Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 45 No. 11
November 2024

Performance of PAPR Reduction in Precoded Hybrid OFDM System

Dr Thota Sravanti [1], A.Srinivasa Reddy [2], G.Ranjith Kumar [3], Mohammed Abdul Raqeeb[4]

[1,2,3,4] Department of ECE, Pallavi Engineering College, Hyderabad, 501505, India

Abstract: The purpose of the paper is to provide a broader understanding of high PAPR in OFDM and proposed a hybrid method to mitigate high PAPR using precoding scheme. This paper advanced a beneficial mode to ease OFDM signals PAPR. The suggested method is data-independent and hence, does not command new dispensing and optimization for every transmitted OFDM blockade. OFDM signal falling in PAPR is achieved through a suitable mixture of a precoding scheme with Selected Mapping (SLM), Partial Transmit Sequence (PTS), which spreads the power of each single modified symbol above the OFDM unit. The PAPR reduction efficiency factor is acquired for different hybrid methods, based on CCDF knowledge. Therefore, in this paper, an optimum PAPR can be achieved with less complexity by converting the OFDM signal into an appropriate precoded matrix with various transforms in conventional SLM-OFDM, PTS-OFDM and SLM-PTS-OFDM systems.

Keywords: OFDM, PAPR, PTS, SLM, Hybrid, Precoder, DFT, DHT, WHT, DCT

1. Introduction

In mobile and wireless communications the demand for expanding in various services day by day requires higher data rate signals. The transmission of high data rate signals is only possible with Multi Carrier Modulation (MCM) methods. One such modulation is the Orthogonal Frequency Division Multiplexing (OFDM). In this technique, a big data stream is isolated into several low data rate streams in which each stream modulates with distinctive orthogonal subcarriers and the data is transferred concurrently over the subcarriers [1-4]. However, OFDM is widely used in a variety of wireless communications systems such as Wireless LANs, Digital Subscriber Line (DSL), Digital Video Broadcasting (DVB), Digital Audio (DAB), because of its intense Spectral Efficiency (SE), robustness to multipath frequency selective fading, low complexity equalization. Because of MCM transmission which is the sum of data on different subcarriers, there is a wide variation in OFDM signal amplitude leading to high Peak to Average Power Ratio (PAPR). The power efficiency of High Power Amplifiers (HPAs) becomes worsened with high PAPR. In literature Signal distortion, scaling techniques, coding methods and hybrid methods are offered. Each method has its own benefits and drawbacks. At all times, there is an agreement between reducing PAPR and another aspects, such as computational complexity, hardware complexity, SE etc. While designing the techniques for reducing the PAPR in OFDM, the following factors should be considered:

- High PAPR reduction may leash to in-band and out of band radiations.
- Increasing power expects a large linear operation in HPAs which defeats the performance of the Bit Error Rate (BER).
- Due to high computational complexity, there is an increase in latency and reducing the data rate.
- Due to side information bits, the bandwidth expands leading to a loss in code rate and a lower SE.
- Any PAPR reduction method should not disturb the features of OFDM signal.

The signal distortion methods mitigate PAPR by making the OFDM signal distorted nonlinearly. The methods like clipping and filtering [5], peak windowing [6], nonlinear companding [7] techniques have nonlinear course steering to out-band and in-band radiations which is a detrimental side effect, degrading the BER performance in the receiver.

The OFDM signal is jumbled through assorted phase series and by using probabilistic methods elects the arrangement which provides optimal PAPR. The approaches like Selective Mapping (SLM) [8-9] and Partial Transmit Sequence (PTS) [10-11] structure muddle the OFDM data by intensifying every single OFDM signal with a phase sequence or departing the successions into disjoint subblocks computing with complicated phase factors. Compared to PTS the SLM increases the complicatedness of the transceiver hardware. Side Information (SI) bits are important for both schemes which can be reduced for maximum SE.

In predistortion methods, the OFDM signal is reoriented (spread) or transformed into transformation matrix linearly to required shape (matrix) before OFDM modulation (IFFT). The methods include DFT spreading, pulse shaping and precoding techniques. In these techniques, the BER performance is improved. This type of precoding technique maximizes the diversity gain of OFDM and minimizes the PAPR without much increase in computational complexity.
Another type of precoding is Linear Constellation Precoding (LCP) [11] which reduces the PAPR by increasing diversity and coding gains. Therefore, in literature, the distortion less precoding techniques [12-15] are signal independent and are very efficient as this technique do not require any enhanced process.

