitigate the interference [5].

On OFDM and other multi carrier technique, fourier transform was usually used to transform time-domain signal to frequency-domain and vice versa because it can reduce the system complexity. Adding cyclic prefix (CP) is the main way of OFDM to mitigate the interference but the DFT MC-CDMA system still provides an opportunity to improve the robustness. High Peak to Average Power Ratio (PAPR) is the other problem in DFT MC-CDMA because it leads to reduced resolution, battery life, and deteriorates system performance [8]. Discrete Wavelet Transform (DWT) waveforms have the property of localization in both frequency and time domain so there is no need to send side information to the receiver, no distortion, no-loss of data rate [5][8]. The disadvantage of DWT system is it will increase the complexity level in the receiver [8].

This paper will analyze the effect of discrete wavelet transform (DWT) as substitution of discrete fourier transform (DFT) in MC-CDMA to see which system has better performance by comparing Bit Error Rate (BER) and PAPR of DWT MC-CDMA and DFT MC-CDMA in Multipath Rayleigh Fading channel with different user's speed. It also calculates the computational time of both systems to see the system's complexity.

This paper is set up into the following sections. Section II presents an insight into Multi Carrier CDMA system and wavelet transform considered for proposed work. Section III illustrates the system model for DWT MC-CDMA set-up in multipath Rayleigh fading channel. Experimental details and respective results are subsumed in Section IV. Finally, Section V concludes the paper.

II. Basic Consideration

A. Multi Carrier CDMA

OFDM system has advantage that robust to frequency selective fading but also has disadvantage that is difficult to synchronize the subcarrier, sensitive to frequency offset and nonlinear amplification [4]. CDMA system also has robustness to frequency selective fading. The combination of both systems called Multi Carrier Code Division Multiple Access (MC-CDMA), has the advantage that can reduce symbol rate in each subcarrier so the duration symbol become longer, it can make the quasi-synchronize on transmission [3]. MC-CDMA is the efficient system because spread the signal data to subcarrier in frequency-domain so the receiver can use all of signal power that spread in frequency-domain. Adding guard interval is the important way to mitigate system from Inter Symbol Interference (ISI). Empty guard interval will generate the Inter Carrier Interference (ICI) because each subcarrier loss their orthogonality. To avoids that the guard interval filled with sample or copy from the signal and called cyclic prefix.

Discrete Fourier Transform (DFT) in OFDM system can reduce the system's complexity. With DFT, the system doesn't need many oscillator, mixer, and filter for every subcarrier. DFT used to generate orthogonal subcarrier [6]. Wavelet Transform is the alternative transformation that can be used. The formula of DFT and IDFT is [2]:

$$\mathbf{X_k} = \sum_{n=0}^{N-1} \mathbf{x_n} \exp\{-j2\pi n f_0\} \quad (1)$$

$$\mathbf{x_k} = \sum_{n=0}^{N-1} \mathbf{X_k}\, exp\{j2\pi n f_0\} \quad (2)$$

One of the most used CDMA code is Walsh-Hadamard. Walsh-Hadamard is the code that spreading in frequency-domain to make each user orthogonal. Basic form of Hadamard matrix is [6]:

$$\mathbf{H_0} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (3)$$

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad (4)$$

Discrete Fourier Transform (DFT) in OFDM system can be replaced by Discrete Wavelet Transform (DWT). The different of DWT and DFT system is there is no cyclic prefix needed in DWT MC-CDMA system.

B. Wavelet Transform

DWT can be used to generate orthogonal subcarrier. The implementation of wavelet transform is by passing the signal into two DWT filter, high pass filter (HPF) and low pass filter (LPF), where HPF used to analyze high frequency and LPF used to analyze low frequency. Mathematic formula of DWT and IDWT is [2][7]:

$$s_n^m = \int s(t)\, 2^{m/2}\, \psi(2^m t - n)\, dt \quad (5)$$

$$s(t) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} s_n^m\, 2^{m/2}\, \psi(2^m t - n) \quad (6)$$

Where Ψ is wavelet kernel and is selected according to the mother wavelet chosen. It is clear that the cyclic prefix is not needed in wavelet-based MC-CDMA due to overlapping properties of DWT. the side lobes in case of DWT contains very low data and that most of the data is carried in the main lobe, hence the amount of interference is very low [2]. Wavelet family that used in this paper is Haar because of its simplicity.

