Performance Analysis of Wavelet Packet Transform for MIMO OWDM Beamforming System over Rayleigh Fading Channel

Yuyun Siti Rohmah
Faculty of Applied Science
Telkom University
Bandung, Indonesia
yuyunsr@tass.telkomuniversity.ac.id

Budi Prasetya
Faculty of Electrical Engineering
Telkom University
Bandung, Indonesia
budiprasetya@telkomuniversity.ac.id

Dadan Nur Ramadan
Faculty of Applied Science
Telkom University
Bandung, Indonesia
dadan.nr@tass.telkomuniversity.ac.id

***Abstract*—Nowadays, the alternative for OFDM that is called as OWDM system have been studied. It replaces Fast Fourier Transformation with Wavelet Transformation. Wavelet transformation has more advantages such as flexibility, low complexity and given low energy consumption. High value of PAPR in OFDM system can decrease performance of system. PAPR is one of important parameter that related with hardware implementation such as power amplifier. In this paper, the performance and PAPR value for both of the system is compared. Simulation result shows that the performance of OWDM system with wavelet packet transformation is better than OFDM system. PAPR Simulation results of OWDM system give ±0.4 dB smaller than OFDM system.**

Keywords*—*OFDM, OWDM, PAPR

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier technique that had been used at many wireless communication technologies such as digital television, cellular technology etc. OFDM system is the multicarrier technique than can mitigate frequency selective fading in multipath channel communication and also can reduce Inter Symbol Interference (ISI). Recently, the alternative of this system have been studied such as the using of wavelet packet modulation that give the flexibility and low complexity [1][2] [3] [4][5]. Wavelet Packet Modulation overcome the problem of using Cyclic Prefix (CP) in OFDM system and produce the efficiency of bandwidth [6][7]. Wavelet modulation can be an alternative for OFDM system as it inherits low energy consumption [8]. The previous research about comparison of Orthogonal Wavelet Division Multiplexing System between Wavelet Packet Transform and Discrete Wavelet Transform [9] that showed better performance of OWDM system if using Wavelet Discrete Transformation. However, the number of discrete wavelet transform sub-bands cannot be as large as wavelet packet transform.

In the wireless communication system, the transmission signal will be damaged due to fading, this condition cause lower performance of the system. Multi Input Multi Output (MIMO) is a technique that uses multi antennas at transmitter and receiver sides. The increasing demand for data rates and the quality of wireless communication system services support to produce new techniques to improve energy efficiency and secure using MIMO Beamforming [10].

Beamforming is the process of forming a beam toward the desired user by suppressing the signal from the other direction. The beam formation in the direction of the desired signal can be accomplished by giving an adaptive weighting to the antenna elements in both the receiving and transmitting systems.

II. LITTERATURE

A. Multi Input Multi Output (MIMO)

In wireless communication system, the transmission signal will be damaged due to fading, thus it will reduce the performance of the system. On the other hand, the increasing demand for data rates and the quality of wireless communication system services support the new techniques to improve spectral efficiency and channel quality. This can be achieved using multiple antennas on both sides of the transmitter and receiver as shown in Figure 1, and this technique is known as MIMO (Multi Input Multi Output). There are two things that are actually given by MIMO system that is multiplexing gain and diversity gain. MIMO has been use at wireless technology such as Long Term Evolution at cellular communication.

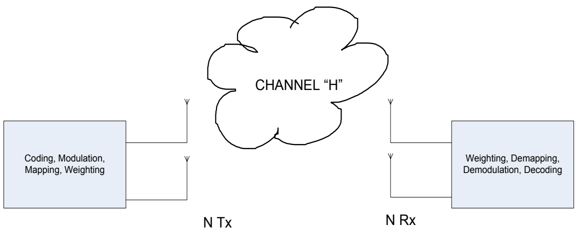

Fig. 1. MIMO System

MIMO (Multiple Input Multiple Output) is a channel formed when diversity technique on the sender and antenna receiver antenna is applied. Each of transmitter antenna will transmit information signal which will be accepted by all receiver antenna. Using the signal coupling technique on the receiver side will result in a higher SNR value that improves the quality of information signal reception.

B. Orthogonal Frequency Division Multiplexing(OFDM)

Orthogonal wavelet Division Multiplexing (OWDM) is an alternative multicarrier technique of Orthogonal Frequency Division Multiplexing (OFDM). OWDM in a communication system consists of a signal synthesis process in the form of a bank filter with multiple inputs and one output on the transmitter. Each input is a sub-symbol of super-symbol as the output of the modulation scheme. While the output is an OWDM signal that represents super-symbol. The synthesis process generates the OWDM signal as a combination of the weighted OWDM pulses. Each weighted OWDM pulse is a representation of the symbol. In the receiver the process of signal analysis using a bank filter, with one input and multiple output.

