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PERFORMANCE COMPARISON OF DFT, DCT AND DWT BASED OFDM WITH WAVELET FAMILY TO MINIMIZE PAPR

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ABSTRACT

The paper presents the analysis of peak average power ratio (PAPR) performance of wavelet based OFDM (WOFDM) using wavelet families. We study on several wavelet from different wavelet families to find out the PAPR performance. The WOFDM system using, Haar, Daubechies, Symlets, Coiflets, Biorthogonal, and discrete Meyer. WOFDM using QPSK modulation to reduce PAPR. Discrete Fourier transform (DFT) and discrete cosine transform (DCT) to compare discrete wavelet transform (DWT). These transform, that DCT with 'Haar' and 'biorthogonal' shows better improvement among the wavelet families since the PAPR achieve almost 5 dB.

Keywords: OFDM, PAPR, DCT, DFT, DWT, Wavelet family

1.INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) system has been used in today wireless communication system. This technique provide more advantages as follows; robust to multipath fading channel, greater to immunity to noise, high spectral efficiency, and eliminates the equalizer through block inverse fast fourier transform (IFFT) and fast fourier transform (FFT).

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It has been employed in many communication applications such as, IEEE 802.16 (WiMAX), IEEE 802.11 (WiFi), Digital audio broadcasting (DAB), and High performance wireless local area network (HIPERLAN) [1, 2]. In OFDM, available broad channel bandwidth is splitted into adjacent narrow band channels, and high data rate stream into several low data rate streams which are multiplexed to the orthogonal subcarriers and transmitted simultaneously [3]. Sub carriers are generated by conventional FFT algorithm, inter symbol interference can be reduced by using cyclic prefix which use 25 % of bandwidth [4]. The high peak-to-average power ratio (PAPR) commonly happen in OFDM implementation, which hurdle in implementation of analog to digital converter (ADC) and digital to analog converter (DAC). It also needs the linear power amplifier which has less power efficiency near saturation limits because PAPR of OFDM is proportional to the number of subcarriers used in OFDM systems. Time and frequency synchronization between transmitter and receiver are important to obtain the accurate detection of the signal at the receiver and set up quality link [5-6]. Due to this problem, one of the techniques to reduce PAPR is wavelet based OFDM transform. In [2] WOFDM has more advantages than FFT OFDM to reduce PAPR. Wavelet provides promising potential application in wireless communication. Due to orthonormal filter in wavelet based OFDM, so the orthogonality is achieved. Wavelet transform has large power spectral density and produced the well contained side lobes with narrow side lobes. The inter carrier interference (ICI) and inter symbol interference (ISI) are balanced due to loss of orthogonality. No cyclic prefix insertion is needed due to overlapping property saves bandwidth 25 % and hence these systems shows better PAPR performance compared to the FFT. Wavelet transform gives the information of signal in time and frequency simultaneously [7] . In this paper we describe some relevant PAPR reduction technique of the literature. Therefore, the paper is organized as follows, section 2 briefly shows the OFDM and Wavelet system model. In section 3 the methodology is presented. The analysis and simulation using matrices laboratory (MATLAB) of the bring different wavelet families are addressed in section 4, finally conclusion are drawn in section 5.

2. SYSTEM MODEL [5]

A wavelet is mathematical function used to divide a given function or continuous-time signal into different scale components. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies (known as “daughter wavelets”) of a finite length or fast decaying oscillation waveform (known as “mother wavelets”). There are classified into discrete wavelet transform (DWT) and continuous wavelet transform (CWT). Several wavelet families have been proposed over these reacent years to perform the DWT analysis, such as; Haar, daubechies, discrete mayer, coiflet, symlets, and biorthogonal. Daubechies derives a family of wavelets, the first of which is the Haar wavelet. The Daubechies wavelets, based on the work of Ingrid Daubechies, are a family of orthogonal wavelets. The Meyer wavelet is an orthogonal wavelet proposed by Yves Meyer. As a type of a continuous wavelet, it has been applied in a number of cases, such as in adaptive filters, fractal random fields, and multi-fault classification. Coiflets are discrete wavelets designed by Ingrid Daubechies, at the request of Ronald Coifman, to have scaling functions with vanishing moments. There are having rather different mathematical properties ; both wavelets with compact support (orthogonal wavelets such as Daubechies or Coiflet, and biorthogonal wavelets) and infinite-supported wavelets (Gaussian, Mexican Hat, Morlet, Meyer, etc.) have led to satisfactory empirical results [9].