Different hybrid schemes are applied to mitigate the PAPR of OFDM along with suppression of the drawbacks in the above reduction techniques. These strategies incorporate one or more strategies to minimize PAPR, such as clipping with precoding, SLM with precoding, PTS with precoding, SLM with PTS etc.

Precoding (P) methods such as Discrete Fourier Transform (DFT), Discrete Hartley Transform (DHT), Walsh Hadamard Transform (WHT) and Discrete Cosine Transform (DCT) are implemented via the PTS-OFDM and SLM-OFDM systems and hybrid methods that incorporate SLM and PTS into the built process.

2. OFDM SYSTEM

In the OFDM method, the class of bits is delineated into array points using M-QPSK, M-QAM techniques that slot at an interval T.

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

The distributed symbols modulate with distributed subcarriers and concurrently transmitted over a time interval T. Such distributed symbols are therefore rendered on IFFT service.

The OFDM signal:

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

For $f_k = k\Delta \mathrm{f}$ and $\Delta \mathrm{f} = \frac{1}{T}$. The signal enmeshes real and imaginary parts of the frequency domain in the OFDM system are altered by IFFT / IDFT into the time domain.
The OFDM signal is oversampled by L times:

$$\boldsymbol{x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{n-1} X_k e^{\frac{j2\pi f_k t}{L}}} ; \quad \text{for } k = 0,1, \dots \dots \dots NL - 1 \qquad (2)$$

3. PAPR REDUCTION SYSTEMS

A. *Peak to Average Power Ratio*

The power is proportional, and the envelope is spread by Rayleigh, as N increases the OFDM signal and can oppress the Gaussian distribution.

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

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

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

Cumulative Distribution Function (CDF) scrutinizes the probability of PAPR, not beyond the threshold level is $F_z(z) = 1 - e^{-z}$and if the likelihood of PAPR beyond the threshold level is expressed in Complementary Cumulative Distributed Function (CCDF) is $\widetilde{F_z}(z) = 1 - (1 - e^{-z})^n$.

B. *PAPR Reduction Techniques*

Multitudinous PAPR reduction techniques have been proposed:

The Signal scrambling procedures are all variations of how the data should be scrambled to reduce the PAPR. Signal scrambling techniques can be used for coding.
With the swell in the carriers the above assorted would rise exponentially with thorough search of the superlative code. More workable resolutions of the signal scrambling methods are block coding, selective stage mapping (SLM), and partial transmission sequences (PTS).

1) *PTS Technique:*

In this technique, the IFFT of OFDM signals are divided into sub blocks and computed separately with complex phase factors.

Let $X = [X_1,\ X_2, \ldots \ldots \ldots X_N]$ and the IFFT for sub-blocks of V is $x = [x_{v,0}, x_{v,1}, \ldots \ldots \ldots . x_{v,N-1}]^T$ computed with a complex phase factor of

$b^v = e^{j\varphi v}$; for $v = 0, 1, \ldots . V-1$.

The search to choose the finest phase factors is curbed to reducing complexity [10-11].

2) SLM Technique:

The OFDM corollary bits are compounded with U as opposed to phase variables, so that X^U signal slabs are promoted with all slabs having the same info. If U = 0, the $X^{(0)}$ the original OFDM signal is generated. These change back and forth U OFDM signal is modelled with U IFFT's to bring about time-domain U alternate OFDM signals. The PAPR of substituted OFDM signals are calculated and the array $X^{\hat{U}}$ having minimum PAPR is tabbed.