C. Wavelet Packet Modulation

OWDM using wavelet packet can be defined as an FIR filter and can be implemented on various types of wavelets. In the reverse wavelet transformation process occurs reconstruction / synthesis form of a signal as the sum of the waveform. This waveform can be constructed with a sequential iteration for each consisting of filtering and up-sampling.

$$\begin{cases} \varphi_{j,2m}[k] = \langle h_{lo}^{rec}[k], \varphi_{j-1,m}[k/2] \rangle \\ \varphi_{j,2m+1}[k] = \langle h_{hi}^{rec}[k], \varphi_{j-1,m}[k/2] \rangle \end{cases} \quad (1)$$

$$\text{with} \quad \varphi_{0,m}[k] = \begin{cases} 1 & k = 1 \\ 0 & others \end{cases}$$

Where j is the iteration index or level, and m is waveform index at the range $0 \le m \le M-1$. In the transformation of advanced wavelet packets occurs decomposition process, performed operations in reverse with the filtering process and down-sampling. For the full picture can be seen in Figure 2.

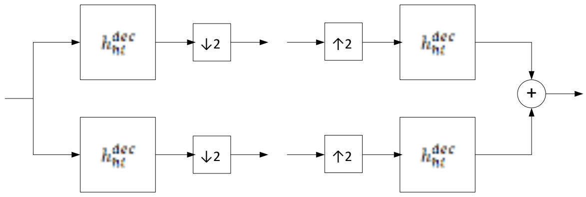

Fig. 2. Decomposition and Reconstruction Process of Wavelet Packet Transform

In orthogonal wavelet systems, filter scaling h_{lo}^{rec} and shifting h_{hi}^{rec} of the same filter pair. Therefore knowledge of filter scaling and wavelet tree depth is sufficient to design wavelet transforms and orthogonal WPT applications. In communication theory, this can be equated in the use of a matched filter to detect the sent waveform.

Special wave formation through WPT is more than the size of the transformation. Therefore, OWDM using wavelet packets including families of overlapping mutations, the beginning of the new symbol is sent before the previous symbol ends. The waveform undergoes a mutually orthogonal shift. Ortogonality between symbols will remain intact even if the overlapping symbols are overlaps. This will provide an increased advantage of domain frequency domainization provided with many waveforms. Wavelength can be obtained from a tree algorithm analysis. The length of the wavelet filter yields M waveforms can be interpreted and is described in the following equation:

$$L = (M-1)(L_0 - 1) + 1 \quad (2)$$

In Daubechie's wavelet family with a length equal to twice the vanishing order. For order 2 Daubechie wavelet is equal to 4 and if there are 32 subcarier WPT, then obtained waveform with length equal to 94. Characteristic data of each wavelet can be seen in table 1.

TABLE I. CHARATERISTIC OF WAVELET FAMILY

Kind of Mother Wavelet	Abbreviate	Vanishing Order	Length
Haar	Haar	1	2
Daubechie	dbN	N	2N
Symlets	SymN	N	2N
Coiflet	CoifN	N	6N

D. Beamforming

In wireless communication, signal from desired user and interferer signal often occupies the same frequency band. Beamforming is the process of forming a beam toward desired user by suppressing signal from other direction. Thus, beamforming can be said to be a spatial filtering signal. The formation of the beam in the direction of the desired signal can be done by giving an adaptive weighting to the antenna elements in the receiving and the transmitter system.
If equation of Mean Square Error is written as:

$$J = E\left[\left|d(n) - y(n)\right|^2\right] \quad (3)$$

where $E[.]$ is the average and output of beamforming is

$$y(n) = w^H x(n) \quad (4)$$

Gradient of Minimum Mean Square Error (MMSE) is zero, so the optimum weighting of MMSE is

$$w_{opt} = R_{xx}^{-1}.r_{xd} \quad (5)$$

where $R_{xx} = E\left[x(n).x(n)^H\right]$ (6)

is value of matrix correlation of beamforming input signal $x(n)$

$$r_{xd} = E\left[x(n)d^*(n)\right] \quad (7)$$

Equation 7 is value of cross correlation between desired signal and beamforming input signal. It is pilot signal of reference signal that is inserted at transmission signal.

