Precoding PTS Scheme for PAPR Reduction in OFDM

ThotaSravanti
Department of ECE
CVR College of Engineering
Hyderabad, Telangana, India
sravanti23@gmail.com

N Vasantha
Department of IT
Vasavi College of Engineering
Hyderabad, Telangana, India
vasanthavasantha@rediffmail.com

***Abstract*—The most important disadvantage of Orthogonal Frequency Division Multiplexing (OFDM) is high Peak-to-Average Power Ratio (PAPR). Designing High Power Amplifiers (HPA) with high peaks is very difficult in manufacturing which becomes costlier and complex. Voluminous PAPR reduction techniques have been proposed in which the present technique is Partial Transmit Sequences (PTS) with finest PAPR reduction. In this paper the evaluation of OFDM system, Precoded PTS OFDM system with assorted precoding methods like Discrete Fourier Transform (DFT) Precoded PTS OFDM, Discrete Hartley Transform (DHT) Precoded PTS OFDM, and Walsh- Hadamard Transform (WHT) Precoded PTS OFDM for M-QAM is scrutinized for enhanced PAPR reduction.**

Keywords—OFDM, PAPR, PTS, Precoder , DFT, DHT, WHT.

I. INTRODUCTION

In wireless and mobile communications,due to the ever-increasing technology, the information rate of the signal rises. In Orthogonal Frequency Division Multiplexing (OFDM), the vast data is split into low rate and these low data rate signal is moderated with N orthogonal subcarriers [1-3].OFDM is extensively expended in Digital Audio Broadcasting(DAB), Digital Video Broadcasting(DVB), Wireless LANs, Digital Subscriber Lines(DSL) as it has elevated power and spectral efficiency. OFDM is a multicarrier system, aches with high PAPR, degrades the proficiency of high power amplifiers (HPA). Voluminous PAPR reduction techniques have been implemented like distortion based techniques: clipping [4] [5] trail to in-band and out-band distortion and Companding [6] demoting the out-band distortion and BER which are not power efficient and probabilistic techniques like selected mapping(SLM), partial transmit sequence(PTS) were implemented [7] [8]. The subcarriers of OFDM signal is used by generated correlated signals. In PTS [9] [10] the multiplication and additional complexity can be lowered by using less IFFTs. To get considerable PAPR of OFDM signal the subcarrier waveforms are biased with different shapes [11-13]. The precoding methods [14-17] are distortion-less, amplifies the diversity gain and degrades PAPR. In this fostered technique the Precoding methods like Discrete Fourier Transform (DFT), Discrete Hartley Transform (DHT), and Walsh Hadamard Transform (WHT) is spread over the PTS OFDM system.