The $X^U = \{X^u[0], X^u[1], \ldots \ldots \ldots \ldots X^u[N-1]\}$ and the phase factor of

$\beta^U = \{\beta^u_{(0)}, \beta^u_{(1)}, \ldots \ldots \ldots . \beta^u_{(N-1)}\}; for\ 0 \le u \le U-1$. So, the time domain SLM signal is given by:

$$x_u(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n\, \beta_{u,n} e^{j2\pi n\Delta f t}\ ;\ \Delta f = \frac{1}{NT}$$

3) Precoded Technique:

The matrix P of precoding of dimension NxN is given by

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

a) DFT:

As a "spreading" file, the limit of the DFT precoder is the consistent as that used by IFFT. Thus, since the DFT and IDFT operations practically wipe-out(cancel) each other, the OFDM System designate to the Single Carrier (SC) System. Here, the OFDM signal transmitted will show the similar PAPR as in a single carrier system that is heading for PAPR reduction growth. In order to minimize PAPR, the discrete Fourier transform Precoding operations are performed on OFDM symbols before IFFT activities.

It can be the DFT of a length N and IDFT sequence to be represented as:

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-j2\pi nk} \quad \text{for k} = 0,1, \ldots \ldots \text{N} - 1$$

$$x(n) = \sum_{k=0}^{N-1} X(k)\, e^{j2\pi nk} \quad \text{for n} = 0,1, \ldots \ldots \text{N} - 1$$

b) DHT:

The DHT is a linear transform that converts N real numbers $x_0, x_1, \ldots \ldots \ldots, x_{N-1}$ into N real numbers $H_0, H_1, \ldots \ldots \ldots, H_{N-1}$. It is possible to describe the N-point DHT as

$$H(k) = \sum_{n=0}^{N-1} x(n)\, [\cos\frac{2\pi nk}{N} + \sin\frac{2\pi nk}{N}] = \sum_{n=0}^{N-1} x(n)\ \text{cas}\frac{2\pi nk}{N}$$

The components of the NxN size precoding matrix P are as follows:

$$p_{m,n} = \text{cas}(\frac{2\pi nk}{N}) \quad for\ m, n = 0,1, \ldots ., N-1$$

c) WHT:

The Walsh Hadamard Transform (WHT) is a non-sinusoidal orthogonal transformation that breaks down a signal into a series of simple functions , i.e. square waves of +1 and -1 values. This transformation has no multiplications and is valid.

$Y_k = \sum_{i=0}^{N-1} h_{k,n} X_n\ ,\quad k = 0,1, \ldots N-1$

Here $h_{k,n}$ implies n-th board, k-th WHT column. Walsh Hadamard can be written as NxN WHT matrix as:

$$H_1 = (1)$$

$$H_N = \begin{pmatrix} H_{N/2} & H_{N/2} \\ H_{N/2} & -H_{N/2} \end{pmatrix}$$

d) DCT:

It is possible to construct a DCT matrix P of the size NxN using equation

$$D_{mn} = \begin{cases} \frac{1}{\sqrt{N}} & m = 0,\ 0 \le n \le N-1 \\ \sqrt{\frac{2}{N}}\ cos\frac{\pi(2n+1)m}{2N} & 1 \le m \le N-1 \\ & 0 \le n \le N-1 \end{cases}$$

The DCT and can be described as

$$X_k = \sum_{n=0}^{N-1} x_n \cos[\frac{\pi}{N}\left(n+\frac{1}{2}\right)k]$$

e) Hybrid Scheme:

The above PAPR reduction strategies raise the numerical sophistication of the hardware, over and above that a piece of side data is to be redirected to the synchronisation receiver. The computational complexity is not as great in SLM technique and hardware complexity necessity is less in the PTS technique. To humiliate both computational complexity and demand of additional hardware both SLM and PTS techniques are combined which is called the hybrid approach. In this structure, the number of SI bits is the value of SI of the SLM system and SI of PTS system called as redundant bits.

$$N_{side} = log_2(U) + (V-1)log_2^W$$

Where W is the phase rotation factor.

The probability that OFDM signal having tremendous PAPR than a certain verge level is

$$P_r\{PAPR_U > z\} = (P_r\{PAPR_{PTS} > z\})^U$$

4.Proposed Method

A.Precoded Hybrid OFDM System:

In a hybrid system seen in Figure 3, to amplify further PAPR reduction, where the OFDM signal sequence is reproduced with different U phase factors so that infrequent OFDM sequences are generated. These sequences are transformed into a precoded matrix and then these precoded U OFDM signal sequences are transformed with U IFFT's to generate time-domain U alternate OFDM signals. The, unlike U OFDM modified signals, are computed with a complex phase factor $b^v = e^{j\varphi v}$ and PAPR of all the U alternative OFDM signals which are computed with complex phase is calculated and the sequence $X^{\hat{U}}$ having an optimum PAPR is selected.