III. SYSTEM MODEL AND SIMULATION RESULT

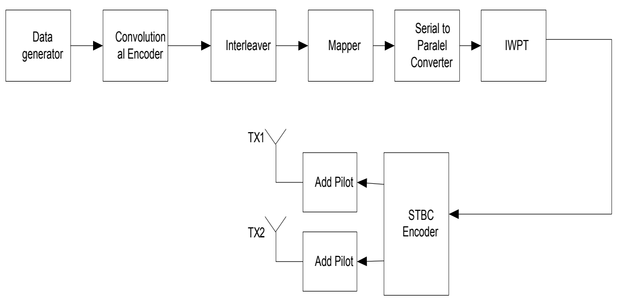

Fig. 3. Transmitter Blok of MIMO Beamforming using Wavelet Packet Modulation

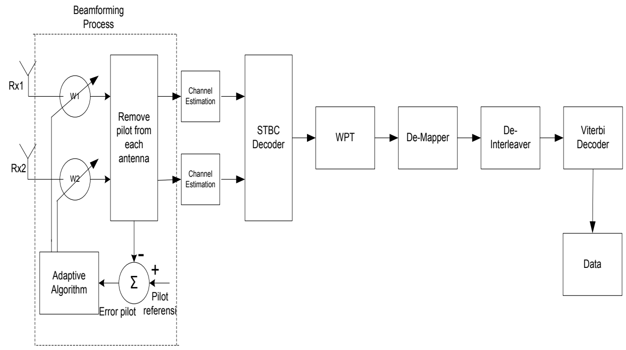

Fig. 4. Receiver Blok of MIMO Beamforming using Wavelet Packet Modulation

Transmitter and receiver block are consists of:

- Block of Data Generator is used to produce bits with uniform distribution.
- Convolutional Encoder is used to correct error receive data that is caused by channel. Value of code rate using ½ with generator polynomial $g_0 = 171_8$,$g_1 = 133_8$ and constraint length (K)= 7.
- Interleaver block is designed to spread the sequence pattern of bits so that the effect of the burst error does not cause a sequential error pattern before entering the decoder.
- Mapper of this system is used to Form binary into data symbols in accordance with the constellation of the symbol. The signal mapper used in the configuration of this research is Quadrature Phase Shift Keying (QPSK) whose constellation mapping is based on gray code.
- Serial to Parallel converter is used to change the serial data into parallel data by changing the matrix size from row to column.
- Inverse Wavelet Packet Transform is used to convert the output complex symbols of QPSK into OWDM symbols. This domain alteration is performed using the inverse transformation technique of the Wavelet Packet Transform using a filter bank that having the same size for each QPSK symbol.

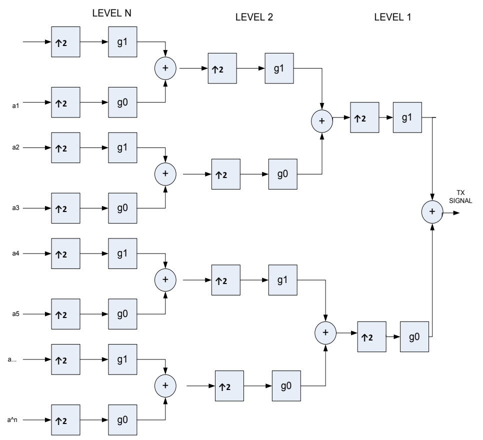

Fig. 5. Diagram block of Inverse Wavelet Packet Transform

- The Space-Time Block Codes transmission method matches Alamouti code for both of transmitting antennas and receiving antennas. After modulation process, data will be transmitted on two different antennas.

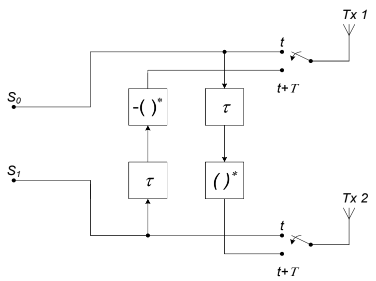

Fig. 6. STBC Transmission Pattern

- Add pilot block is using for the channel estimation process, an "experimental" signal, called a pilot signal, is known by the transmitter and receiver.
- Adaptive algorithm used Least Mean Square (LMS). This algorithm will determine the continuing weighted vector until get the most optimum weighted value resulting in a minimum error between the reference pilot and the pilot receiving of estimation result.

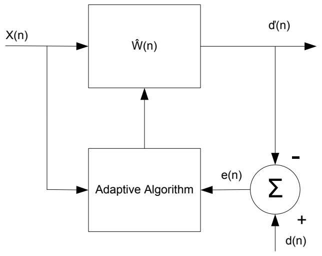

Fig. 7. Diagram block of adaptif filter

The weighting vector is recursively determined by the following equation:

$$w(n+1) = w(n) + \mu x(n) * e(n) \quad (8)$$

$$e(n) = d(n) - w_n^T x(n) \quad (9)$$

In the equation above, μ is the step-size that determines the system convergence of the adaptive algorithm. The requirement of LMS algorithm is know the transmitting signal. This is accomplished by sending several pilot signals or periodic training signals that are known in the receiving system.