A. Fourier- based OFDM

A typical block diagram of an fourier based OFDM is shown in Figure 1. The QPSK modulation scheme is used to mapping data input digital with *N* sub carriers which are implemented using the IFFT block at the transmitter. After mapping of data, a serial to parallel converter (S/P) is used to convert the data into parallel form which show each parallel data stream into a sub carrier. IFFT block is used for modulation of low data rate signal, and output is time domain signal which is sum of information signal. After applying IFFT at the transmitter, the cyclic prefix is added in the symbol to eliminate ISI and ICI.]. Equation 1 shows the mathematical representation of IFFT, discrete Time OFDM signal can be written [3].

$$X_n = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_k e^{\frac{j2\pi kn}{NL}}, 0 \leq n \leq NL-1 \qquad (1)$$

Where $Xn(n) \mid 0 \leq n \leq NL-1$, is a sequence in the discrete time domain and $X_k(i) \mid 0 \leq i \leq NL-1$ are complex numbers in the discrete frequency domain. X_n is the symbol carried by the k_{th} sub-carrier , L is the over sampling factor. An OFDM signal consist of “*N*” number of independently modulated subcarriers, which can give a very large PAPR when added up coherently. The cyclic prefix (CP) is lastly added before transmission to minimize the inter-symbol interference (ISI). At the receiver, the process is reversed to obtain the decoded data. The CP is removed to obtain the data in the discrete time domain and then processed to FFT for data recovery[8]. At the receiver, the reverse process is adopted using FFT. The data is parallel converted and remove cyclic prefix. Equation 2 shows the mathematical representation of DFT.

$$X_k = \sum_{n=0}^{N-1} X_n e^{-\frac{j\pi kn}{NL}} \quad (2)$$

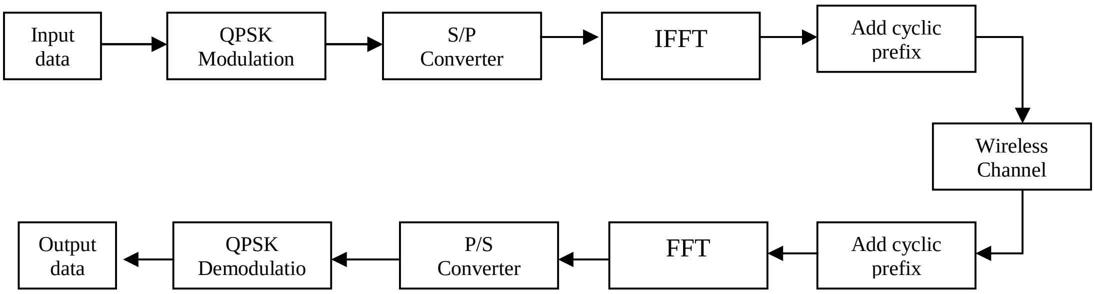


Fig.1. Diagram block conventional OFDM transceiver

B. Wavelet based OFDM

In proposed method as shown in fig 2. It can be seen that IFFT and FFT blocks of conventional OFDM are replaced by IDWT and DWT blocks. The main advantage is removing the cyclic prefix which increases bandwidth and spectral efficiency. The simulation, additive white Gaussian channel (AWGN) is used for channel model. For analysis of digital signal, it use discrete wavelet transform (DWT). DWT decomposes the feeding signal into approximation and detailed coefficients. There are two important step, interleaving and modulation. This step is done after performing conventional encoding step. After modulation, two steps are performed, firstly insertion of pilot symbol is done and secondly the sub carrier mapping. After performing two steps the IDWT process performed by which orthogonality is preserved. The signal is converted from time domain to frequency domain, before passing through the channel. In the receiver, the signal is processed by DWT than removal of pilot insertion, and finally demodulation is done. The transmitted data is decoded at the receiver end [10].