The schematic diagram of IDWT and DWT are showed in Figure 1 and Figure 2 respectively:

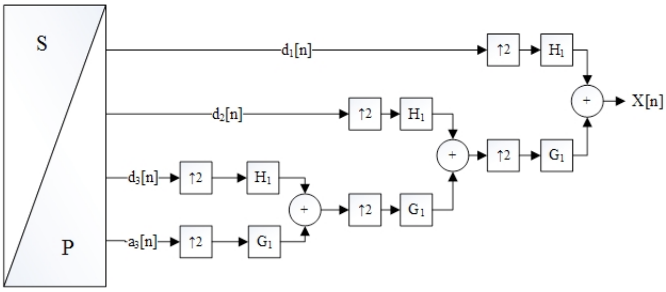

Fig. 1. IDWT diagram block [1].

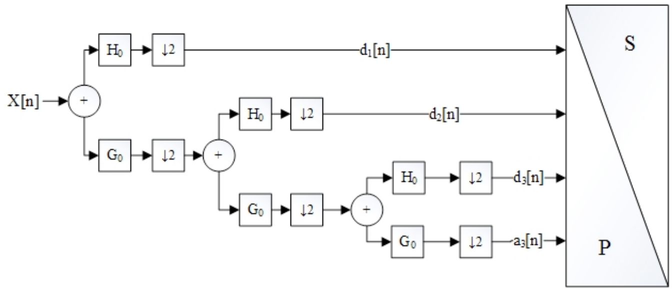

Fig. 2. DWT diagram block [1].

Figure 1 shows the process done with IDWT filter banks. The low or approximate coefficients are up sampled and re-filtered. Figure 2 shows the process of DFT that is the inverse process of IDWT.

III. SYSTEM MODEL FOR DWT MC-CDMA

In this paper, the system model is objecting to analyze the effect of discrete wavelet transform (DWT) as substitution of discrete fourier transform (DFT) in MC-CDMA. The model is a solution to reduce the PAPR level without increasing BER.

The system model will configure based on LTE-A downlink communication system with Single Input Single Output transmitter (SISO). The system will simulate in multipath Rayleigh fading channel to test the system in cellular wireless communication and Not Line of Sight (NOLS) environment with many scattering and shadowing. The system using 16-QAM mapper as miniature of high speed data access. The cell type that will be reference modelling is macro cell because it has width coverage for high mobility users.

The output of this modelling system is diagram block that will be simulate in software simulation. To evaluate the system performance, there will be 2 parameters. First parameter is BER by comparing Signal to Noise Ratio (SNR) value in BER≈0.0001. Second parameter is PAPR calculating with complementary cumulative distribution function (CCDF). The system model is shown in Figure 3.

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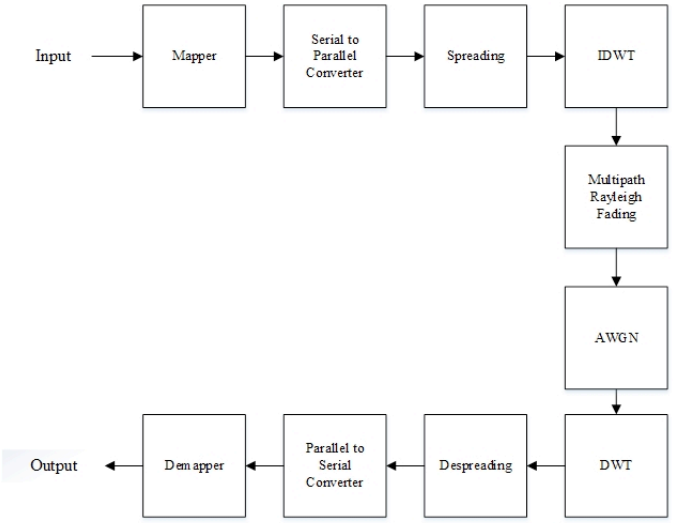

Fig. 3. DWT MC-CDMA system.

