

Modified PAPR Reduction Scheme by Integrating DCT and WPT with Partial Transmit Sequence

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is one of the multicarrier modulation methodology efficiently used for transmission of high data rate in communication system. OFDM consists of number of independent sub carrier, where the peak value of amplitude is high, which is a cause for high Peak to Average Power Ratio (PAPR). Hence unique techniques are proposed for PAPR reduction. Here we have proposed an innovative method by integrating the modified Partial Transmit Sequence (PTS), Discrete Cosine Transformation (DCT) and Wavelet Packet Transform (WPT) in a single system. The simulation results of the proposed system shows significant reduction in the PAPR performance than the ordinary PTS technique. Using our proposed method we have attained noticeable reduction in PAPR without causing imbalance in BER performance of the signal.

Keywords: DCT, FFT, OFDM, PTS, WPT

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a well organized multicarrier modulation data transmission technique used everywhere in new generation wireless communication systems. OFDM technique separates the communication channel into many equally spaced frequency bands. In each band the user information is transmitted using a subcarrier. Each sub carrier is independent of other i.e., orthogonal to each other. The high data rate bit stream information is divided in to several simultaneously low data rate sub streams and they are used to perform modulation by number of orthogonal frequency subcarriers by different transformation methods like DFT, FFT, DCT, DWT, WPT and others. Figure 1 depicts the spectrum of OFDM. It has distinguished spectral efficiency, non susceptible to the frequency selective fading channel; multipath delay spread indulgence and power efficiency. Due to these advantages OFDM is

already implemented in international standards such as IEEE 802.11, IEEE 802.16, IEEE 802.20, Digital Video Broadcasting (DVB), and Digital Audio Broadcasting (DAB) and suggested by European Telecommunications Standards Institute (ETSI) and Broadcast Radio Access Network (BRAN) committees¹.

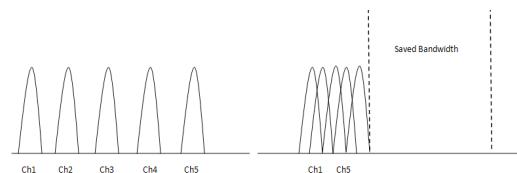


Figure 1. OFDM spectrum.

However, still the unresolved challenging issues are present in OFDM. One of the main disadvantages is high Peak-to Average Power Ratio (PAPR) of transmitted signal. For which it requires an expensive High Power Amplifier (HPA) operating over a wide linear range. A

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high PAPR also increases the complexity of ADC and DAC in turn reduces the performance of power amplifier. This severely reduces the efficiency of the system due to detection efficiency degradation and induced spectral re-growth. For example, HPA is employed in transmitter to obtain sufficient power and to have maximum power efficiency. Due to high PAPR a nonlinear distortion is introduced into channel. The HPA should operate in linear region if not it is difficult to keep the transmitted power in the specified limit, which leads to unproductive amplification and transmission becomes unaffordable. Therefore it is vital to have a research on PAPR reduction in OFDM system, focusing in improving the performance of OFDM wireless communication.

The PAPR has a random probability distribution which can be manifest in terms of Complementary Cumulative Distribution Function (CCDF). Number of methodologies have been proposed to minimize PAPR which includes amplitude clipping, coding schemes, Clipping and filtering, tone injection, tone reservation, phase optimization, nonlinear companding, selective mapping, partial transmit sequence, Iterative flipping algorithm etc²⁻¹⁶. The PAPR reduction techniques can be categorised into two broad ways signal scrambling techniques like PTS, block code etc., and signal distortion technique viz clipping.

Several theoretical analysis and simulation results are been done and compared with some distinctive techniques of PAPR reduction to get a exhaustive review which includes some stimulus to reduce PAPR, such as power saving, complexity reduction, less area consumption. Several methods are trading off between extent of PAPR reduction and power transmitted is given for effective PAPR reduction, loss of data rate, hardware realization and Bit-Error-Ratio (BER) etc.

