PAPR Comparison Of OWDM and OFDM System

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Abstract— **PAPR is the ratio of peak power of the signal with average power. Large PAPR value causes difficulty in the implementation of power amplifier device and higher cost of implementation. Recently it has been developed a system as an alternative to multicarrier 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. One of the weaknesses of OFDM is high PAPR value, so in this study the PAPR value of OFDM and OWDM system will be compared. Simulation PAPR in OWDM and OFDM systems show that more number of sub-bands cause higher PAPR value, but PAPR of OWDM is smaller than OFDM system.**

Keywords—PAPR;OWDM;OFDM

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 value 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 OWDM system, Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) is replaced by the Inverse Discrete Wavelet Transform (IDWT) and Discrete Wavelet Transform (DWT) [6].In this study, the 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].

A.1. Discrete Wavelet Transformations (DWT) [5] [10]

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

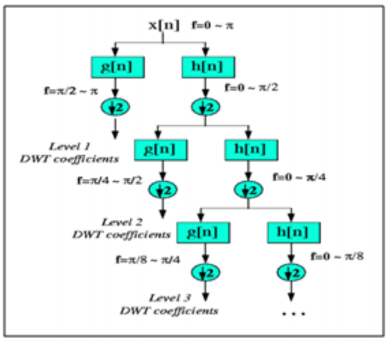

Figure. 1.Signal decomposition procedure with Discrete Wavelet Transform

Based on Figure.1, x[n] has 512 sample points with a frequency range of 0- πrad/s. The first level of decomposition, signal is passed through a high pass and low pass and then followed by down sampling process respectively. High pass output has 256 sample points with a range π/2 - π rad/s. Low pass output also has 256 samples with a range 0 –π/2 rad/s.

Then low pass is divided again into other high pass and low pass. So the second level low pass has 128 samples with arrange of 0–π/4 rad/s and high pass second level have 128 samples with a range ofπ/4 – π/2rad/s. This process will be done until sample in the output low pass and high pass filtering have 1 sample.

Figure 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:

$$x[n] * h[n] = \sum_{-\infty}^{\infty} x[k].h[n-k] \quad (1)$$

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

$$y[n] = \sum_{-\infty}^{\infty} h[k].x[2n-k] \quad (2)$$

- DWT analyzes 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 low pass 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:

$$y_{high}[k] = \sum_{-\infty}^{\infty} x[n].g[2k-n] \quad (3)$$

$$y_{low}[k] = \sum_{-\infty}^{\infty} x[n].h[2k-n] \quad (4)$$

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:

$$g[L-1-n] = (-1)^n .h[n] \quad (5)$$

Where L is the length of the filter

A.2. *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:

$$x[n] = \sum_{-\infty}^{\infty}(y_{high}[k].g[2k-n]) + \sum_{-\infty}^{\infty}(y_{high}[k].g[2k-n]) \quad (6)$$

- 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. *Orthogonal Frequency Division Multiplexing (OFDM)*[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-carrier. 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.

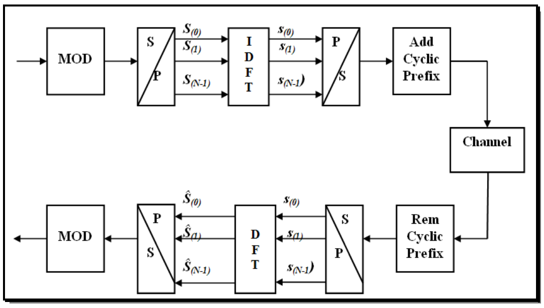

Figure.2. OFDM Transceiver system

To generate base band OFDM symbol, the first serial data sequence is converted into parallel data sequences by using a serial to parallel converter. After that, each serial to parallel converter output of each subcarrier is modulated with a frequency that is orthogonal to each other with sampling rate N/T, where N is the number of sub-carrier and T are the OFDM symbol duration. OFDM symbol generated from the following equation:

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

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

C. *Peak to Average Power Ratio (PAPR)*[17]

PAPR is the ratio of peak power to average power signal. PAPR value of output base band signal mapping is zero dB, because all symbols have the same power. But after IFFT process, the signal power will be various so PAPR value higher. Variation of power is caused by modulating of each sub-carrier that is done with different frequencies. If signal output of multiple sub-carrier has a phase coherent, it will appear with a much greater level of average power signal. High value of PAPR will cause OFDM system needs system component that has a wide linear operation area to accommodate amplitude of signal. Non linear operation area produces wave form distortion that is caused by non orthogonal sub-carriers. This condition causes lower performance of OFDM.

