Comparison Performance Analysis of OWDM and OFDM System on Multipath Fading Rayleigh Channel

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Abstract*— Improvement of information technology especially in telecommunication system support wireless communication system must provide high data rate service. OFDM is the system that have high data rate and had been used as the method to overcome multiple channel effect. But the weakness of OFDM system is PAPR. Large PAPR causes non linear distortion of signal and non orthogonal of sub carrier that caused performance of OFDM system will decrease. Recently, it has been developed a system as an alternative to OFDM system called OWDM (Orthogonal wavelet division multiplex). Basic idea of OWDM is replaced Inverse Discrete Fourier Transform (IDFT) with the Inverse Discrete Wavelet Transform (IDWT) for generating orthogonal sub-carrier. Like IDFT on OFDM systems, function of IDWT on OWDM system is modulator, while demodulator process used DFT (Discrete Fourier Transform) on OFDM and DWT (Discrete Wavelet Transform) on OWDM. This paper will compare the performance between OWDM and OFDM system on fading Rayleigh channel. Simulation both of system resulted same performance on multipath Rayleigh fading channel but different PAPR value PAPR of OWDM system is smaller than OFDM system. Thus OWDM techniques can be chosen as an alternative method to overcome the problems of the high PAPR value in OFDM techniques.

Keywords—owdm; ofdm; papr; dwt; idwt ;rayleigh fading

I. INTRODUCTION

Today's mobile wireless communications system are required to provide high speed data service. One technique that can provide high speed data services is OFDM (Orthogonal frequency-division multiplexing). OFDM is multicarrier technique that has long been used as an efficient method to counteract the effect s of multipath channel on a system that has a high data rate. However, one drawback of this system is the high value of Peak to Average Power Ratio (PAPR). PAPR is the ratio of peak power of the signal with average power. Large PAPR causes non linear distortion of signal and non orthogonality of sub carrier and produce peak value of signal so performance of OFDM system will decrease. Large PAPR value also causes the difficulty of implementation of power amplifier device and higher cost of implementation. Nowadays, multicarrier systems have been proposed based on wavelet transform that called as Orthogonal Wavelet Division Multiplexing (OWDM). Wavelet theory has been predicted by some experts as a good platform for building-based multicarrier waveform. Akansu et.al.emphasizes the relationship between filter bank and predicts theory about OWDM multiplexers that has the ability to play in the upcoming communication systems [2]. In this study, Performance on fading Rayleigh and Peak to Average Power Ratio (PAPR) of both systems will be compared.

II. OVERVIEW OF OWDM AND OFDM SYSTEM

A. OWDM (Orthogonal Wavelet Divison Multiplexing)

OWDM in a communication system consists of processes such as signal synthesis filter bank with multiple inputs and one output in transmitter. OWDM synthesis process generates a signal as a combination of weighted pulses OWDM. Each pulse OWDM weight is representation of the symbol. In the receiver, signal is analyzed by using the filter bank with single input and multiple output[1].

- Discrete Wavelet Transformations (DWT) [5] [10]

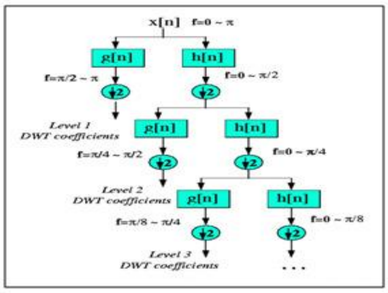

Fig. 1. Signal decomposition procedure with Discrete Wavelet Transform

In discrete wavelet transform, digital signal representation is obtained by using digital filtering techniques. Filter with different cut off frequency is used to analyze signals at different scales. The signal is passed to the circuit High Pass Filter (HPF) for analyzing high frequency, and also passed to the Low Pass Filter (LPF) to analyze the low frequency. Signal resolution is a representation of amount signal detailed information that is converted by filtering operation, while the scale is converted by down-sampling and up-sampling operations (sub-sampling). Down-sampling process means lowering the sampling rate or throw some signal samples, while up-sampling process means

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raising the sampling rate of a signal by adding new samples to the signal.