This paper is summarized as follows. Section 2 gives an OFDM signal characteristics Section 3 presents the overview of OFDM systems and PAPR. The proposed method is discussed in section 4. Section 5 gives simulation results and conclusion of the work

2. OFDM Signal Characteristics

Let us assume a set of N data sub carriers, where N is 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 d-set of subcarriers. Let f_m , $m = 0, 1, 2, \dots, N-1$, the subcarriers in OFDM system should be orthogonal to each

other i.e., $f_m = m\Delta f$, where $\Delta f = 1/NT$ and T is duration of symbol in vector Y. Hence the transmitted envelope of complex OFDM signal is written as

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

Where $j = \sqrt{-1}$, Δf is the subcarrier spacing, and NT denotes the period of useful data set. PAPR is described as the ratio of high instantaneous power to its mean power during a period of OFDM symbol.

The Peak Average Power Ratio of OFDM symbol can be denoted as

$$\text{PAPR} = \frac{\max_{0 \leq t \leq NT} [|Y(t)|^2]}{1/NT \int_0^{NT} |Y(t)|^2 dt} \quad (2)$$

Where $x(t) \rightarrow$ input signal.

The idea behind PAPR reduction is to minimize the $\max x(t)$. Since majority of the system involves discrete-time signals, dealt is sampled amplitude in many peak average power reduction methods. If some time the signal peak missies, symbol spaced sampling shown in (1) produces an optimistic decision for the PAPR. With a factor of L on oversampling (1) signal samples are obtained which come close to the true PAPR. The time domain L-times oversampled samples are derived by an LN-point Inverse Fast Fourier Transform (IFFT) of the given data block considering zero-padding.

The behavior of the PAPR is measured using cumulative distribution function of OFDM signal. The Cumulative Distribution Function (CDF) is repeatedly used procedure to evaluate the efficiency of PAPR reduction technique used¹⁷⁻¹⁹. The CDF of a signal is written as

$$F(z) = 1 - \exp(-z) \quad (3)$$

However, instead of CDF the Complementary CDF (CCDF) is used to assess the possibility of PAPR occurrence. The CCDF is given by

$$\begin{aligned} P(\text{PAPR} > z) &= 1 - P(\text{PAPR} \leq z) \\ &= 1 - (F(z))^N \\ &= 1 - (1 - \exp(-z))^N \end{aligned} \quad (4)$$

3. Partial Transmit Sequence (PTS)

In Orthogonal FDM the powerful probabilistic based peak to average power minimization technique is PTS.

The sketch of PTS is depicted in Figure 2. In this scheme the indigenous data X is split into N non-overlapping sub blocks. In every sub-block the sub carriers are weighted by a phase factor. The selection of phase factors make sure that the PAPR is minimized.

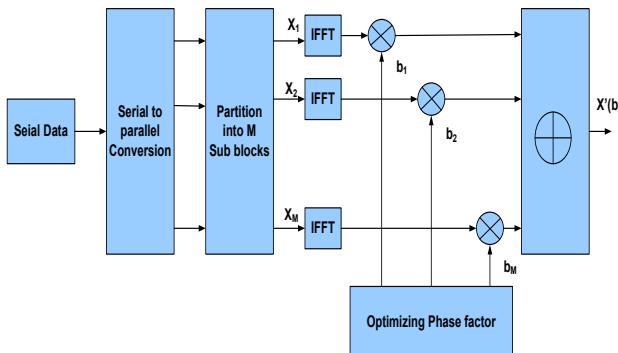


Figure 2. PTS scheme.

The divided input data X is denoted as

$$\mathbf{X}^{(m)} = [X_0^{(m)}, X_1^{(m)}, X_2^{(m)}, \dots, X_{N-1}^{(m)}] \quad (5)$$

$$m = 1, 2, \dots, M$$

The summation of each sub blocks gets the original signal, which is given by

$$X = \sum_{m=1}^M X^{(m)} \quad (6)$$

The stages of PTS algorithm is narrated below.

- The OFDM sub carrier is divided into M sub blocks which are not overlapped.
- For individual sub block the OFDM signal is generated by taking IFFT.
- The OFDM signal combined with weighted phase factor b_i .
- By using optimization algorithm the phase factors are generated.
- To retrieve the data at the receiver, receiver should know the generation scheme.

4. Discrete Cosine Transform (DCT)

The DCT is widely handed-down in image processing and communication systems. Like other transformations the DCT is used to minimize the autocorrelation of the input signal which reduces the PAPR. Transmission of

side information is not required. The DCT in proposed work supports the functionality of de-correlation, energy compaction and reparability. The 2D algorithm is split into two 1-D operations on the rows and columns²⁰.

