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Discrete Wavelet Transform with Discrete Cosine Transform (DCT) For Peak-To-Average Power Ratio (PAPR) Reduction In OFDM System

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) has been widely used in high data rate wireless communications systems. High transmission bit rate, high spectral efficiency and robustness to frequency fading channels is the benefit for the application of OFDM. . However, high Peak-to-Average Power Ratio (PAPR) value is still the agenda which being looked into by a lots of researchers who are specialize in OFDM. This is because high value of PAPR restrict the achievement of signal transmission. Several techniques has been proposed to reduce PAPR. This paper discusses the improved method of Discrete Wavelet Transform to bring down PAPR values of OFDM system. This proposed methods able to provide better performance in PAPR reduction. The proposed method of DCT precoded Wavelet with the 1024 numbers of subcarriers improves the greatest performance by 17.268%.

Key words: DCT, IDCT, DWT, OFDM, PAPR

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) helps in separating frequency selective fading channel into a number of orthogonal channels. In terms of parallel stream, transmission of high bit rate data is undergone over several lower data rate subcarriers. Instead of using single wide-band carrier, multiple narrow band subcarriers is applied to ensure that more data can be transmitted more than one path. In this instance, ISI will occur due to long symbol duration [1]. Cyclic prefix is applied for eliminating the effect of ISI. In addition, OFDM will unintentionally causes unparalleled bandwidth density, which brings to high spectral efficiency [2].

Wireless Local Area Network (WLAN), Wireless Personal Area Network (WPAN) and Digital Audio Broadcasting (DAB) are the examples of network policy which applied OFDM modulation. OFDM has its own advantages and disadvantages same goes to OFDM system. High peak–to-average power ratio (PAPR) is the agenda which are usually investigated by most researcher who are major in field of digital signal processing. PAPR increases the complexity of design implementation and decreases the linearity of the system.

Compared to other technique, wavelet techniques requires a lot of energy and power consumption during the decomposition process. Thus, discrete cosine transform is implemented here to decrease the consumption power by implementing autocorrelation to induce the improvement on wavelet technique. In this study, DCT is introduced to further enhance the wavelet technique in peak power reduction agenda. A hypothesis is made that further reduce the peak power signal after the decomposition process of wavelet technique by using DCT could give better result.

2. PAST RESEARCH

PAPR in OFDM system creates a lot of problems and causes deficiency to devices and facilities and creates unfriendly user problem as well. The over-exceeding value in the time interval of the signal transmitted due to the high amount of subcarriers present in OFDM leads to overwhelming limit of preferable values for Peak Power to Average Power Ratio (PAPR). A multicarrier signal is the addition of whole set value consists of narrow band signals in a time domain [3]. When the value set of multicarrier signals changes occasionally, the larger peak value of the modulated data will be expected compared to the other data. This is where PAPR being introduced. Thus, this will leads to implementation of High Power Amplifier (HPA) to subjugate PAPR but HPA is costly and high power consumption as well [4].

FFT based OFDM and WTOFDM (wavelet transform Orthogonal Frequency Division Multiplexing) is studied by Chandra et al. [5]. It is found that the wavelet OFDM has a larger gradient of graphs compared to FFT based OFDM. This shows that wavelet based OFDM shows lower bit error rates than FFT based OFDM [5]

Jamalludin et al. [6] investigated on BER performance in the influence of different wavelet level in Daubechies Families WTOFDM does not require cyclic prefix to enhance the bandwidth efficiency due to the overlapping nature of wavelet transform which maintains the orthogonality of the output signal [6]. Wavelet OFDM also outperform the FFT OFDM by showing the lowest power of 8.5dB among the 6 variables which are Haar, dB3, dB5, dB10 and dB20. The difference between the Haar OFDM and FFT OFDM is 2 dB in terms of power.

Several hybrid methods with DCT will be discussed here. DCT has been implemented in several ways. DCT could be applied before or after the implementation of main algorithm or main methods or DCT could be applied to replaced Fast Fourier transform (FFT) due to its simplified nature which focus only on Cosine Summation Signal.

Sroy Abouty et al. [7] proposed a DCT with Clipping and Filtering for PAPR reduction method. There is comparison between both of the precoded combined techniques which are first, DCT is used before FFT and second, DCT is used after Clipping and Filtering. Based on simulation results, the second scheme, which is DCT is used after Clipping and Filtering have more better performance of PAPR reduction than the first scheme, which is DCT is used after FFT/IFFT [7]. Besides that, Sroy Abouty et al. also found that larger the number of iteration for clipping and filtering method, the better PAPR performance [7]

Suma et al. [8] proposed Analytic Discrete Cosine harmonic wavelet transform (ADCHWT). The BER Performance between ADCHWT-OFDM, Haar WT-OFDM and DFTOFDM was carried out. The Eb/No of ADCHWT is lesser than Haar and DFT at 15dB which shows that the BER of ADCHWT excels other two techniques [8].