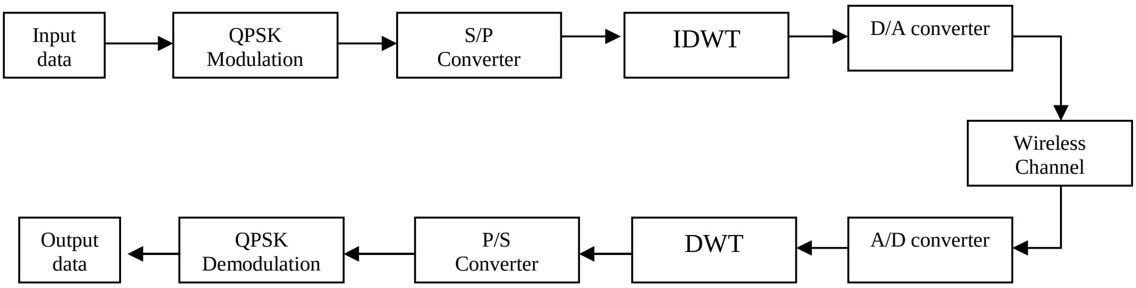


Fig.2. Block Diagram of Wavelet OFDM

In DWT scaling is done by using up sampling and down sampling. The signal is passed through series of high pass and low pass filter to analyze high and low frequency, respectively. The discrete signal is passed through half band digital low pass filter having impulse response *h(n)*, and filtering to the mathematical operation of convolution of signal with filter impulse response. Equation 3, shows the convolution operation in discrete time [10].

$$x(n) * h(n) = \sum_{k=-\infty}^{\infty} x(k).h(n-k) \quad (3)$$

$$x(n) * g(n) = \sum_{k=-\infty}^{\infty} x(k).g(n-k) \quad (4)$$

Where *x(n)* is the original signal that decomposed through a half and low pass filter *h(n)* and high pass filter *g(n)*. The choice of wavelet is dictated by the signal or image characteristic and the nature of application. This choice can be optimized your application. The wavelet families have several important properties, such as; support of the wavelet in time and frequency and rate of decay, symmetry or anti-symmetry of the wavelet, the accompanying perfect reconstruction filters have linear phase, wavelets with increasing numbers of vanishing moments result in sparse representations for a large class of signals and images, regularity of the wavelet, smoother wavelets provide sharper frequency resolution. Additionally, iterative algorithms for wavelet construction converge faster, and existence of a scaling function, φ [2].

C. PAPR in OFDM System

We assume, after IDWT block at transmitter, $x(t)$ is continuous orthogonal signal. PAPR is the ratio between the maximum power and the average power of the complex pass-band signal of $\tilde{x}(t)$ [2] :

$$PAPR\{\tilde{x}(t)\} = \frac{P_{peak}}{P_{average}} = \frac{max\left|Re\left(\tilde{x}(t)e^{j2\pi f_c t}\right)\right|^2}{E\left\{\left|Re\left(\tilde{x}(t)e^{j2\pi f_c t}\right)\right|^2\right\}} = \frac{max|\tilde{x}(t)|^2}{E\{|\tilde{x}(t)|^2\}} \quad (5)$$

where P_{PEAK} represents peak output power, $P_{AVERAGE}$ means average output power. E[·] denotes the expectation operation.