The simulation parameters and configurations are listed in Tables I.

TABLE I. PARAMETERS

Parameter	Description
Data size	1024 bits
Mapper	16-QAM
Spreading Code	Walsh Code
Wavelet Transform	Haar wavelet
Modulation	OFDM
Channel type	Multipath Rayleigh Fading
Number of subcarrier	128
Number of User	4
User's speed	3 km/h, 100 km/h
Number of Iteration	98

IV. Simulation Results

The simulation results and comparisons of the proposed system are executed and analyzed using software simulation.

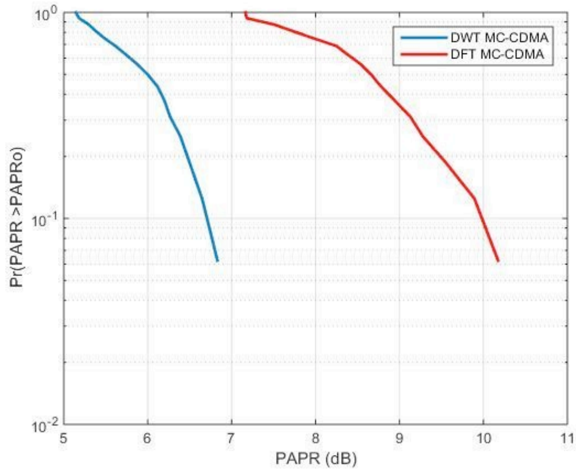

Fig. 4. PAPR value of DWT and DFT MC-CDMA.

Figure 4 shown that DWT outperformance DFT in PAPR. DWT has PAPR ≈ 3.34 dB lower than DFT. The CDMA method can reduce the PAPR. Then wavelet transformation reduces more PAPR than fourier transform. DWT MC-CDMA can reduce more PAPR because it only transmits a few numbers of large coefficients which dominates the representation.

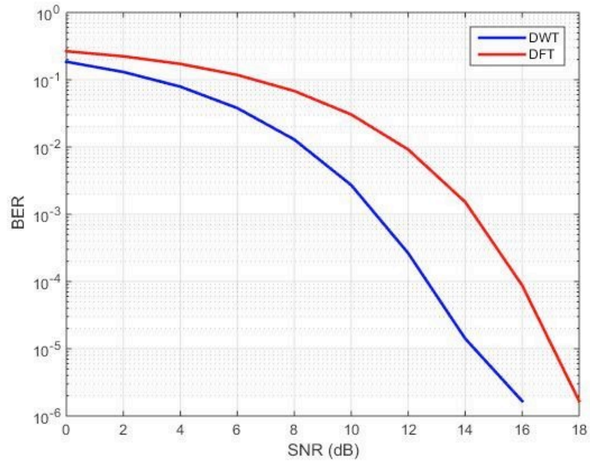

Fig. 5. DWT and DFT MC-CDMA in 3 km/h.

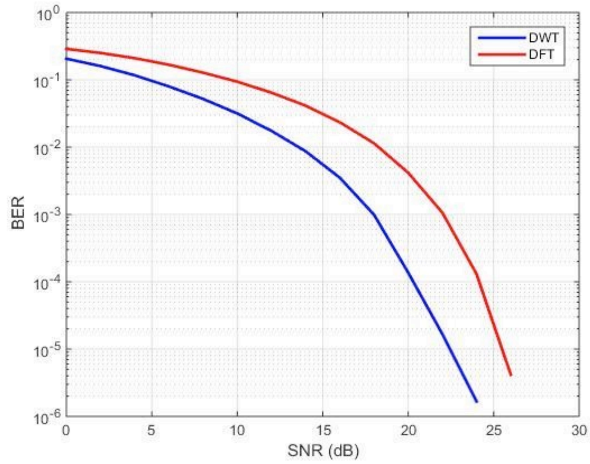

Fig. 6. DWT and DFT MC-CDMA in 100 km/h.