Fig. 1 explains the procedure of the Discrete Wavelet Transform:

The signal is passed to the HPF and LPF to analyze high frequency and low frequency signals. Filtering process is the convolution operation between signals and response impulse of filter. Mathematically filtering process can be written as:

$$* h \quad = \quad . h \quad - \tag{1}$$

After the signal through the LPF and HPF, conducted subsampling by a factor of2. Mathematically it can be written as:

$$= \quad h \quad . \; 2 \; - \tag{2}$$

DWT analyze the signal at different frequency bands by means of the decomposition of the signal into detail coefficients and approximation coefficients. DWT consists of two sets of functions, namely the scaling function and wavelet function. Decomposition of the signal into different frequency bands obtained by high pass and lowpass filtering. After filtering process, output of each filter is done subsampling by a factor of 2. The output signal for each level of decomposition process can be written mathematically as:

$$= \quad . \; 2 \; - \tag{3}$$

$$= \quad . h \, 2 \; - \tag{4}$$

Where y_{high}[k] and y_{low} [k] are the output of the HPF and LPF after subsampling by a factor of 2

The most important properties of the transformation wavelet is the relationship between the impulse response of the HPF and LPF that can be seen from the equation:

$$- 1 - \quad = (-1) \; . h \tag{5}$$

Where L is the length of the filter

- Inverse Discrete Wavelet Transform (IDWT) [5][10]

IDWT is used to reconstruct process that consists of up sampling and filtering. The procedures of IDWT are:

Each signal level consists of up sampling process by a factor of 2and then passed to the synthesis high pass filter g'[n] and a low pass h' [n] which is summed finally. Up sampling is the restore and combine process of signals with insert in a column of zeros between each column and perform convolution on each line with a filter.

Reconstruction equation can be written:

$$= \quad (\quad . \; 2 \; - \;) + \quad (\quad . \; 2 \; - \;) \tag{6}$$

If the filters are not ideal, the perfect reconstruction cannot be achieved. It is impossible to achieve the ideal filter, but it is possible to find filters that provide perfect reconstruction.That is called Daubechies wavelets which developed by Ingrid Daubechies.

B. OFDM (Orthogonal Frequency Divison Multiplexing)[12]

OFDM is a multicarrier modulation technique using mutually orthogonal frequency .The basic concept of OFDM is to split a high-speed serial data into a low-speed parallel data transmitted by multiple sub-carriers. In OFDM systems, each sub-carrier spacing is set to overlap but do not cause interference between adjacent sub-carriers. OFDM signal generation process can be done at the base band level by using Inverse Discrete Fourier Transform (IDFT) as a modulator and Discrete Fourier Transform (DFT) as a demodulator. OFDM symbol generated from the following equation:

$$s(k) = \frac{1}{N}\sum_{n=0}^{N-1} S(n) e^{j[2\pi nk/N]}; 0 \le k \le N-1 \tag{7}$$

where:

N = Number of IDFT point (sub-carriers total)

S(n) = Symbol of transmitted data on k^{th} sub-carriers

s(k) = Output of IDFT

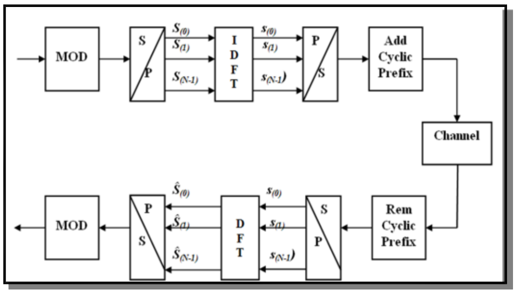

Fig. 2. OFDM Transceiver system

III. SYSTEM MODEL

A. OWDM System Model

System model of OWDM consists of the reconstruction process of transmitter that is done with IDWT (Inverse DWT) and while decomposition at the receiver uses DWT. The numbers of sub-bands that used in system model are 4, 8 and 16. OWDM is illustrated in the following blocks [2] [3]:

- IDWT (Inverse Discrete Wavelet Transform)

The results of QPSK encoding are transformed with IDWT from frequency domain to the time domain. Conversion process is performed by using the 2-band wavelet transform. Sub-symbols output of S/P converter at each level is passed to up sampling process with a factor of 2. The sub-symbols of the upper sub-band to the one sub-band before lower sub-band is set as the detail coefficients (Cd) entered into a high pass filter (HPF) while for the lower sub-band symbol is set as an approximation coefficient (Ca) entered into the low pass filter (LPF). All sub symbols of HPF and LPF output are summed at each level use (6).