It is easier to analyze the PAPR using of complementary cumulative distributive function (CCDF). The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold . The CCDF expression of the PAPR of OFDM signals with relatively small subcarriers N can be written as [2, 11]:

$$CCDF = P(PAPR > PAPR_o) = 1 - (1 - \exp(PAPR_o))^N \quad (6)$$

3. METHODOLOGY

The methodology applied in this paper can be shown in flow chart Fig.3.

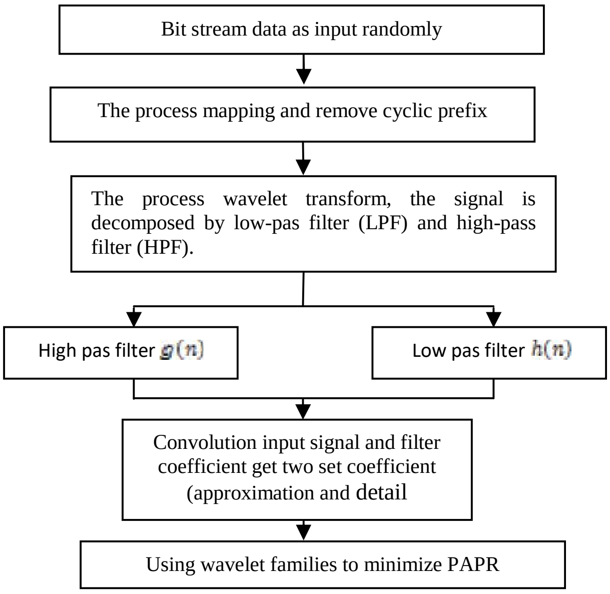


Fig. 3. The flow chart Wavelet based OFDM

The original signal x(n) has 128 sample points. At the first the decomposition level, the signal is passed through the high-pass and low-pass filter, followed by sub sampling by 2. The output of the high-pass filter has 64 points (hence half the time resolution). These 64 samples constitute the first level of DWT coefficient. The output of the low-past filter also has 64 samples, frequency from $0\ to\ \frac{\pi}{2}\ rad/s$. This signal is then passed through the same low-pass and high-pass filters for further decomposition. The output of the second low-pass filter followed by sub-sampling has 32 samples spanning a frequency band of $0\ to\ \frac{\pi}{4}\ rad/s$, and the output of the second high-pass filter followed by sub-sampling has 32 samples spanning a frequency band of $\frac{\pi}{4}\ to\ \frac{\pi}{2}\ rad/s$. The second high-pass filter signal constitutes the second level of DWT coefficient.

4. SIMULATION AND RESULT

Theoretically, Wavelet Transform promises an improved performance in comparison with the FFT and cosine transform. The MATLAB simulations were done to achieve this goal. Firstly, the conventional FFT-based OFDM block diagram is designed using 128 subcarriers, the cyclic prefix is 32. The Discrete Fourier Transform (DFT) is replaced by the DWT, as the Wavelet family Haar, Deubachies, Symlets, Coiflet, Discrete Meyer, and Biorthogonal are used. The input data stream is modulated with the Quadrature phase shift keying (QPSK). The channel is assumed as Additive White Gaussian Noise (AWGN) channel. The PAPR using of complementary cumulative distributive function (CCDF). Table 1, shows the parameter that used to PAPR simulation, and Table 2, shows the various wavelet characteristic.

Table 1. Simulation Parameter for PAPR reduction technique

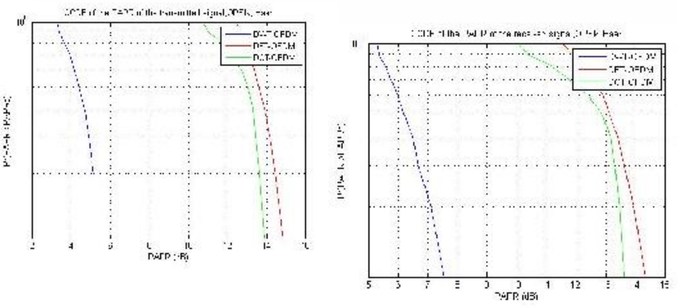
Parameter	Value
Modulation	QPSK
Number of subcarriers	128
Message size	10
Cyclic Prefix	32
Channel model	AWGN