The 1-D DCT of length N is expressed as:

$$X[k] = \alpha(t) \sum_{n=0}^{N-1} x(n) \cos \left\{ \frac{(2n+1)\pi k}{2N} \right\} \quad (7)$$

$$0 \leq k \leq N - 1$$

Where

$$\alpha(k) = \sqrt{\frac{1}{N}} \quad \text{if } k = 0 \quad (8)$$

$$\alpha(k) = \sqrt{\frac{2}{N}} \quad \text{if } k \neq 0 \quad (9)$$

The inverse discrete cosine transform is expressed as:

$$X[n] = \alpha(t) \sum_{k=0}^{N-1} X(k) \cos \left\{ \frac{(2n+1)\pi k}{2N} \right\} \quad (10)$$

$$0 \leq n \leq N - 1$$

5. Wavelet Packet Transform (WPT)

The generalization of wavelet tree decomposition is WPT, was first introduced for analysing the data and compression. WPT functions are confined with both time and frequency domains²¹. The basic building block of the WPT is quadrature mirror filters, which is expressed as

$$\sum_{n=-\infty}^{\infty} g_1(n) = 2 \quad (11)$$

$$\sum_{n=-\infty}^{\infty} g_1(n) g_1(n-2k) = 2\delta(k) \quad (12)$$

$$g_0(n) = (-1)^n g_1(L-n-1) \quad (13)$$

The disintegration of WPT is depicted in Figure 3. The approximation coefficients are segmented into two halves namely approximation coefficient vector and detail coefficient vector. The distorted information in the approximation coefficient vector is captured in detail coefficient vector. The next step involves in dividing both approximation and detail coefficient vector.

6. Proposed System

We have proposed a wavelet based OFDM system for the reduction of PAPR, which effectively reduces the PAPR on

rational selection of phase values. First the original input signal is modulated with BPSK and PTS technique had been applied, where the phase values are generated using optimized algorithm. This helps to minimise the PAPR of the input signal. Then WPT is applied and has been followed by DCT which is applied with a help of viterbi algorithm then transmitted through an AWGN channel. At the receiver the reverse process will happen. Figure 4. Depicts the block diagram of proposed system.

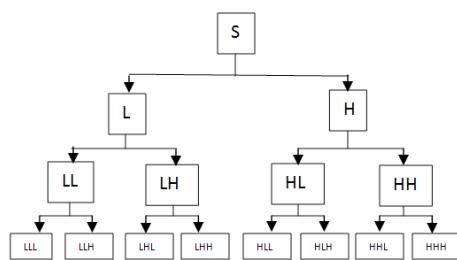


Figure 3. WPT decomposition.

Algorithm for proposed OFDM

- Map the input bit stream into BPSK symbols (-1 and +1).
- Divide the input signal into N sub blocks.
- Combine the N sub blocks with the weighted phase value.
- Apply WPT
- Apply Discrete Cosine transform
- Calculate PAPR for all the techniques
- Plot the graph SNR vs. BER
- Finally demodulate and detect the transmitted bits at receiver.

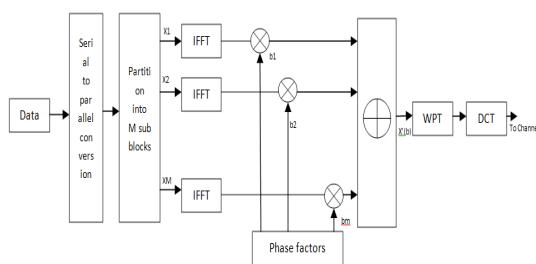


Figure 4. Enhanced transmitter block diagram.

7. Simulation results

BER Rate

Possibility of reducing bit error rate (high performance) is another important issue in wireless communication...

The BER can be described as a function of SNR for different levels of noise. This is the relationship between BER & SNR. Then wavelet family that outcomes in increased performance gain is chosen for optimum performance of wavelet OFDM. The performance affected by BER in receiver side like channel noise, interference, distortion, etc. The strength of the signal is improved by choosing a right error correction code to improve bit error rate.

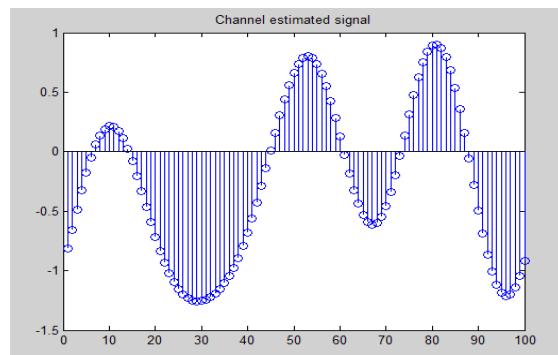


Figure 5. Channel estimated signal.