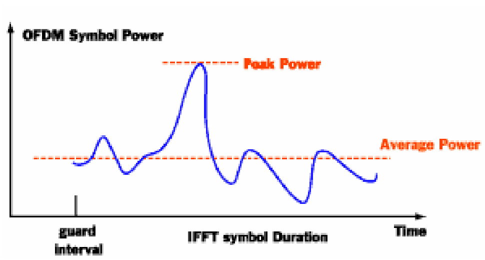

Figure.3.Amplitude fluctuation of OFDM signal

PAPR has a random value that depends on combination of symbols mapping phase, with a maximum value of PAPR is N. Appearance probability PAPR of OFDM system is modeled in equation:

$$P(PAPR > PAPR_0) = 1-\left(1-e^{-PAPR_0}\right)^N \qquad (8)$$

III. System Model

A. System model of OWDM

System modelof 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 block diagram [2] [3]:

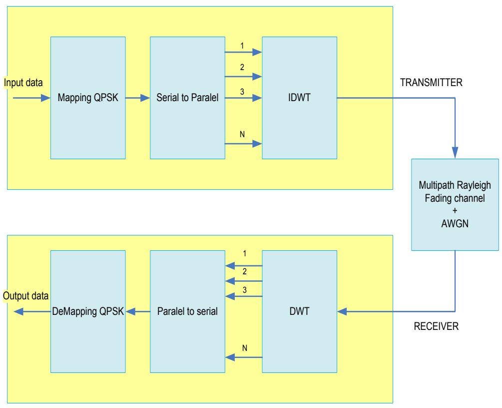

Figure 4.Block diagram of OWDM system

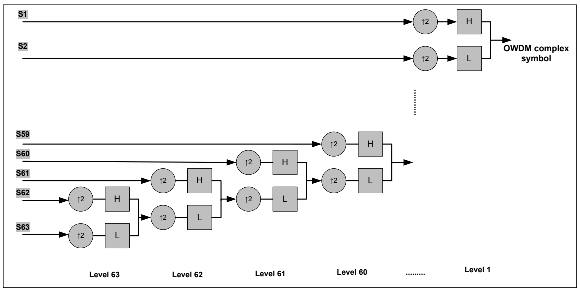

Figure.5.IDWT (synthesis filter bank) with N level[10]

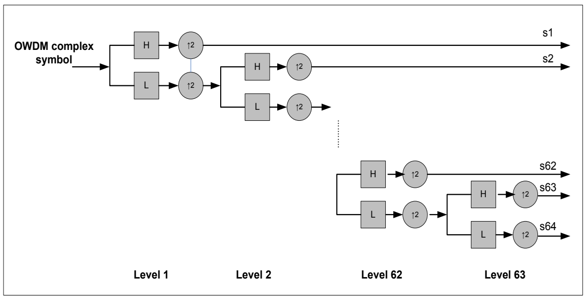

Figure.6.DWT (analysis filter bank) with N level[10]

A.1. Random Data Generator

Random generator block generates binary data such bit '0 'and bit '1' randomly. Each of binary data has same probability of occurrences.

A.2. Signal Mapper

Signal mapper is used to form the binary data into symbol data in accordance with a certain constellation symbols. Signal mapper configuration that was used in this study is Quadrature Phase Shift Keying (QPSK) constellation .

A.3 S/P Converter

S/P Converter is a block which changes serial bit stream of modulated output signal. Changing the shape of the serial into parallel form is done by changing the size of the matrix .The number of rows should be matched with the number of sub-bands that is used in OWDM signal. For each input sub-band, reconstruction process uses Inverse Discrete Wavelet Transform (IDWT) with different inputs, except for the sub-band at the same level.

A.4. 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).

A.5 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).

A.5 P/S Converter

On the receiver side, the P/S Converter is used to convert a parallel bit stream into serial data. Changing the form of parallel into serial form is done by changing the size of the matrix of columns into rows.

A.6 Signal Demapper

This block is used to map the symbol-stream back into the bit-stream based on the area of the symbol constellation.

B. System Model Of OFDM

B.1 OFDM Modulation

Modulation process of OFDM system is done by IFFT (Inverse Fast Fourier Transform). It transforms data from frequency domain to time domain. The purpose of using IFFT process is to make the orthogonal sub-carriers so that the spectra can overlap each other without causing interference.

B.21 OFDM Demodulationj

The purpose of this process is to perform the conversion of OFDM signal in the form of symbols into complex numbers according to the QPSK constellation mapping at the transmitter. The number of FFT points used which is equal to the number of FFT data also serves as a base band demodulator.

C. Simulation Parameter

Determining the planning parameters to be simulated has a very important role for the success of the simulation.