- Space Time Block Code (STBC) decoder and Channel estimation. The channel estimation is performed to determine the channel response that occurs during the transmitted signal from the transmitter to the receiver. The path to be estimated consists of h_{11} which is the channel response of the passing channel path between Tx_1 and Rx_1, h_{12} between Tx_2 and Rx_1, h_{21} between Tx_1 and Rx_2 and h_{22} between Tx_2 and Rx_2.

- Wavelet Packet Transform (WPT) is the kind of wavelet transform which is more of comprehensive sub-band division. In the sense that in wavelet transform only give iteration at low pass branch, whereas in iteration of wavelet packet transform done both of high and low pass so it produce more sub-band with high resolution.
- The working principle of the Viterbi decoder is based on the principle of maximum likelihood decoding and the knowledge of the trellis diagram on the convolutional encoder at the sender.

IV. Simulation Result and Analisys

A. BER Vs SNR Simulation of MIMO OFDM Beamforming and MIMO OWDM Beamforming at Fading Rayleigh Channel

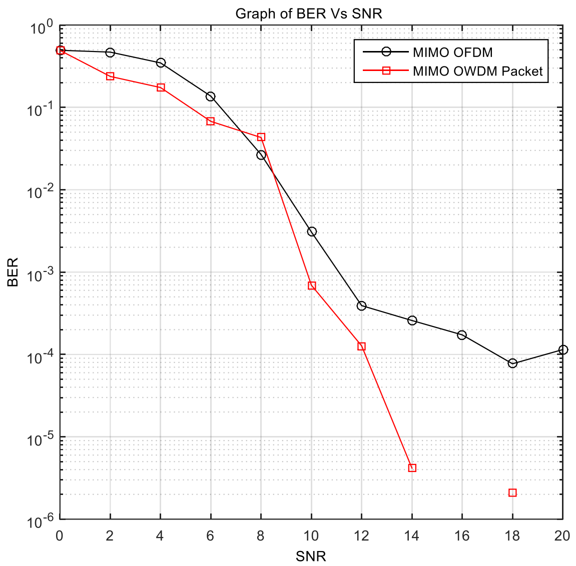

Fig. 8. Graph of Simulation BER Vs SNR over rayleigh channel

This simulation using 256 sub-bands/sub-carriers, QPSK Mapper with gray code, user velocity 10 km/hour, degree of arrival = 1/3*pi and μ=0.01. Figure 8 shows the comparison of SNR value for BER 10^3, SNR of MIMO OWDM Beamforming system is ±10 dB while ± 11 dB for MIMO OFDM Beamforming. The value of SNR between two system is doesn't much different. This is because the similarity of orthogonality and bandwidth division of OFDM and Wavelet Packet Modulation system. In OFDM the orthogonality of subcarrier give the bandwidth efficiency and mitigate the frequency selective fading because each of subcarrier have the coherence bandwidth > signal bandwidth. In the OWDM system, the using of orthogonal sub-band principle will produce sub-carriers that are orthogonal to each other.

B. BER Vs SNR Simulation of MIMO OFDM Beamforming and MIMO OWDM Beamforming at Fading Rayleigh Channel with variation of user velocity

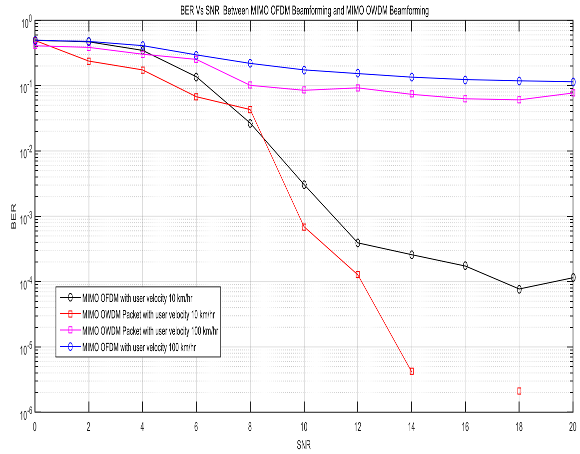

Fig. 9. Graph of Simulation BER Vs SNR with variation of user velocity

The simulation resulted that for the higher user velocity give the poor performance of both of system and affects larger of Doppler shift. The greater of Doppler shift caused required bandwidth will be wider too. From figure 9, SNR of MIMO OWDM Beamforming system with user velocity 10 km/hour is ±10 dB while ± 11 dB for MIMO OFDM Beamforming.