3. METHODOLOGY

PAPR is known as the ratio between the peak power and the average power of OFDM signal, x_n^v [9, 10]. PAPR equation can be shown as:

$$PAPR = \frac{max|x_n^v|^2}{E|x_n^v|^2} \quad (1)$$

Where E is expectation.

CCDF graph illustrates the period of signal applied within the designated power level. The CDF is not applied here, instead complimentary CDF was applied to counter the probability of PAPR of numerous data block exceeds threshold limit [11].

In the progress for alleviating the PAPR values, DCT is also being proposed by researcher to minimize the autocorrelation in conjunction with the implementation of IFFT command. The transform helps in further doubling the single data point sequence to double sequence by applying duplication of the N-point data sequence. Since the both end of data is always bonding to each other's, the factors with lower order will be replaced by the domain signal [12].

Discrete wavelet transform undergoes decomposition by separating signal into approximation coefficients and detailed coefficients. The information gathered follows different basis functions of low-pass and high-pass transformation [13]. Decomposition is undergone by the bit stream being degraded into a half-band low-pass /high-pass filter. Wavelet functions and the scaling functions have identical energy [14]. The low-pass filter eliminates all signals above half-band frequencies while high-pass filter filters all data streams below the half-band frequencies with the same scale. The low pass filter divides the resolution into two while leaving the constant scale.

In wavelet analysis, IFFT and FFT blocks are substituted by IDWT and DWT blocks respectively to avoid insertion of a cyclic prefix which improves the spectral efficiency [15].

Figure 1 shows the implementation flow chart for the proposed method.

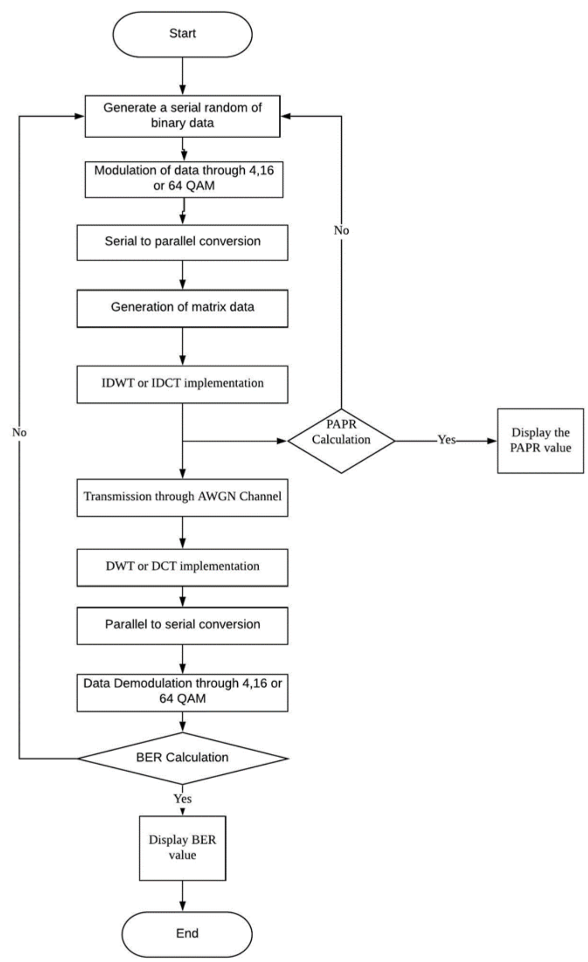

Figure 1: The implementation flow chart for DCT precoded wavelet technique

Steps for the program procedure are as follows:

Assume a set of N data subcarriers, where N as the number of subcarriers represented as a vector Y = {Y_0, Y_1, Y_2, Y_{N-1}}. Each symbol in the vector Y modulates one set of subcarriers. Let f_m, m=0, 1, 2… N-1, the subcarriers from the proposed method must be orthogonal to each other. For instance, $f_m = m\Delta f$, where $\Delta f = 1/NT$ and T is the duration of symbol in vector Y. Hence the transmitter complex OFDM signal can be stated as:

$$X(t) = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} Y_m e^{j2\pi m\Delta f}, \ 0 \le t \le NT \qquad (2)$$

Where $j = \sqrt{-1}$, Δf the subcarrier spacing, and NT is denotes the period of useful data set.