Figure 5 shows the performance comparison of DWT MC-CDMA and DFT MC-CDMA system in 3 km/h. In this figure, DWT MC-CDMA needs SNR ≈ 12,66 dB and DFT MC-CDMA needs SNR ≈ 15.9 dB to reach BER 0.0001.

Figure 6 shows the performance comparison of DWT MC-CDMA and DFT MC-CDMA system in 100 km/h. DWT needs SNR ≈ 20.3 dB to reach BER 0.0001 meanwhile DFT needs SNR ≈ 24.15 dB.

It is shown that DWT MC-CDMA more robust to interference in Rayleigh channel than DFT MC-CDMA. Overlapping properties in wavelet transform improve the robustness of the system. Wavelet transformation that have time-frequency variance can make system more robust to interference without CP.

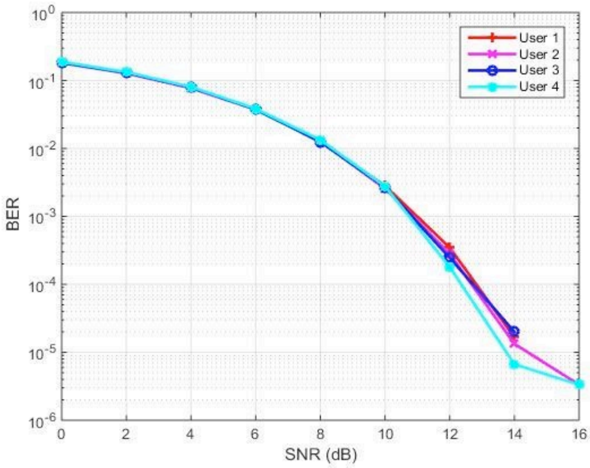

Fig. 7. Each users of DWT MC-CDMA in 3 km/h.

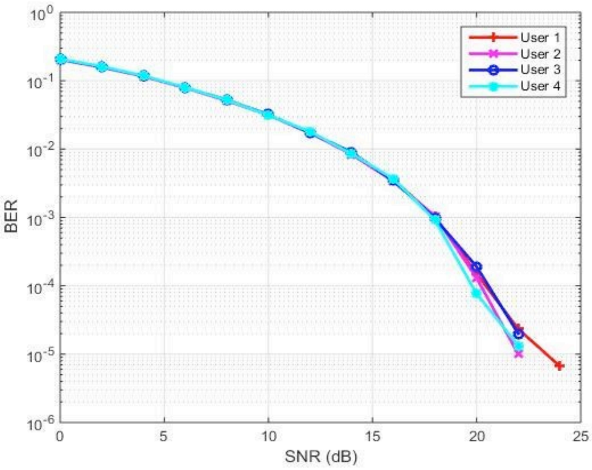

Fig. 8. Each users of DWT MC-CDMA in 100 km/h.

Figure 7 shows the performance comparison each users of DWT MC-CDMA system in 3 km/h. To reach BER 0.0001 it needs SNR ≈ 12.81 dB for user 1, SNR ≈ 12.67 dB for user 2, SNR ≈ 12.71 dB for user 3, and SNR ≈ 12.35 dB for user 4.

Figure 8 shows the performance comparison each users of DWT MC-CDMA system in 100 km/h. It needs SNR ≈ 20.42 dB for user 1, SNR ≈ 20.2 dB for user 2, SNR ≈ 20.57 dB for user 3, and SNR ≈ 19.78 dB for user 4.

From there we can see that Doppler frequency factor have big effect to destroy user orthogonality in DWT MC-CDMA but still classified as reasonable error.