Figure 5 shows the channel estimated signal of OFDM. In order to perform coherent detection at OFDM receiver the Channel State Information (CSI) is important parameter. The pilots are transmitted along with the data symbols to estimate the CSI at the receiver. The channel estimation computation is built on comb type pilots are of two parts into pilot signal estimation and channel interpolation.

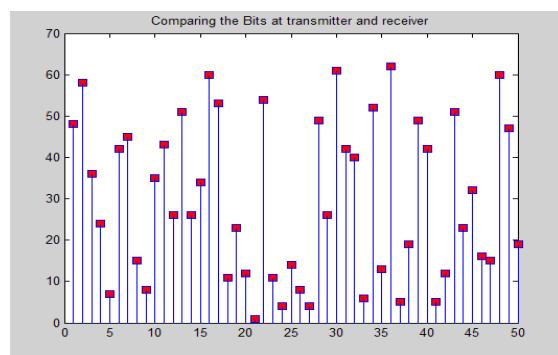


Figure 6. Comparing the bits at transmitter and receiver.

Figure 6 shows the comparison of data at both transmitter and receiver.

Figure 7 shows the plot between PAPR and CCDF for different coding techniques. One can observe that there is significant amount of PAPR reduction in proposed method. When compared with other conventional methods.

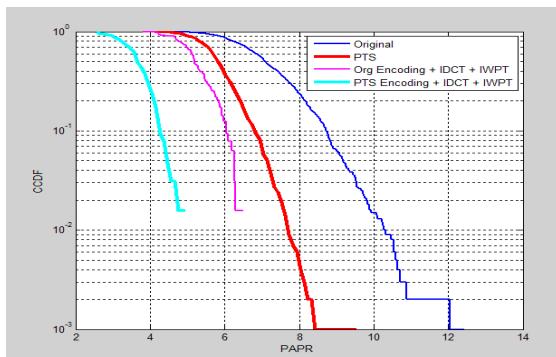


Figure 7. PAPR vs. CCDF.

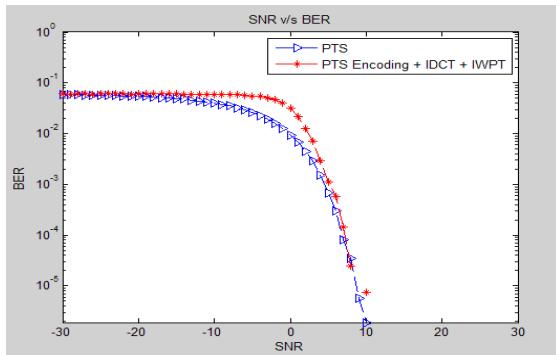


Figure 8. SNR vs. BER.

Figure 8 shows the BER plot for the proposed method and the ordinary PTS. We can observe that BER is not affected much in the proposed method where there is a slight deviation at the transition period. It shows that the proposed method performs better in minimising PAPR without compromising the BER.

8. Conclusion:

OFDM is one of the efficient techniques in wireless, mobile communication systems. In this paper we have presented a distinguished method for PAPR reduction. In most of the techniques there is a small amount of reduction in PAPR, but the computational complexity is there and few techniques are trying to achieve it but not so great. In our proposed method, we have integrated the modified PTS with DCT and WPT to minimize the computation complexity along with spectral efficiency and reduction in PAPR in OFDM systems. The Simulation results showed that considerable reduction in PAPR has been achieved. Apart from that a PAPR reduction up to 7dB can be achieved using wavelet functions.