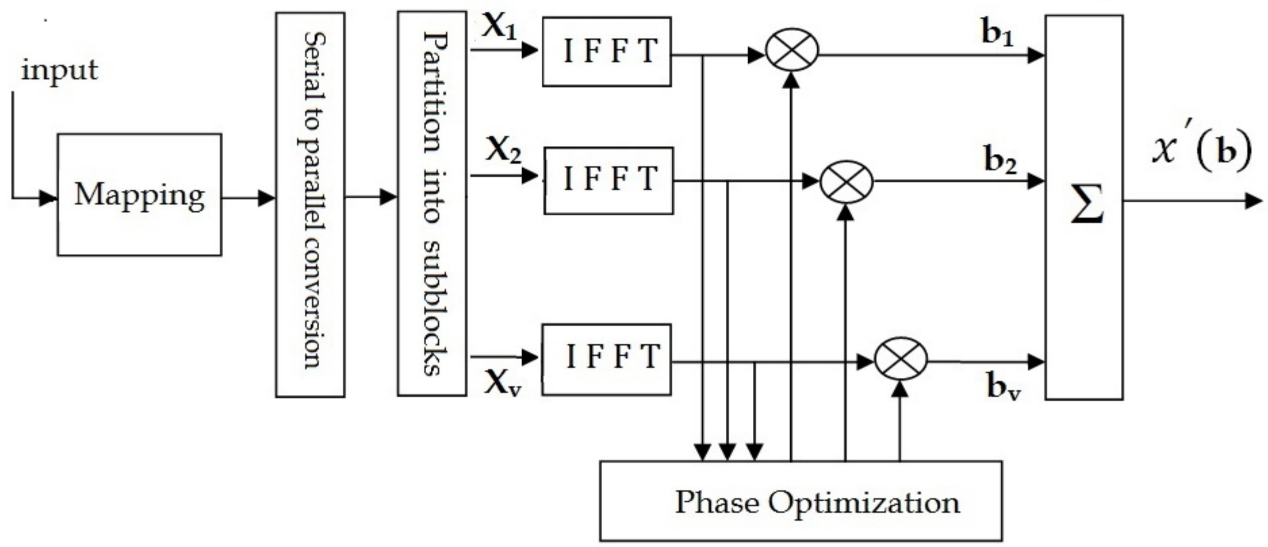

Figure 1. Block Diagram of OFDM System with PTS Technique

IEEE ISBN No.978-1-5090-4527-3

II. OFDM SYSTEM

The OFDM signal is created by using sum of parallel subcarriers. The set of bits are plotted into some constellation points by using different digital modulations like M-PSK, M-QAM. Let us consider N parallel subcarriers which are used to transfer the signal.

$$X = \{X_k \ , k = 0,1, \dots \dots \dots \dots . N\}$$

The N subcarriers are orthogonal and are stored within the time interval T. Each symbol is used to modulate with one of the subcarriers and at last all modulated signals are transferred simultaneously over the time interval T. Each symbol is made on IFFT operation.

The OFDM signal:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{n-1} X_k e^{\frac{j2\pi f_k t}{N}}$$

where $f_k = k\Delta f$ and $\Delta f = \frac{1}{T}$

Fig 1. shows the OFDM system assuming the signal consists of real and imaginary parts which are in frequency domain and converted into time domain by IFFT/IDFT.

Calculating PAPR for continuous time signal is difficult therefore estimating PAPR for discrete time is same as continuous time by oversampling the signal L times.

The OFDM signal:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{n-1} X_k e^{\frac{j2\pi f_k t}{L}}$$

for $k = 0,1, \dots \dots \dots NL - 1$

III. PAPR REDUCTION TECHNIQUES

PEAK TO AVERAGE POWER RATIO

According to central limit theorem, the OFDM signal will be close to Gaussian distributed if N is large, therefore the real and imaginary parts are Gaussian distributed and envelope is Rayleigh distributed and power is exponential distributed.

The PAPR for discrete – time version x[n] is:

$$PAPR(x[n]) = \max_{0 \le n \le N-1} \frac{|x[n]|^2}{E[|x[n]|^2]}$$

$$PAPR\{x(t)\} = \frac{P_{peak}}{P_{avg}}$$

The probability of PAPR is analyzed by cumulative distributed function(CDF) within threshold level is$F_z(z) = 1 - e^{-z}$and if probability of PAPR exceeding threshold level is expressed in complementary cumulative distributed function (CCDF) is

$$\widetilde{F_z}(z) = 1 - (1 - e^{-z})^n.$$

PAPR REDUCTION TECHNIQUES

Voluminous PAPR reduction methods have been projected [7] [8] [13]

(i) Signal Alteration techniques: Clipping and Filtering, Peak Windowing, Peak Cancellation. The PAPR is reduced but introduces in-band and out-band distortion.

(ii) Signal Probabilistic techniques: Selective Mapping (SLM), Partial Transmit Sequence (PTS), interleaving.