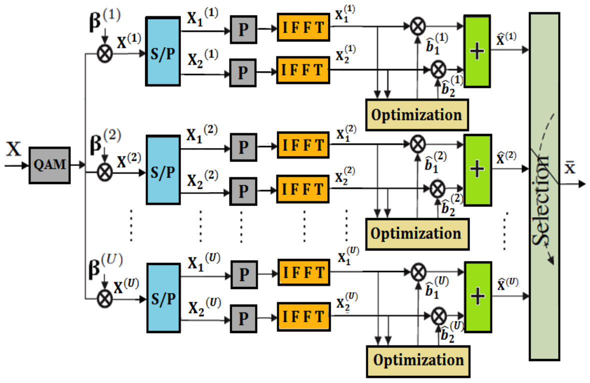


Fig 1. The precoded hybrid OFDM system

The complementary bits of the OFDM are repeated with alternate phase U factors to stimulate U alternate X^U signal blocks where both blocks have the same data.If U = 0, the $X^{(0)}$ the original OFDM signal is generated. This alternate U OFDM signal is transformed with U IFFT's to generate time-domain U alternate OFDM signals.

Let $X^U = \{X^u[0], X^u[1], \dots\dots\dots\dots X^u[N-1]\}$ and Phase factor $\beta^U = \{\beta^u_{(0)}, \beta^u_{(1)}, \dots\dots\dots.\beta^u_{(N-1)}\}$ $0 \le u \le U-1$.

Therefore, the SLM time domain signal is given by

$$x_u(t) = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n\, \beta_{u,n} e^{j2\pi n\Delta f t};\ \Delta f = \frac{1}{NT} \quad (3)$$

These U different OFDM sequences are divided into V disjoint subblocks. The precoded OFDM signal of these subblocks is:

$$Y_v^u = \sum_{k=0}^{N-1} P_{v,k} X_v^u \quad (4)$$

As the OFDM signal is over-sampled by $L = N + N_p$ with N total number of subcarriers and N_p overhead subcarriers, the distributed length block N is pre-coded by a $L\ x\ N$ matrix (P) and $p_{i,j}$ is the dynamic or real pre-coding matrix number[15]

$$P = \begin{bmatrix} p_{(0),(0)} & p_{(0),(1)} & \cdots & p_{(0),(N-1)} \\ p_{(1),(0)} & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ p_{(L-1),(0)} & \cdots & \cdots & p_{(L-1)(N-1)} \end{bmatrix} \quad (5)$$

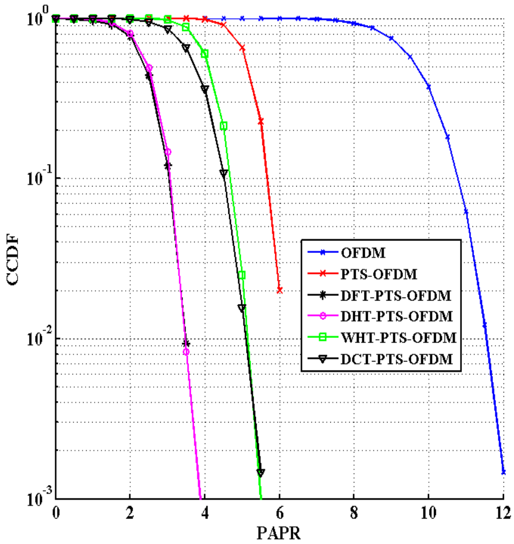
The precoding matrix transform of the input X vector of length L is

$$Y_v = PX_v = \left[Y_{v,0}, Y_{v,1}, \dots \dots \dots Y_{v,L-1}\right]^T \quad (6)$$

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

Such blocks' IFFT is measured and biased with specific phase factors. Let $X = [X_1,\ X_2, \dots \dots \dots X_N]$ and the IFFT with parts V is $x = \left[x_{v,0}, x_{v,1}, \dots \dots \dots . x_{v,N-1}\right]^T$ computed with complex phase factor of $b^v = e^{j\varphi v};\ for\ v = 0,1,2, .. V-1$.
The hunt was limited to a reduced complexity by means of choosing the optimal step factors [10-11]. The set of permitted step factors(W) is set as $b^v = e^{\frac{j\varphi k}{W}}$ where $k = 0,1, \dots \dots \dots W-1$. The benefit of going this method varies from two variables V and W, i.e. the greater the V, the greater the decrease in PAPR and the greater the uncertainty of V.