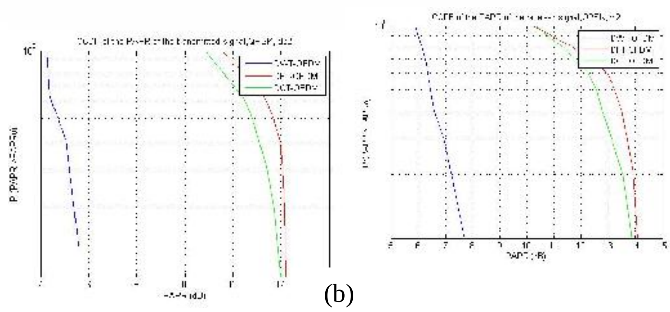
Table 2. Wavelet Characteristic Summary

Full Name	**Abbreviated Name**	**Vanishing Order**	**Selected Order**
Haar	haar	1	1
Deubachies	*dBN*	N	2,4
Symlet	*symN*	N	2,3,10
Coiflet	*coifN*	N	1,3
Discrete Meyer	*dmay*	-	-
Biorthogonal	*biorN*	N	1.1,2.4

The basic idea is that a wavelet has p vanishing moments or vanishing order (see Table 2) if and only if the wavelet scaling function can generate polynomials up to degree $p-1$. The "vanishing" part means that the wavelet coefficients are zero for polynomials of degree at most $p-1$, that is, the scaling function alone can be used to represent such functions. More vanishing moments means that the scaling function can represent more complex functions. Each wavelet has a number of *zero moments* or *vanishing order* equal to half the number of coefficients (in selected order). The index number refers to the number *N* of coefficients [12]. The simulation using matlab program and comparing between discrete fourier transform (DFT), discrete cosine transform (DCT) and discrete wavelet transform (DWT). Figure 4,5,6, and 7 show wavelet transform at different wavelet families (Haar, Deubachies, Symlets, Coiflets, Discrete Meyer, and Biorthogonal) . Fig. 4 shows the performance comparison between DFT, DCT and DWT OFDM system, with Deubachies family. In the transmitter and receiver, Haar wavelet is better than Deubachies family other and Biorthogonal, that reduce 6 dB until 8 dB PAPR compare DFT (around 13 dB). The PAPR value reached 5 dB in the transmitter and 7 dB in the receiver because the Haar wavelet is the only orthogonal wavelet with linear phase. Biorthogonal using two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one.

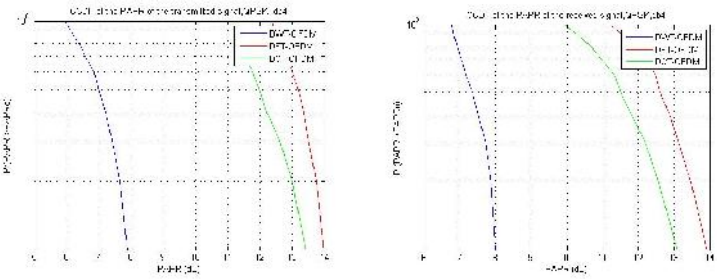
Fig 5 and 6,shows the comparison between various wavelet (symlet, coiflet, and discrete meyer) and DFT and DCT, these wavelet family almost have the same value around 7 dB until 8 dB. Biorthogonal (bior 1,1) wavelet, in Fig 7, has almost 5 dB PAPR, this can reduce PAPR 8 dB compare DFT. Tabel 3 and 4, shows PAPR result to compare various wavelet with DFT and DCT. We can clearly observe that the DWT based system outperforms the FFT and reduces a “8 dB” performance.