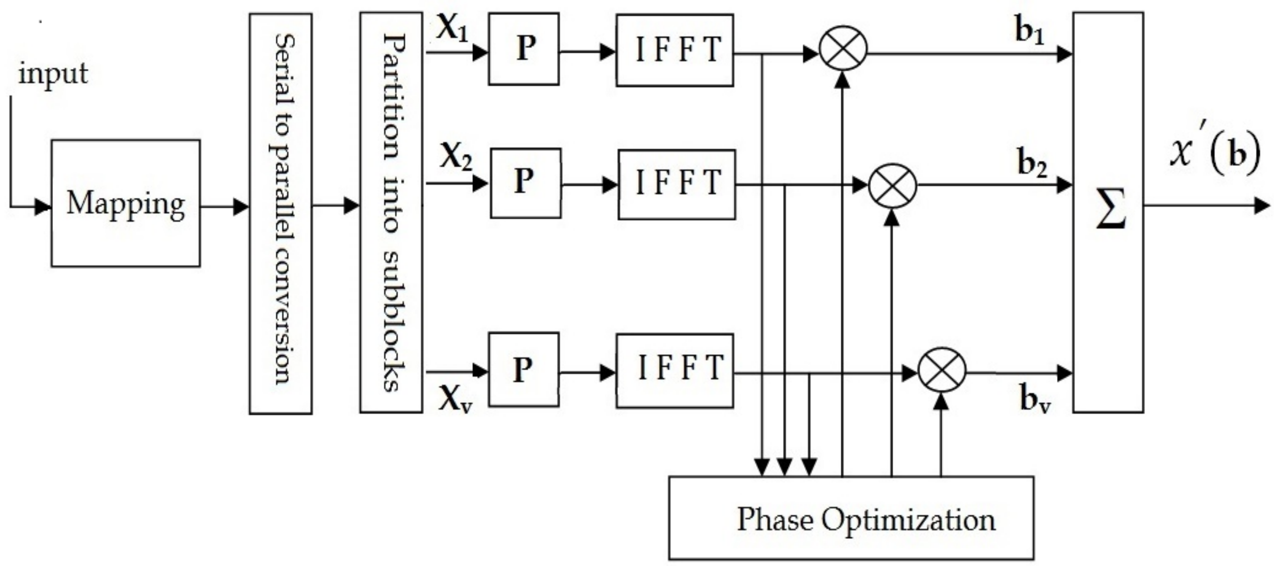

Figure 2. Precoded PTS OFDM System

IEEE ISBN No.978-1-5090-4527-3

PTS TECHNIQUE:

In PTS procedure, the input data of length N is isolated into V disjoint blocks. The IFFT of these blocks is calculated separately and weighted with complex phase factors. Figure 1. shows diagram of PTS OFDM system. Let $X = [X_1, X_2, \dots\dots\dots X_N]$ and the IFFT of V sub blocks is $x = [x_{v,0}, x_{v,1}, \dots\dots\dots . x_{v,N-1}]^T$ computed with complex phase factor$b^v = e^{j\varphi v} for v = 0,1,2, \dots . V-1$.

The process of selecting optimum phase factors, the search is limited to reduce complexity [9] [10].

Hence the set of allowed phase factors (W) are defined as $b^v = e^{\frac{j\varphi k}{W}}$ where $k = 0,1, \dots\dots\dots W-1$. The advantage of using this method depends on two factors V and W i.e., larger the V, greater the PAPR reduction and complexity is increasing exponentially with V.

IV. PROPOSED METHOD

In proposed method, the OFDM system with N symbols and M-QAM are considered. In Figure 2, the modulator is tracked by a serial to parallel converter, division block then Precoder and PTS technique i.e., precoder followed by OFDM modulation computed with weighting factors. The information is plotted and is sorted into blocks which consists of N symbols each. Let the input data of OFDM is defined in blocks consisting of N symbols.

$$X = [X_1, X_2, \dots\dots\dots X_N]^T$$

The input blocks of length N are partitioned into V disjoint subblocks. $X = X_v$

Each divided block of length N is precoded by an L X N matrix (P) because the OFDM signal is oversampled with $L = N + N_p$ is total number of subcarriers and N_p is the overhead subcarriers, where as $p_{i,j}$ are the complex or real numbers of precoding matrix. [14]

$$P = \begin{bmatrix} p_{0,0} & p_{0,1} & \cdots & p_{0,N-1} \\ p_{1,0} & \vdots & & \vdots \; \vdots \\ \vdots & \vdots & & \vdots \; \vdots \\ p_{L-1,0} & \cdots & \cdots & p_{(L-1)(N-1)} \end{bmatrix} \quad (1)$$

The precoding matrix transform input X to a new vector of length L is

$$Y_v = PX_v = [Y_{v,0}, Y_{v,1}, \dots\dots\dots Y_{v,L-1}]^T \quad (2)$$

Where

$$y_v = \sum_{m=0}^{V-1} p_{i,m}\, x_m for i = 0,1, \dots\dots\dots V-1$$

The precoded signals is shifted over diversed subcarriers is called OFDM modulation i.e., the IFFT (Y_v) is:

$$x(t) = \sum_{i=0}^{V-1} Y_i\, e^{\frac{j2\pi it}{T}} \quad (3)$$

The OFDM moderated signals are calculated by using complex phase factor

$$b^v = e^{j\varphi v} for v = 0,1,2, \dots . V-1. \quad (4)$$

The OFDM signal using Precoded PTS expression with N=2048, L=4, M=8,64 and V=2 subblocks are optimally combined to achieve lowest PAPR is:

$$\widetilde{x(b)} = \sum_{i=0}^{V-1} Y_i\, e^{\frac{j2\pi it}{T}} b_v = \sum_{i=0}^{V-1} e^{\frac{j2\pi it}{T}} b_v \sum_{m=0}^{V-1} p_{i,m}\, x_m = b_v \sum_{m=0}^{V-1} x_m \left(\sum_{i=0}^{V-1} p_{i,m} e^{\frac{j2\pi it}{T}} \right) \quad (5)$$