- DWT (Discrete Wavelet Transform)

  Wavelet modulated signal x [n], which has passed through the channel will have additional noise from the result as y[n]. To get back sub symbols, the transformation process using Discrete Wavelet Transform (DWT) is performed. This signal is obtained by extracting the signal y[n] to approximation coefficients and detail coefficients. Each level of decomposition is done by using (3) and (4).

4	1

From the table it is seen that after use OWDM techniques, each sub - band bandwidth value is smaller than a coherent bandwidth channel . So that each sub - band feels flat fading .

b) Doppler Spread and *Coherence Time*

TABLE IV. DOPPLER FREQUENCY VALUE AND COHERENCE TIME

User velocity (km/h)	Doppler Shift	Coherence Time
0	0 Hz	∞ (!" ≫ !$)
3	5.56 Hz	0.076 s (!" ≫ !$)
75	138.88 Hz	0.003045 s (!" ≫ !$)
100	185.185 Hz	0.00228 s (!" ≫ !$)

Based on calculation results obtained (Tc >> Ts) , so the transmission channel is a slow fading .

IV. SIMULATION RESULT

A. Comparative Performance Analysis OWDM and OFDM on AWGN channel and rayleigh Multipath Fading

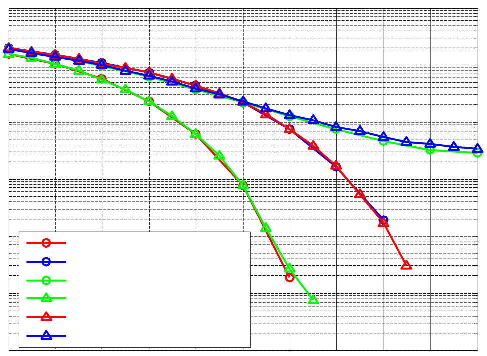

Fig. 6. Graph of comparison OWDM and OFDM system on AWGN and Multipath Rayleigh Fading

Fig.6 shows comparisons OWDM system and OFDM in AWGN channel and Multipath Rayleigh Fading, OFDM and OWDM system with 16 sub-band/ sub-carrier. In OWDM system uses *wavelet Daubechies* 1 (db1). Both system provide the same performance. This is because the orthogonality between sub - band / sub - carrier and OFDM systems OWDM same.SNR value for each system can be seen in Table below.

TABLE V. SNR REQUIRED FOR BER 10-3 ON AWGN AND RAYLEIGH FADING CHANNEL

Channel Model	SNR for BER 10^{-3}(dB)
OWDM AWGN	±9.8
OWDM Rayleigh 0 km/h	±14.6
OFDM AWGN	±9.8
OFDM Rayleigh 0 km/h	±14.6
OFDM Rayleigh 100 km/h	≫ ±20

B. Comparison Performance Analysis of OWDM and OFDM with variation of user velocity

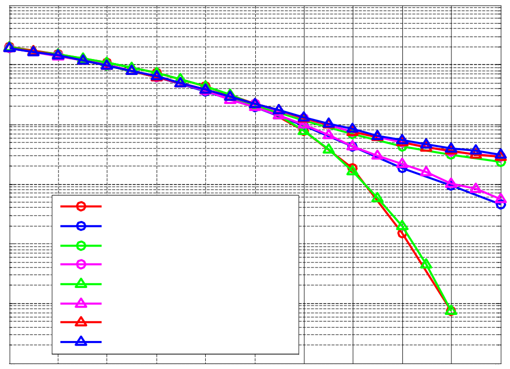

Fig. 7. Graph of comparison OWDM and OFDM system with variation of user velocity

In this simulation used QPSK modulation number of sub-carrier is 16 for OFDM system. OWDM system used daubechies wavelet second order (db2). Figure. describe that the greater the speed of the user make higher Doppler frequency which will affect degrade system performance. OWDM and OFDM system at variation condition user velocity give same performance.