TABLE I. PARAMETERS OF OFDM AND OWDM

Parameter	Unit and Value
Modulation	BPSK, QPSK
Number of sub-band/sub-carrier	4,8,16
Bit rate	2 Mbps
Carrier Frequency	2 GHz
Number of bit	262144
Wavelet Filter	db1,db2,db4,db8,db10

IV. SIMULATION RESULT

A.1 The Influence of different Sub-band number for OWDM system

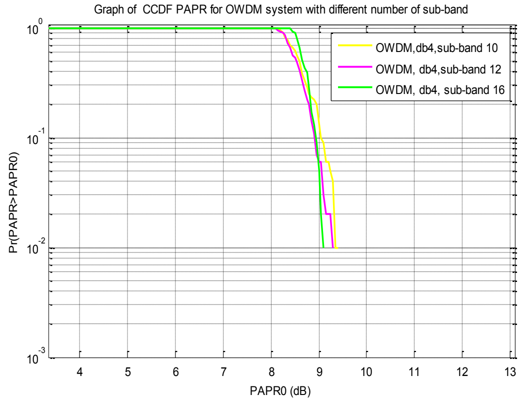

Figure. 7. Graph of PAPR CCDF of OWDM for different number of sub-band

TABLE 2. $PAPR_0$ Value where Pr (PAPR> PAPR0) = 10^{-2} For the case of different number of sub-bands

	$PAPR_0$(dB)
OWDM db4 sub-band 10	9.1
OWDM db4 sub-band 12	9.3
OWDM db4 sub-band 16	9.35

Analysis of PAPR for both systems is performed by taking the quantity value of PAPR, called Cumulative Distribution Function (CCDF). For this simulation, QPSK is used as modulation technique. While OWDM system uses the 4th order of Daubechies wavelet filter. From figure 7, it can be seen that more number of sub-bands causes higher PAPR value.

A.2 PAPR comparison of OWDM and OFDM system for OWDM case with different Daubechies wavelet order.

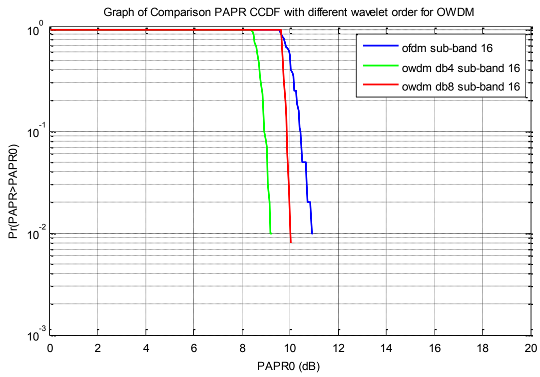

Figure.8.Graph of PAPR CCDF of OWDM and OFDM for OWDM case with different Daubechies wavelet order

TABLE 3.Value of $PAPR_0$, Pr (PAPR>PAPR0) = 10^{-2} for OWDM case with different Daubechies wavelet order.

	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 4th order (db4) and Daubechies filter 8 th order (db8) with 16 sub-band. While OFDM system use QPSK mapping and 16 sub-carrier. Figure 8 describes that OWDM system give reduction of PAPR value about ± 1.5 dB for OWDM with db4 and ± 0.8 dB for OWDM with db8.

The PAPR value of OWDM system is smaller than OFDM system. This is because the complex symbols of OFDM are widely available with a coherent phase so that the value of PAPR is also enlarged. 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 1st sub-bands to-Nth sub-band, so that when signal with phase coherence from each sub-band is summed, it does not cause high value of PAPR.

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 OWDM system, the symbols on each sub-band will be added together and produce a row of symbols of the new complex. This allows the growing number of sub-bands which means that the probability summation of coherent symbols is also getting bigger. Thus OWDM techniques can be chosen as an alternative method to overcome the problems of the high PAPR value in OFDM techniques.

V. CONCLUSION

Our result show that a greater number of sub-bands result in a higher PAPR value for OWDM and OFDM system. But The PAPR value of OWDM system is smaller than OFDM system.

Simulation of peak to average power ratio (PAPR) in OWDM and OFDM system shows that PAPR of OWDM is smaller than OFDM system about ± 1.6 dB for OWDM with db4 and ± 0.8 dB for OWDM with db8. Thus OWDM techniques can be chosen as an alternative method to overcome the problems of the high PAPR value in OFDM techniques.

OWDM system in this research uses discrete wavelet. Filtering division of each sub-band in discrete wavelet is not symmetric so that the bandwidth per sub-band is not the same. That is caused number of sub-band in OWDM system is limited. Maximal number sub-band of OWDM system in this research is 16. So for future development research , OWDM system use other wavelet filter such as wavelet packet.

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