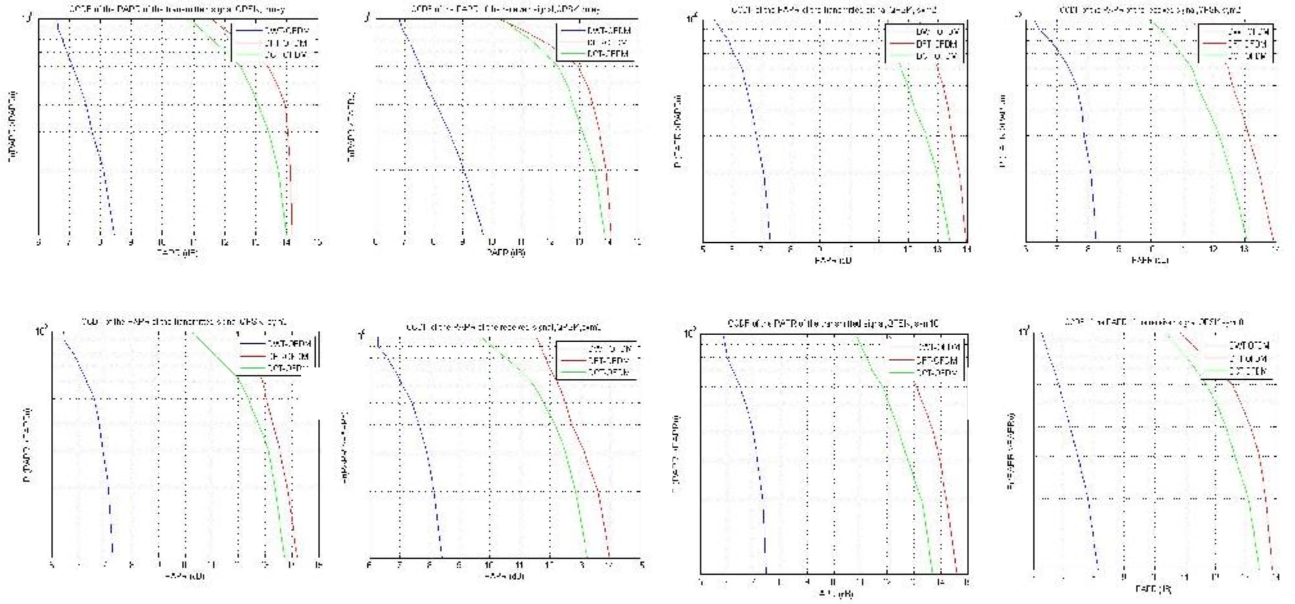
(b)

(a)



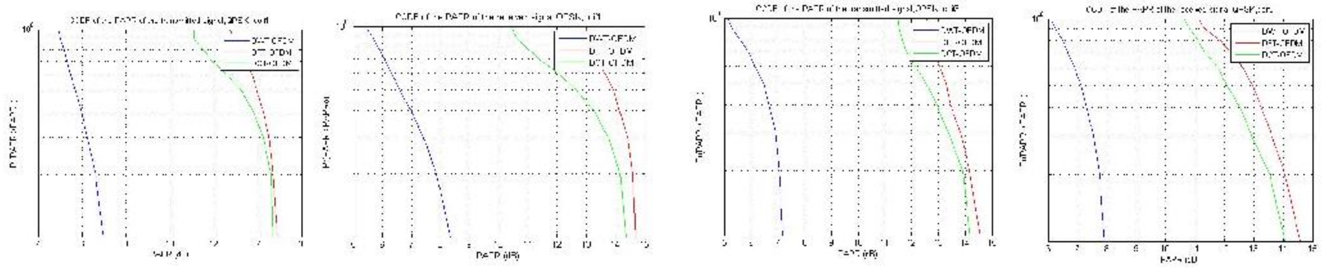
(c)