The precoded signal is transferred over distinct subcarriers i.e., the IFFT (Y_v) is:



$$x(t) = \sum_{i=0}^{V-1} Y_i\, e^{\frac{j2\pi it}{T}} \quad (7)$$

Those signals are measured using a complex phase factor:

$$b^v = e^{j\varphi v};\ for\ v = 0,1,2, \dots . V-1 \quad (8)$$

To obtain the lowest PAPR, the precoded OFDM signal with N subcarriers, with V subblocks, is optimally coupled to:

$$\widetilde{x(b)} = \sum_{i=0}^{V-1} Y_i\, e^{\frac{j2\pi it}{T}} b_v$$

$$= \sum_{i=0}^{V-1} e^{\frac{j2\pi it}{T}}\, b_v \sum_{m=0}^{V-1} p_{i,m}\, x_m \quad (9)$$

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

The system's PAPR is described as follows:

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

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

5. Simulation Results and Discussion

In OFDM systems the parameters from Table I are considered. In MATLAB, CCDF-based simulation results are simulated for three methods for evaluating the PAPR reduction performance assessment in the OFDM framework and revised OFDM scheme, as shown in Figure 2. The decrease in PAPR is calculated using the standard likelihood of 10^{-2}.

TABLE I: Simulation parameters

S No	Parameters	No:
	Modulation	64-QAM
	Subcarriers	64
	Symbols	2048
	Oversampling Factor (L)	4
	U Phase Sequences	8
	V Sub blocks	2

For traditional PTS, SLM and a modern hybrid method, precoding techniques including Discrete Fourier Transform
(DFT), Discrete Hartley Transform (DHT), Walsh Hadamard Transform (WHT), Discrete Cosine Transform (DCT) are implemented. In PTS scheme the performance of PAPR reduction progresses as several subblocks increases preceding to computational difficulty, in SLM performance of

PAPR reduction raises with an increase in *U* phase sequences leading to hardware complication. For additional improvement in performance, both PTS (*V=2*) and SLM (*U=4*) is merged lessening both computational and hardware complexity.

From Figure 2 (a), the PAPR reduction is better for all the precoding techniques. Here in DFT-PTS, the OFDM symbol is divided into two disjoint subblocks are distributed uniformly multiplied with orthogonal unitary matrix reducing has more PAPR reduction to 3.6 *dB* and in DHT-PTS, each subblock signal is transformed into the matrix through factorization has reduced the PAPR to 3.6 *dB*.

In WHT-PTS, the subblocks are decayed with Walsh functions with +1 and -1 values reducing the PAPR to 5.0 *dB* and in DFT if only the cosine terms are considered with different frequencies and amplitudes it is called discrete cosine transform (DCT) applied, the DCT-PTS reduces PAPR to 5.0 *dB*.

In precoded-SLM (Figure 2(b)), WHT-SLM and DCT-SLM PAPR reduction are poor than convention SLM with *U=8* sequences whereas DFT-SLM and DHT-SLM have better PAPR reduction to 3.2 *dB* and 3.0 *dB*. In the new hybrid precoding scheme, the same PAPR reduction is achieved with less complexity. From Figure 2 (c), the performance of DFT-Hybrid and DHT-Hybrid is better with PAPR reduction to 3.1 *dB*.

a) Precoded PTS OFDM Systems
b) Precoded SLM OFDM Systems
c) Precoded hybrid OFDM systems

Fig 2. The PAPR comparison of hybrid OFDM systems

A. Reduction Efficiency

$$OFDM_{PAPR\ Reduction} = OFDM_{PAPR} - Modified\ OFDM_{PAPR} \quad (13)$$

$$PAPR_{Reduction\ Efficiency}\ (\eta) = \frac{OFDM_{PAPR\ Reduction}}{OFDM_{PAPR}}$$

The PAPR reduction efficiency from Table II shows that the hybrid method outperforms than other methods with only V=2 and U=4 factors. Hence the hybrid method is best suitable for OFDM systems in reducing the nonlinearity of HPAs.