The PAPR of the OFDM with precoded PTS system is expressed as:

$$PAPR(t) \le \frac{1}{N} \left(\sum_{m=0}^{V-1} \left| \sum_{i=0}^{V-1} p_{i,m}\, e^{\frac{j2\pi it}{T}} b_v \right| \right)^2$$

$$PAPR(t) \le \frac{1}{N} \max_{0 \le t \le T} \left(\sum_{m=0}^{V-1} \left| \sum_{i=0}^{V-1} p_{i,m}\, e^{\frac{j2\pi it}{T}} b_v \right| \right)^2 \quad (6)$$

PRECODING TECHNIQUES

The precoding methods shape the signals in the form transformation. These transformations transform the OFDM signal into required shape (matrix) before IFFT

A. Discrete Fourier Transform (DFT) Precoding:

In this the series of N complex numbers $x_0, x_1, x_2, \dots\dots\dots\dots\dots\dots x_{N-1}$ are converted into N complex numbers.

$$X(k) = \sum_{n=0}^{N-1} x[n]\, e^{\frac{-j2\pi k}{N}}$$

for $k = 0,1, \dots\dots\dots\dots . N-1$

Because of periodicity always the DFT is implemented via Fast Fourier Transform (FFT). DFT has many properties like linearity, orthogonality, periodicity, convolution, circular convolution and so on.

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X(k)\, e^{\frac{j2\pi k}{N}}$$

B. Discrete Hartley Transform (DHT) Precoding:

The DHT transform was introduced in early 1980s like other transforms such DCT, DFT, this can be applied efficiently through a factorization of transform matrix. DHT is defined as

IEEE ISBN No.978-1-5090-4527-3

$$X_H(k) = \sum_{n=0}^{N-1} x(n)\ cas\frac{2\pi nk}{N}$$

Where$cas\emptyset = cos\emptyset + sin\emptyset$. The signal $x(t)$ which are real values are transformed into real- valued.

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} x(n)\ cas\frac{2\pi nk}{N}$$

C. Walsh Hadamard Transform (WHT) Precoding:

The Walsh Hadamard Transform (WHT) is a non-sinusoidal orthogonal transform that decomposes a signal into set of basic functions which are walsh functions i.e., square waves of values +1 and -1. This transform has no multiplications and is real.

$$y_n = \frac{1}{N}\sum_{i=0}^{N-1} x_i\, WAL(n,i) \qquad \text{for} \quad i = 0,1,\dots\dots\dots\dots N-1$$

$$x_i = \sum_{i=0}^{N-1} y_n\, WAL(n,i)$$

V. Simulation Results

The simulation is simulated by using MATLAB for assessing the performance analysis of OFDM Precoded PTS system. For analysis the input is aimlessly generated and then moderated with M-QAM (M=8, 64). The simulation results are compared with DFT/DHT/WHT –Precoded PTS OFDM system,PTS OFDM system and OFDM system for N=64 and V=2.

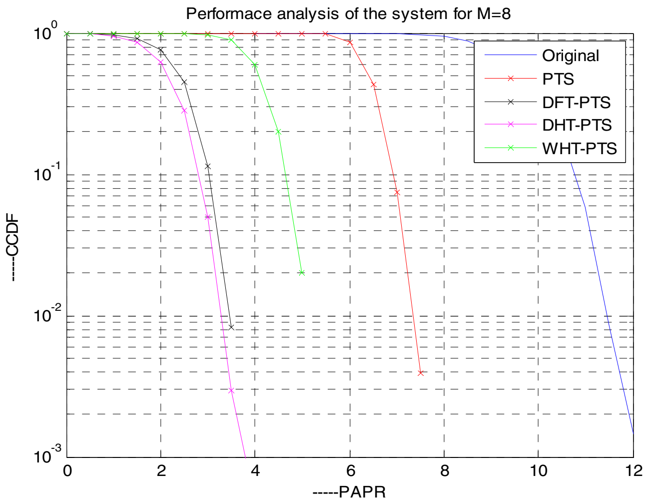

Figure 3. Comparison of PAPR of OFDM, PTS OFDM and Precoded PTS OFDM for 8-QAM

Figure 3. displays CCDF comparison of OFDM Precoded PTS using DFT, WHT, DHT for V = 2 and N = 64. At clip rate of 10^{-2} , the PAPR of OFDM is 11.7dB, PTS OFDM is 7.5dB, DFT-PTS OFDM is 3.6dB, DHT-PTS OFDM is 3.2dB, and WHT-PTS OFDM is 5.2dB for 8 – QAM. Compared to all, the great PAPR reduction is achieved by precoding techniques. For 8 – QAM the DHT performance is superior to all other precoding techniques. The DFT is better than WHT. In this case DHT and DFT precoding is enhanced technique for PAPR reduction.