Fig.4. Performance of PAPR , DWT,DFT, and DCT based ofdm transceiver in QPSK modulation and various wavelet (a) Haar (db1), (b) db2, (c) db4



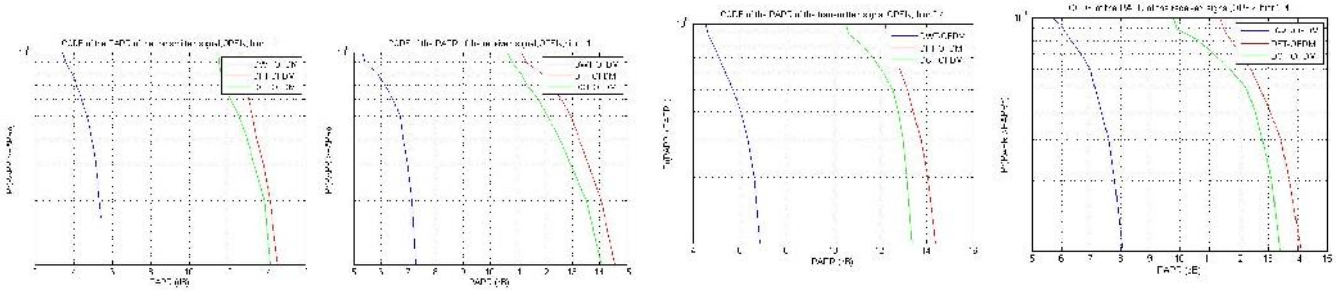
(c) (d)

Fig.5. Performance of PAPR , DWT,DFT, and DCT based ofdm transceiver in QPSK modulation and various wavelet (a) dmey, (b) sym2, (c) sym3, (d) sym10



(a) (b)

Fig.6. Performance of PAPR , DWT,DFT, and DCT based ofdm transceiver in QPSK modulation and various wavelet (a) coif1 and (b) coif2



(a) (b)

Fig.7. Performance of PAPR , DWT,DFT, and DCT based ofdm transceiver in QPSK modulation and various wavelet (a) bior1.1 and (b) bior2.4

Table 3. PAPR Transmit signal (dB), QPSK modulation

	Haar	Db2	Db4	Dmey	Sym2	Sym3	Sym10	Coif1	Coif3	Bior1.1	Bior2.4
DWT	5.68	7.12	7.10	7.99	6.46	6.98	7.32	7.54	7.04	5.06	6.39
DFT	13.75	13.83	13.91	14.23	14.61	14.17	14.73	13.76	14.42	14.31	14.65
DCT	12.99	13.37	13.02	13.32	14.61	13.90	13.84	13.30	14.07	13.53	13.85

Table 4. PAPR Receive signal (dB), QPSK modulation

	Haar	Db2	Db4	Dmey	Sym2	Sym3	Sym10	Coif1	Coif3	Bior1.1	Bior2.4
DWT	7.08	8.08	7.62	8.26	7.71	7.78	7.64	8.15	8.02	7.19	7.94
DFT	14.25	14.01	13,28	13.66	14.6	14.06	14.52	13.66	14.18	13.88	14.00
DCT	14.15	13.25	12.88	13.08	14.15	13.54	13.60	12.93	13.69	12.99	12.92

4. CONCLUSION

In this paper, the PAPR performance is investigated and analyzed for the OFDM. The simulation results show that wavelet based OFDM has better performance PAPR than traditional DFT and DCT OFDM. The PAPR can be reduce by using wavelet, the unique thing in the usage of wavelet based OFDM does not the cyclic prefix, so decreases usable bandwidth and when bandwidth decreases simultaneously spectral efficiency decreases. The haar wavelet is discontinuous, resembles a step function and represents the same wavelet as Daubechies db1. It is memory efficient, fast and exactly reversible without the edge effect. Haar and biorthogonal are exhibits the property of linear phase. Haar and biorthogonal wavelet have better PAPR performance compare other wavelet families.

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