TABLE II: PAPR Reduction Efficiencies of Conventional Methods

S.no	Type	PAPR (dB) (10^{-2})	Efficiency (η) (%)
1	OFDM	11.5	-
2	PTS-OFDM	6	47.82
3	SLM-OFDM	4	65.21
4	HYBRID-OFDM	3.8	66.9

1) Precoded PTS OFDM System:

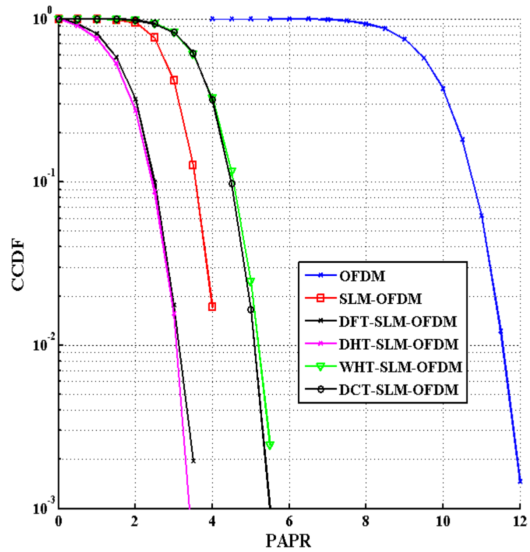
$$OFDM_{PAPR\ Reduction} = OFDM_{PTS-PAPR} - OFDM_{Precoded\ PTS-PAPR} \quad (14)$$

$$PAPR_{Reduction\ Efficiency}\ (\eta) = \frac{OFDM_{PAPR\ Reduction}}{OFDM_{PTS-PAPR}}$$

TABLE III: PAPR Reduction Efficiencies of Precoded PTS Method

S No	Type	PAPR (dB) (10^{-2})	Efficiency (η) (%)
1	PTS	6.0	-
2	DFT- PTS	3.6	40.0
3	DHT- PTS	3.6	40.0
4	WHT- PTS	5.0	16.6
5	DCT- PTS	5.0	16.6

In this type i.e., from Table III all precoding methods



have fairer PAPR reduction than PTS systems. DFT and DHT reduction efficiency performance is well than WHT, DCT techniques.

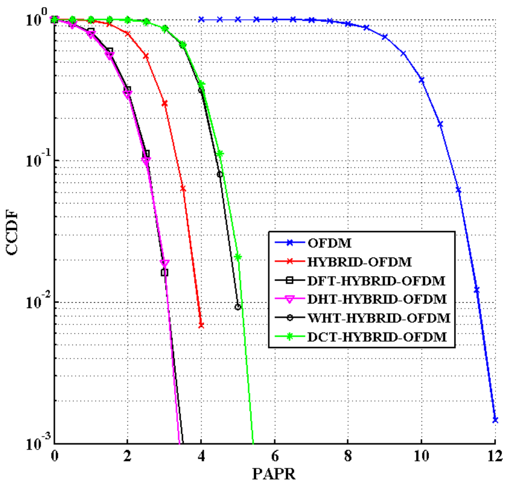
2) Precoded SLM OFDM System:

$$OFDM_{PAPR\ Reduction} = OFDM_{SLM-PAPR} - OFDM_{Precoded\ SLM-PAPR} \quad (15)$$

$$PAPR_{Reduction\ Efficiency}\ (\eta) = \frac{OFDM_{PAPR\ Reduction}}{OFDM_{SLM-PAPR}}$$

TABLE IV: PAPR reduction efficiencies of precoded SLM method

S No	Type	PAPR (dB) (10^{-2})	Efficiency(η) (%)
1	SLM	4.0	----
2	DFT- SLM	3.2	20.0
3	DHT- SLM	3.0	25.0
4	WHT- SLM	5.2	----
5	DCT- SLM	5.0	----



In precoded SLM system from Table IV, DFT and DHT reduction efficiency performance is improved, whereas WHT, DCT techniques are flawed.