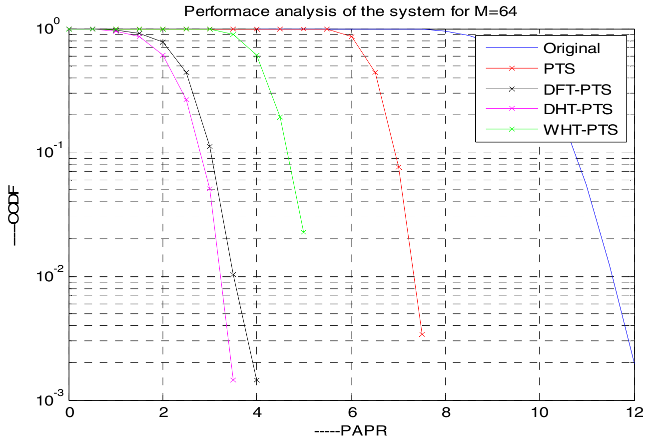

Figure 4.Comparison of PAPR of OFDM, PTS OFDM and Precoded PTS OFDM for for 64-QAM

Figure 4. displays CCDF comparison of OFDM Precoded PTS using DFT, WHT, DHT for V = 2 and N = 64. At clip rate of 10^{-2} , the PAPR of OFDM is 11.5dB, PTS OFDM is 7.2dB, DFT-PTS OFDM is 3.3dB, DHT-PTS OFDM is 3.1dB, and WHT-PTS OFDM is 5.0dB for 64 – QAM. Compared to all, the great PAPR reduction is achieved by precoding techniques. For 64 – QAM the DHT performance is superior to all other precoding techniques. The DFT is better than WHT. In this case DHT and DFT precoding is enhanced technique for PAPR reduction.

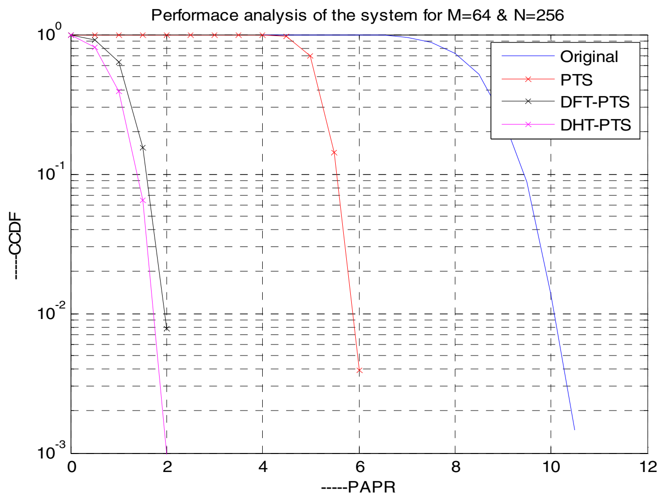

Figure 5. Comparison of PAPR of OFDM, PTS OFDM and Precoded PTS OFDM for 64-QAM, N=256

IEEE ISBN No.978-1-5090-4527-3

Figure 5. displays CCDF comparison of OFDM Precoded PTS using DFT, WHT, DHT for $V = 2$ and $N = 256$. At clip rate of 10^{-2}, the PAPR of OFDM is 10.1dB, PTS OFDM is 5.8dB, DFT-PTS OFDM is 1.9dB, DHT-PTS OFDM is 1.7dB for 64 – QAM. Compared to all, the impressive PAPR reduction is achieved by precoding techniques. For 64 – QAM the DHT performance is superior to all other precoding techniques.