TABLE VI. SNR REQUIRED FOR BER 10-3 WITH VARIATION OF USER VELOCITY

User Velocity	SNR for BER 10^{-3}(dB)
OWDM 0 km/h	± 14.5
OWDM 3 km/h	± 18
OWDM 75 km/h	±20
OWDM 100 km/h	≫ ±20
OFDM 0 km/h	± 14.5
OFDM 3 km/h	± 18
OFDM 75 km/h	≫ ±20
OFDM 100 km/h	≫ ±20

C. Comparison Performance Analysis of OWDM and OFDM with variation of number of sub-band/sub-carrier.

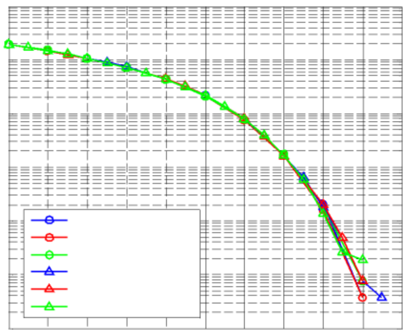

Fig. 8. **C**omparison Graph OWDM and OFDM system in Rayleigh Multipath Fading Channels with variation number of su-band/sub-carrier

In this simulation used QPSK modulation number of sub-carrier is 16 for OFDM system. OWDM system used daubechies wavelet second order (db2). Fig.8 describe that performance of both system is same in this condition. Figure also describe that number of sub-band did not affected performance of system. This is caused by flat fading occurs at each bandwidth sub-band/sub-carrier of OWDM for 4 sub-bands, 8 sub-band and 16 sub-band. Where for every sub-bands have signal bandwidth that more less than coherence bandwidth.

TABLE VII. SNR REQUIRED FOR BER 10-3 WITH VARIATION OF NUMBER OF SUB-BAND/SUB-CARRIER

Number of Sub-band/sub-carrier	SNR for BER 10^{-3}(dB)
OWDM 4 sub-bands	± 14.5
OWDM 8 sub-bands	± 14.5
OWDM 16 sub-bands	± 14.5
OFDM 4 sub-carriers	± 14.5
OFDM 8 sub-carriers	± 14.5
OFDM 16 sub-carriers	± 14.5

D. Comparison Performance Analysis of OWDM and OFDM with variation of modulation technique.

In this simulation, OWDM and OFDM system uses BPSK and QPSK modulation. OWDM uses wavelet Daubechies second order (db2). The picture shows that the performance OWDM and OFDM system has the same performance for each type of modulation. Additionally seen also for both of system, BPSK modulation types provide better performance compared with QPSK modulation types. This is because the BPSK 1 bit = 1 symbol on the receiver side so that the chances of error is less than QPSK where one symbol = 2 bits . in BPSK modulation space between symbols have more tenuous than other modulation types . So that the current through the transmission channel that is lossy and occur shifting the phase , the signal with large value of M (number of symbols) will be more cause error. So that, a decrease in power level and phase change is able to l changes in the symbol so that the decision circuit will be wrong in decision process accordance point constellation at the transmitter .

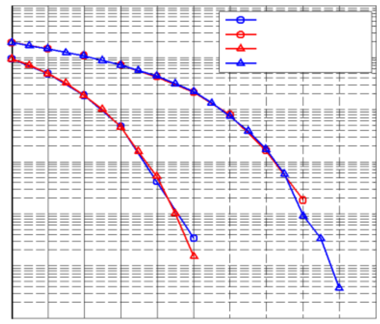

Fig. 9. **C**omparison Graph OWDM and OFDM system in Rayleigh Multipath Fading Channels with variation number of modulation technique

TABLE VIII. SNR REQUIRED FOR BER 10-3 WITH VARIATION MODULATION TECHNIQUE

Type of Modulation	SNR for BER 10^{-3}(dB)
OWDM with BPSK	± 7.5
OWDM with QPSK	± 14.8
OFDM with BPSK	± 7.6
OFDM with QPSK	± 14.8