3) Precoded HYBRID OFDM System:

$$OFDM_{PAPR\ Reduction} = OFDM_{HYBRID-PAPR} - OFDM_{Precoded\ HYBRID-PAPR} \quad (16)$$

$$PAPR_{Reduction\ Efficiency}\ (\eta) = \frac{OFDM_{PAPR\ Reduction}}{OFDM_{HYBRID-PAPR}}$$

In Precoded SLM system and Precoded Hybrid system i.e., from Table V DFT, DHT reduction efficiency performance is improved, whereas WHT, DCT techniques are flawed.

TABLE V :PAPR Reduction Efficiencies of Precoded Hybrid Method

S.No	Type	PAPR (dB) (10^{-2})	Efficiency (η) (%)
1	HYBRID	3.8	
2	DFT- HYBRID	3.1	22.5
3	DHT- HYBRID	3.1	22.5
4	WHT- HYBRID	4.8	----
5	DCT- HYBRID	5.0	----

6. CONCLUSION

This paper compares the new hybrid method which is designed with available solutions like SLM, PTS and precoding techniques. In the precoded PTS scheme, PAPR is reduced for all transformation techniques for V=2 subblocks. The disadvantage of this process is many subblocks increases, the PAPR also increases directing to computational difficulty. In this, SLM technique for U=8 sequences have more PAPR reduction (4.0 dB) than PTS system (6.0 dB), therefore when precoding is applied to SLM further the PAPR is reduced with DFT (3.2 dB) and DHT (3.0 dB). In SLM as the U sequences increase the PAPR decreases leading to hardware complexity. Hence a new hybrid method is designed by combining precoders, SLM (U=4) and PTS (V=2). In this method the PAPR reduced with DFT precoder and DHT precoder is 3.1 dB with high reduction efficiency and less complexity. It is concluded that the above techniques can be extended to the OFDM system as well as in future spectrum spreading techniques for 5 G and beyond, as per the system requirement based on complexity and PAPR reduction, since this proposed approach is data-independent and hence does not need new dispensing and optimization for every OFDM blockade transmitted.

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, March 1995.

[3] T. Sravanti and N. Vasantha, "Performance analysis of PAPR reduction in OFDM using combined approach method," 2015 International Conference on Computing and Communications Technologies (ICCCT), Chennai, pp. 205-209, 2015.

[4] Yong Soo Cho, Jaekwon Kim, Won Young Yang and Chung G. Kang “MIMO-OFDM wireless communications with MATLAB,” John Wiley & Sons, 2010.

[5] Xiaodong Li and L. J. Cimini, "Effects of clipping and filtering on the performance of OFDM," in *IEEE Communications Letters*, vol. 2, no. 5, pp. 131-133, May 1998.

[6] S. Cha, M. Park, S. Lee, K. J. Bang and D. Hong, "A new PAPR reduction technique for OFDM systems using advanced peak windowing method," in *IEEE Transactions on Consumer Electronics*, vol. 54, no. 2, pp. 405-410, May 2008.

[7] Xianbin Wang, T. T. Tjhung and C. S. Ng, "Reduction of peak-to-average power ratio of OFDM system using a companding technique," in *IEEE Transactions on Broadcasting*, vol. 45, no. 3, pp. 303-307, Sep 1999.

[8] Chin-Liang Wang and Yuan Ouyang, "Low-complexity selected mapping schemes for peak-to-average power ratio reduction in OFDM systems," in *IEEE Transactions on Signal Processing*, vol. 53, no. 12, pp. 4652-4660, Dec. 2005.

[9] S. J. Heo, H. S. Noh, J. S. No and D. J. Shin, "A modified SLM scheme with low complexity for PAPR reduction of OFDM systems," in *IEEE Transactions on Broadcasting*, vol. 53, no. 4, pp. 804-808, Dec. 2007.

[10] S. H. Muller and J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences," in *Electronics Letters*, vol. 33, no. 5, pp. 368-369, 27 Feb 1997.

[11] L. J. Cimini and N. R. Sollenberger, "Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences," in *IEEE Communications Letters*, vol. 4, no. 3, pp. 86-88, March 2000.

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

[13] 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.

[14] 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, pp. 1065-1068, 2012.

[15] 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.

[16] 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, pp. 1-4, 2010.