9. References

- Wahab AAA, Ain MF. Clipping and time domain statistical method for PAPR reduction in OFDM system. 9th International Conference on Environment and Electrical Engineering (EEEIC), Institute of Electrical and Electronics Engineers (IEEE); 2010 May 16–19. p. 487–90.
- Wang H. PAPR reduction for OFDM system with class of HNN. International Symposium on Communications and Information Technologies, Institute of Electrical and Electronics Engineers (IEEE); 2006 Oct 18 – Sep 20. p. 492–7.
- Zolghadrasli A, Ghamat MH. PAPR reduction in OFDM system by using hadamard transform in BSLM techniques. 9th International Symposium on Signal Processing and its Applications, Institute of Electrical and Electronics Engineers (IEEE); 2007 Feb 12–15. p. 1–4.
- Mobasher A, Khandani AK. Integer-based constellation-shaping method for PAPR reduction in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Communications. 2006 Jan 16; 54(1):119–27.
- Hu Y. An improved algorithm for PAPR reduction in OFDM system. Advanced Research on Computer Education, Simulation and Modeling, Springer. 2011 Jun 18–19; 175:372–8.
- Chen H, Liang H. Combined selective mapping and binary cyclic codes for PAPR reduction in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Wireless Communications. 2007 Oct; 6(10):3524–8.
- Wang JS, Lee JH, Park JC, Song I, Kim YH. Combining of cyclically delayed signals: a low-complexity scheme for PAPR reduction in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Broadcasting. 2010 Dec; 56(4):577–83.
- Ghassemi A, Gulliver TA. A low-complexity PTS-based radix FFT method for PAPR reduction in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Signal Processing. 2008 Mar; 56(3):1161–6.
- Sudha V, Balan S, Kumar DS. Performance analysis of PAPR reduction in OFDM system with distortion and distortion less methods. International Conference on Computer Communication and Informatics (ICCCI), Institute of Electrical and Electronics Engineers (IEEE), Coimbatore, Indai; 2014 Jan 3–5. p. 1–4.
- Reny A, Reshma C, Rajeev SK. PAPR reduction in OFDM systems: using DCT. International Journal of Engineering Research and Technology (IJERT). 2013 Apr; 2(4):1548–51.
- Wang Z. Reduction PAPR of OFDM signals by combining SLM with DCT transform. International Journal of

- Communications, Network and System Sciences. 2010; 3:888–92.
- 12. Wu X, Wang J, Zhou B, Mao Z, Gao Z. Companding schemes based on transforming signal statistics into trigonal distributions for PAPR reduction in OFDM systems. International Journal of Communication Systems. 2011 Jun; 24(6):776–88.
 - 13. Chen JC, Chiu MH, Yang YS, Li CP. A suboptimal tone reservation algorithm based on cross-entropy method for PAPR reduction in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Broadcasting. 2011 Sep; 57(3):752–6.
 - 14. Mukunthan P, Dananjanay P. PAPR reduction by modified PTS combined with interleaving technique for OFDM system with QPSK subcarriers. Institute of Electrical and Electronics Engineers (IEEE) International Conference on Advances in Engineering, Science and Management (ICAESM); 2012 Mar 30–31. p. 410–5.
 - 15. Singh K, Bharti MR, Jamwal S. A modified PAPR reduction scheme based on SLM and PTS techniques. Institute of Electrical and Electronics Engineers (IEEE) International Conference on Signal Processing, Computing and Control; 2012 Mar 15–17. p. 1–6.
 - 16. Hasan MM. VLM precoded SLM technique for PAPR reduction in OFDM systems. Wireless Personal Communications, Springer. 2013 May 19; 73(3):791–801.
 - 17. Yoshizawa R, Ochiai H. Mutual information and coded BER analysis of PAPR reduced OFDM system with active constellation extension. Institute of Electrical and Electronics Engineers (IEEE) Global Communications Conference (GLOBECOM); 2015 Dec 6–10. p. 1–6.
 - 18. Ramavath S, Kshetrimayum RS. Analytical calculations of CCDF for some common PAPR reduction techniques in OFDM systems. Institute of Electrical and Electronics Engineers (IEEE) International Conference on Communications, Devices and Intelligent Systems (CODIS); 2012 Dec 28–29. p. 393–6.
 - 19. Patil UV, Dawande SV. BER and PAPR reduction in OFDM system using wavelet based OFDM analysis. International Journal of Advanced Research in Computer and Communication Engineering. 2015 Oct; 4(10):33–5.
 - 20. Wang Z. Reduction PAPR of OFDM signals by combining SLM with DCT transform. International Journal of Communications, Network and System Sciences. 2010 Jan; 3(11):888–92.
 - 21. Suma MN, Kanmani B. Coded wavelet packet OFDM with companding for PAPR reduction. International Journal of Electronics Communication and Computer Engineering. 2013 May; 4(3):884–7.