E. Comparison Performance Analysis of OWDM and OFDM with variation order of Daubechies wavelet for OWDM system.

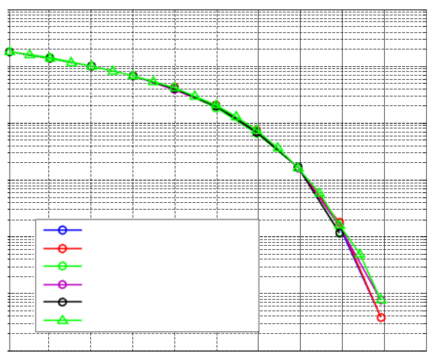

Fig. 10. **C**omparison Graph OWDM and OFDM system in Rayleigh Multipath Fading Channels with variation order of Daubechies wavelet for OWDM system

In Fig.10 ,simulation performed on QPSK modulation , number of sub - band / sub – carrier is 16. It shows that

OFDM and OWDM system performance resulted the same performance . Where the order does not affect the Daubechies wavelet to system performance OWDM .

TABLE IX. SNR REQUIRED FOR BER 10-3 WITH VARIATION ORDER OF DAUBECHIES WAVELET FOR OWDM SYSTEM

Wavelet daubechies order	SNR for BER 10^{-3}(dB)
OWDM with db1	± 14.5
OWDM with db2	± 14.5
OWDM with db4	± 14.5
OWDM with db8	± 14.5

F. Comparison PAPR of OWDM and OFDM system.

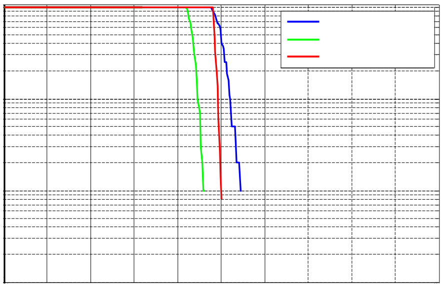

Fig. 11. **C**omparison PAPR CCDF Graph of OWDM and OFDM System

TABLE X. VALUE OF $PAPR_0$, PR (PAPR>PAPR0) = 10^{-2} FOR OWDM AND OFDM SYSTEM

Type of Modulation	Pr(PAPR>$PAPR_0$)	$PAPR_0$(dB)
OWDM db4	10^{-2}	9.35
OWDM db8	10^{-2}	10
OFDM	10^{-2}	10.8

Each sub-band of OWDM in this simulation used Daubechies filter 4^{th} order (db4) and Daubechies filter 8 th order (db8) with 16 sub-band. While OFDM system use QPSK mapping and 16 sub-carrier. Fig 11 describes that OWDM system give reduction of PAPR value about ± 1.45 dB for OWDM with db4 and ± 0.8 dB for OWDM with db8.

The PAPR value of OWDM system is smaller than OFDM system. In OFDM system, IFFT process produces signal that has variation of power. This condition causes PAPR value will be enlarged. The power variation caused by modulating each sub-carrier is performed by different frequencies so that if output signal of multiple sub-carrier has a phase coherent amplitude, it will appear with a much greater level of average power. In contrast to OWDM, because each sub-bands of each level IDWT has 2 different frequency bands where the scale and the shift have been set before, from the 1^{st} sub-bands to-N^{th} sub-band, so that when signal with phase coherence from each sub-band is summed, it does not cause high value of PAPR. Thus OWDM techniques can be chosen as an alternative method to overcome the problems of the high PAPR value in OFDM techniques.

V. CONCLUSION

1. Simulation of OFDM and OWDM system resulted the same performance . In the AWGN channel for both system, BER 10^{-3} For SNR required ± 9.8 dB . While the multipath rayleigh fading channel with user velocity 0 km / h required SNR of ± 14.6 dB.

2. The result show that a greater number of sub-bands result in a higher PAPR value for OWDM and OFDM system. This allows the growing number of sub-bands which means that the probability summation of coherent symbols is also getting bigger.

3. Simulation of (PAPR) in OWDM and OFDM system shows that PAPR of OWDM is smaller than OFDM system about ± 1.45 dB for OWDM with db4 and ± 0.8 dB for OWDM with db8.

4. OWDM techniques can be chosen as an alternative method to overcome the problems of the high PAPR value in OFDM techniques.

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