VI. Conclusion

In this document, a precoded PTS scheme is applied for PAPR reduction of OFDM signals. In this offered method, for calculating PAPR the information signal of N-sequence (real or complex) is altered into N-sequence in matrix form by means of different precoding methods like DFT, DHT, and WHT. It is also proved that the system computational complexity is less as only two IFFT blocks (V=2) are used. The model results show the PAPR with label of CCDF. The analyzation shows that as M rises the PAPR is shrinking with a diminutive alteration in all parts, but as the quantity of subcarriers are swelling (ex. N=256) the PAPR is getting diminished. Hence the DHT-precoding converts input signal existent values to actual values shows noble performance and is looked for applying in wireless communications presentations.

References

[1] R. van Nee and R. Prasad, OFDM for Wireless Multimedia Communications, Boston: Artech House, 2000.

[2] W. Y. Zou and Y. Wu, “COFDM: An Overview,” IEEE Transactions on Broadcasting, Vol. 41, No. 1, pp. 1-8, Mar. 1995.

[3] Yong Soo Cho, Jaekwon Kim, Won Young Yang and Chung G. Kang “MIMO-OFDM WIRELESS COMMUNICATIONS WITH MATLAB” John wiley& Sons,2010

[4] X. Li and L. J. Cimini, Jr., “Effects of clipping and filtering on the performance of OFDM,” in Proc. Globecom, 1997, pp. 1634-1638

[5] T. Jiang and G. Zhu, “Nonlinear companding transform for reducing peak-to-average power ratio of OFDM signals,” IEEE Trans. Broadcast., vol. 50, no. 3, pp. 342–346, Sep. 2004.

[6] G. Ren, H. Zhang, and Y. Chang, “A complementary clipping transform technique for the reduction of peak-to-average power ratio of OFDM system,” IEEE Trans. Consum. Electron., vol. 49, no. 4, pp. 922–926, Nov. 2003.

[7] Jiang T., Wu Y., “An Overview: Peak-to-average power ratio reduction techniques for OFDM signals”, IEEE Trans. Broadcasting, vol. 54, No. 2, pp. 257–268, Jun. 2008.

[8] S. Mohammady, N.Sulaiman, P. Varaham, R. M. Sidek, M.N. Hamidon, “Study of PAR Reduction Methods in OFDM Systems”, Advanced Communication Technology (ICACT) 2011 13th International conference on, Vol., No., pp.127-130, 13-16 Feb,2011.

[9] L. J. Cimini and N. R. Sollenberger, “Peak-to-average power reduction ofan OFDM signal using partial transmit sequences,” in Proc. IEEE ICC,Vancouver, BC, Canada, 1999, pp. 511–515.

[10] S. J. Ku, C. L. Wang and C. H. Chen, "A Reduced-Complexity PTS-Based PAPR Reduction Scheme for OFDM Systems," in IEEE Transactions on Wireless Communications, vol. 9, no. 8, pp. 2455-2460, August 2010.

[11] S. B. Slimane, “Peak-to-average power ratio reduction of OFDM signalsusing pulse shaping,” in Proc. VTC, 1998, pp. 2067–2071.

[12] Z. Liu, Y. Xin, and G. B. Giannakis, “Linear constellation precodingfor OFDM with maximum multipath diversity and coding gains,” IEEETrans. Commun., vol. 51, no. 3, pp. 416–427, Mar. 2003.

[13] Y. Rahmatallah and S. Mohan, "Peak-To-Average Power Ratio Reduction in OFDM Systems: A Survey And Taxonomy," in IEEE Communications Surveys & Tutorials, vol. 15, no. 4, pp. 1567-1592, Fourth Quarter 2013.

[14] S. B. Slimane, "Reducing the Peak-to-Average Power Ratio of OFDM Signals Through Precoding," in IEEE Transactions on Vehicular Technology, vol. 56, no. 2, pp. 686-695, March 2007.

[15] D.Roque, C. Siclet, J. M. Brossier and P. Siohan, "Weighted cyclic prefix OFDM: PAPR analysis and performances comparison with DFT-precoding," 2012 Conference Record of the Forty Sixth Asilomar Conference on Signals, Systems and Computers (ASILOMAR), Pacific Grove, CA, 2012, pp. 1065-1068.

[16] Wang, Z. and Chen, S. (2014) Reduction PAPR of OFDM Signals by Combining Grouped DCT Precoding with PTS. Journal of Signal and Information Processing, 5, 135-142.

[17] Baig and V. Jeoti, "PAPR analysis of DHT-precoded OFDM system for M-QAM," Intelligent and Advanced Systems (ICIAS), 2010 International Conference on, Kuala Lumpur, Malaysia, 2010, pp. 1-4.