The IDWT block processes the signal data with the IDWT equation as follows [37]:

$$x(k) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} X_m^n \ 2^{\frac{m}{2}} \psi(2_k^m - n) \qquad (3)$$

Where k represents the number of subcarriers ($0 \le k \le N - 1$), D_m^n are the wavelet coefficients, representing the signal in both scale and position of time-axis and $\psi(t)$ is the wavelet function, it will have a compressed factor m times and shifted n times for each subcarrier.

After the decomposition process, IDCT is equation is applied here as follows:

$$X(t) = \sqrt{\frac{2}{N_s} \sum_{n=0}^{Ns-1} d_n \beta_n \cos\left(\frac{n\pi t}{T_s}\right)} \qquad (4)$$

Where d_0, d_1……d_{Ns-1} are Ns independent data symbols obtained from a modulation constellation

$$\beta_n = \begin{cases} \frac{1}{\sqrt{2}}, n = 0 \\ 1, n = 1,2, \ldots \ldots Ns - 1 \end{cases} \qquad (5)$$

The output of Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) and this is the process where the receiver side is exactly reverse. Which is given by

$$X_m^n = \sum_{k=0}^{N-1} x(k) DCT \ 2^{\frac{m}{2}} \psi(2_k^m - n) \qquad (6)$$

For PAPR calculation, the combined IDWT and IDCT method of time-domain transformation gives the data signal of OFDM

$$x_{papr}(t) = X\{IDWT(IDCT(t)\} \qquad (7)$$

$$x_{IDWT}(t) = \sum_n \sum_{j=J}^{J-1} \sum_{k=0}^{2^j-1} w_{j,k} \psi_{j,k}(t - nT) + \sum_n \sum_{k=0}^{2^{J_0}-1} \alpha_{J_o,k} \phi_{J_o,k}(t - nT \qquad (8)$$

(x_{papr}) and is given by

Where $w_{j,k}$= wavelet coefficients located at k-th position from scale j, $\alpha_{J_o,k}$ approximation coefficients located at k-th position from the first scale J, $\psi_{j,k}$ and $\phi_{J_o,k}$ are the wavelet and scaling functions.

PAPR is equalized as:

$$PAPR = \frac{max_k |x_{papr}{}^2|}{\sum_{k=1} |x_{papr}|^2} \qquad (9)$$

In order to investigate the improvement of PAPR reduction, CCDF of PAPR is formulated as:

$$CCDF\left(PAPR(x_{papr})\right) = \Pr(PAPR(x_{papr}) > PAPR^0 \qquad (10)$$

Which represent the probability that the PAPR symbols tops the threshold $PAPR^0$.

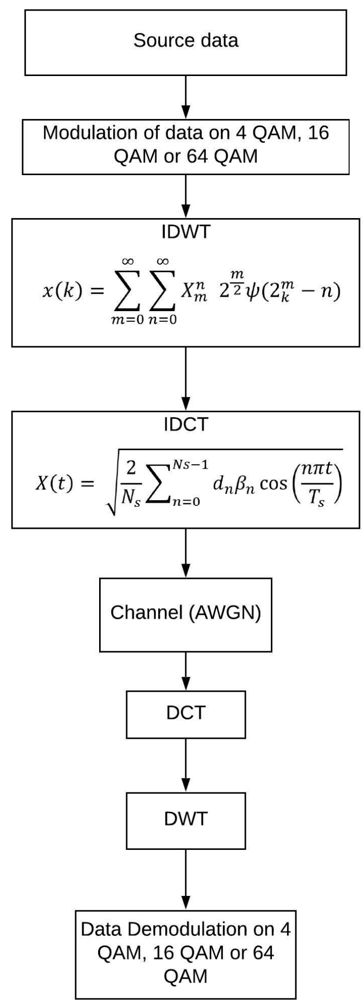

Figure 2: Block Diagram for DCT precoded Wavelet

4. RESULT AND DISCUSSION

In this section, comparison in term of PAPR reduction performance between DCT precoded wavelet and clipping and filtering with DCT will be carried out on number of subcarriers

N= 64, 256, 1024 with 64 QAM scheme. The PAPR CCDF was taken for 10-3 transmitted frames. The CCDF of comparison simulation is simulated and displayed in the graph for 64 respectively at Figure 3. The remaining CCDF graph with 256 and 1024 number of subcarriers are shown in Appendix with the name of Figure 4, and Figure 5 respectively.