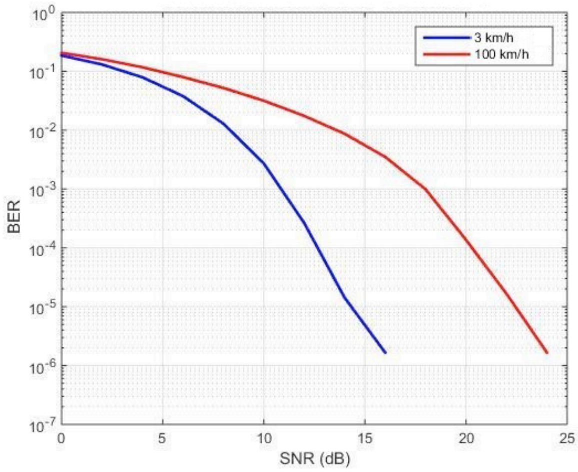

Fig. 9. DWT MC-CDMA in 3 km/h and 100 km/h.

Figure 9 shows the performance comparison of DWT MC-CDMA system in 3 km/h and 100 km/h. It is shown that to reach BER 0.0001, DWT MC-CDMA needs SNR ≈ 12.66 dB in 3 km/h and SNR ≈ 20.3 dB in 100 km/h. From there we can know that user's speed given big difference in system performance. The performance reduces as the user's speed increase because of Doppler effect. The error number in 100 km/h shown that there is big amount of interference that happens.

TABLE II. COMPUTATIONAL TIME

System type	***Time (s)***
DFT MC-CDMA	0,552574
DWT MC-CDMA	0,850383

Table II is shown that DWT MC-CDMA has more computational time than DFT MC-CDMA. It means that DWT MC-CDMA system is more complex. This computational time will very matter when the system implemented in hardware.

V. CONCLUSION

This work studies comparison of DWT MC-CDMA and DFT MC-CDMA in multipath Rayleigh fading channel with two different user's speed. The work achieves better performance using DWT in MC-CDMA system. DWT MC-CDMA is better than DFT MC-CDMA because DWT can reduce PAPR and BER of the system. However, DWT MC-CDMA have more computational time than DFT MC-CDMA which mean DWT increase the amount of system's complexity.

REFERENCES

[1] Baig, Sobia dan Fazal-ul-Rehman. 2005. "Performance Comparison of DFT, Discrete Wavelet Packet and Wavelet Transforms, in an OFDM Transceiver for Multipath Fading Channel". IEEE.

[2] El-Askalani, Mohamed. 2012."Performance Evaluation of DWT based OFDM System With DAPSK Modulation". Liverpool John Moores University.

[3] Hara, Shinsuke and Ramjee Prasad. 1997. *"Overview of Multicarrier CDMA"*. IEEE.

[4] Hara, Shinsuke and Ramjee Prasad. 2003. *"Multicarrier Techniques For 4G Mobile Communications"*. Universal Personal Communications.

[5] Medhi, Mayurakshi Roy and Kandarpa Kumar Sarma. 2015. "DWT Based Multi Carrier CDMA Using ANN-Aided Channel Estimation". International Conference on Signal Processing and Integrated Networks.

[6] Prafitri, Elsa. 2010. "Performance Analysis of MIMO MC-CDMA with Smart Antenna Using LMS Algorithm". Bandung: Telkom University.

[7] Renando, Randy. 2007. "Performance Analysis of Wavelet MC-DS-CDMA System with Combination Reed-Solomon Codes and Convolutional Codes". Bandung: Telkom University.

[8] Sarala B. and D.S.Venkateswarulu, B.N.Bhandari. 2012.*"Overview of MC-CDMA PAPR Reduction Techniques"*. International Journal of Distributed and Parallel Systems.

[9] Yang, Lie-Liang and Lajos Hanzo. 2003.*"Multicarrier DS-CDMA: A Multiple Access Scheme for Ubiquitous Broadband Wireless Communications"*. IEEE Communications Magazine.