C. PAPR Simulation of MIMO OFDM Beamforming and MIMO OWDM Beamforming at Fading Rayleigh Channel with variotion of user velocity

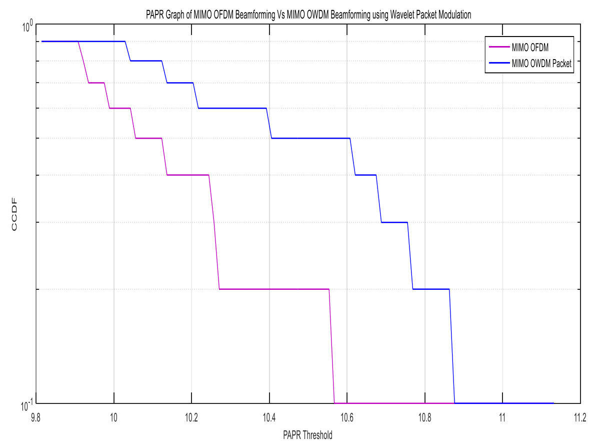

Fig. 10. Graph of PAPR Simulation Ratio between MIMO OFDM Beamforming and MIMO OWDM Beamforming

Figure 10 shows that the OWDM system is lower ± 0.4 dB compared to using Orthogonal Frequency Division Multiplexing system. It is the effect of many symbols with coherent phases of OFDM. So that the PAPR value is also becomes enlarged.

V. Conclusion

The performance of MIMO OWDM Beamforming System using Wavelet Packet Transformation is better than MIMO OFDM Beamforming. Comparison of SNR value for BER 10^3, SNR of MIMO OWDM Beamforming system is ±10 dB while ± 11 dB for MIMO OFDM Beamforming. Furthermore, the using of wavelet packet transformation in OWDM system give the smaller PAPR value if compare with OFDM system with difference about ± 0.4 dB.

References

[1] P. Jamin, Antony., Mahonen, "Wavelet Packet Modulation for Wireless Communicatio," *Wirel. Commun. Mob. Comput. Journal,Vol.5, Issue 2.*, vol. 5, no. 2, 2005.

[2] S. L. Linfoot, M. K. Ibrahim, S. Member, M. M. Al-akaidi, and S. Member, "Orthogonal Wavelet Division Multiplex : An Alternative to OFDM," vol. 53, no. 2, pp. 278–284, 2007.

[3] S. F. Hassen, "The Performance of Orthogonal wavelet Division Multiplexing (OWDM) in Flat Rayleigh Fading Channel," *J. Eng. Dev.*, vol. 12, no. 1, pp. 131–147, 2008.

[4] X. Yu and G. Bi, "Performance of Complex Orthogonal Wavelet Packet Based MC-CDMA System with Space-Time Coding over Rayleigh Fading Channel," *2009 IITA Int. Conf. Control. Autom. Syst. Eng. (case 2009)*, pp. 136–139, 2009.

[5] H. J. Taha, S. Member, and M. F. M. Salleh, "Performance Comparison of Wavelet Packet Transform (WPT) and FFT-OFDM System Based on QAM Modulation Parameters in Fading Channels 3 . Discrete Wavelet Packets Transform," vol. 9, no. 8, pp. 453–462, 2010.

[6] P. Hoang and Q. Ngo, "Wavelet packet transform in MIMO - OFDM systems," pp. 98–101, 2013.

[7] I. Journal and O. F. Engineering, "A Review on wavelet transform as a substitute to cyclic prefix removal in FFT in OFDM *1,2,3," vol. 3, no. 2, pp. 1–4, 2014.

[8] M. Chafii, J. Palicot, and R. Gribonval, "Comptes Rendus Physique Wavelet modulation : An alternative modulation with low energy consumption," *Comptes Rendus Phys.*, vol. 18, no. 2, pp. 156–167, 2017.

[9] Y. S. Rohmah, "Performance Comparison of Orthogonal Wavelet Division Multiplexing (OWDM) System using Discrete Wavelet Transform and Wavelet Packet Transform on Rayleigh Channel," pp. 104–108, 2016.

[10] N. T. Nghia, H. D. Tuan, T. Q. Duong, and H. V. Poor, "MIMO Beamforming for Secure and Energy-Efficient Wireless Communication," *IEEE Signal Process. Lett.*, vol. 24, no. 2, pp. 236–239, 2017.

978-1-5386-2373-2/17/$31.00 ©2017 IEEE