Table 1: PAPR value of CF-DCTand DCT precoded wavelet for 64QAM N = 64,256and 1024 for 64-QAM

Number of Subcarrier s	CF-DCT	DCT Precoded wavelet	Improvement DCT Precoded wavelet
64	10.807	8.889	1.918(17.748)
256	12.009	9.867	2.142(17.837)
1024	13.362	10.921	2.441(18.268)

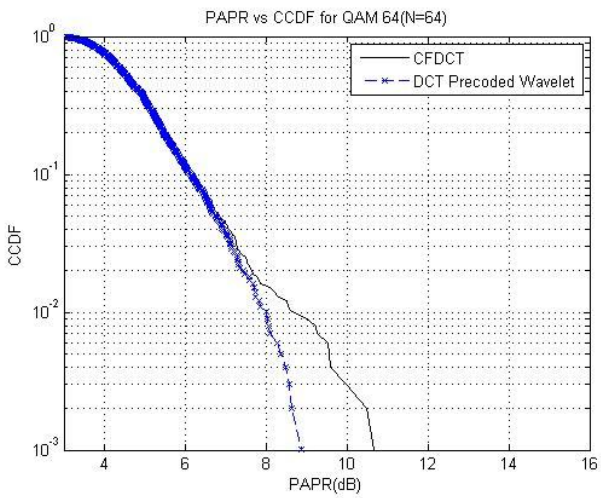

Figure 3: CCDF vs PAPR on N=64

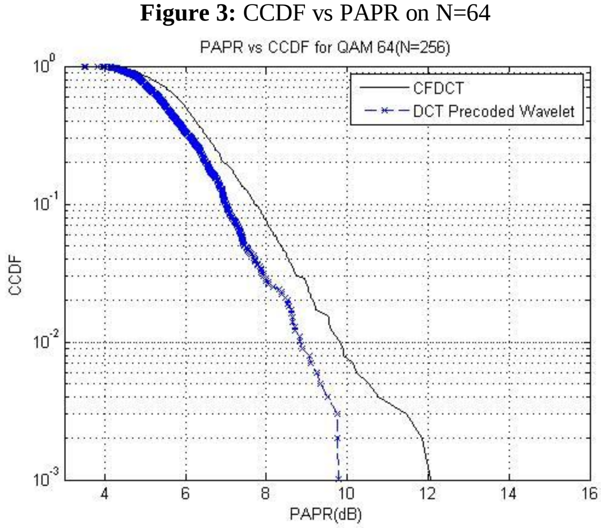

Figure 4: CCDF vs PAPR on N=256

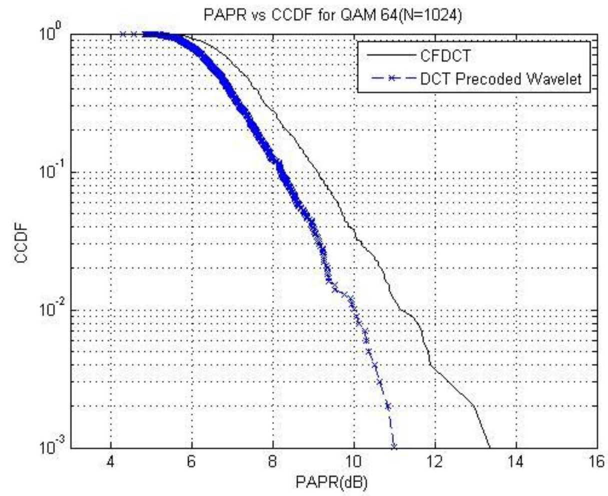

Figure 5: CCDF vs PAPR on N=1024

From table 1, the proposed method gives lower PAPR values compared to Clipping Filtering with DCT which indeed shows the significant improvement of PAPR reduction for both proposed method of discrete wavelet transform with DCT. For all subcarriers, DCT precoded wavelet perform better than Clipping and Filtering with DCT in term of PAPR reduction. For N=1024, the improvement of PAPR reduction is achieved by 18.268% by implementation of DCT precoded wavelet compared to Clipping and Filtering with DCT.

5. CONCLUSION

The proposed DCT precoded wavelet method is implemented to reduce PAPR based on the number of subcarriers being compared shown. This improved technique is used due to DCT helps in reducing the amplitude values of the transmitted signal. Therefore, the more the subcarriers involved, the better the improvement of PAPR decreasing. Number of subcarriers of 1024 shows the greatest reduction improvement of PAPR by 18.268%. Throughout the research, the proposed improved DCT precoded wavelet can lower the PAPR value compared to Clipping and Filtering with DCT.

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