

**PERFORMANCE ASSESSMENT OF PAPR REDUCTION TECHNIQUES IN OFDM SYSTEM****Purva Tiwari****Mtech 2nd Student (Alpine Engineering college Ujjain)****DOI: 10.5281/zenodo.569374**

Abstract

To achieve better performance using multi carrier modulation we should make the subcarriers to be orthogonal to each other i.e. known as the Orthogonal Frequency Division Multiplexing (OFDM) technique. But the great drawback of the OFDM method is its high Peak to Average Power Ratio (PAPR). As we are using the linear power amplifier at the transmitter side so it's operating point will go to the saturation region due to the high PAPR which leads to in-band distortion & out-band radiation. This can be evaded with growing the dynamic range of power amplifier which hints to high cost & high consumption of power at the base station. It is known that the PAPR reduction arrangements can be generally categorized into two groups, i.e. distortion-less systems such as SLM & PTS & the pre-distortion systems such as clipping & companding. In this Paper, we demonstrate the performance of existing algorithms (PTS, SLM and Clipping) which has been compared using MATLAB simulations. The proposed procedure exploited standard PTS, Clipping and SLM methods. We proved that by comparison of these PAPR reduction techniques, PTS perform much better than other standard methods like Amplitude clipping, selective mapping projected earlier with respect to CCDF.

Introduction

Orthogonal frequency division multiplexing (OFDM) is an effectual multicarrier transmission method for wireless communications over frequency selective channels. Using an inverse fast Fourier transform (IFFT) & a fast Fourier transform (FFT) for the baseband modulation & demodulation, respectively, shortens the proposal of the transceiver & offers for an effectual hardware execution. A typical OFDM transmission system is shown in Fig. 1. However, the time-domain OFDM signal can show a big peak-to-average power ratio (PAPR). These peaks can cause nonlinear distortion which offering spectral distribution, intermodulation, & variations in the signal collection. One solution to this difficulty is to employ an exclusive power amplifier with a huge linear range. Other methods are based on signal modification.

Several methods have performed in the literature to decrease the PAPR [1]- [33]. They can mainly be categorized as distortion or distortionless methods. Distortion methods are presented in [1]- [8]. They produce in-band distortion [1], peak regrowth [2], or out-of-band radiation [3]- [7]. In [8], a linear nonsymmetrical transform is given that realizes a sensible tradeoff among PAPR reduction & BER performance.

Many distortionless methods have been projected [9]- [21]. Coding systems [9]- [12] drop the data rate. They involve memory to store the code words, & present delay due to the time essential to find a low PAPR code word, chiefly when the amount of subcarriers is huge. Additional class of distortionless methods employ constellation mapping [13]-[15]. The constellation development in [13] involves a complex optimization procedure, particularly with a huge number of subcarriers. Modest & practical constellation mapping methods are active constellation extension [14] & tone reservation [15]. Phase optimization methods attain.

So far, several methods [16] have been projected increase the PAPR performance in OFDM systems, comprising direct clipping [17], recursive clipping & filtering (RCF) [18], companding method [19], active constellation extension (ACE) [20], coding method [21], selective mapping (SLM) [22], & partial transmit sequence (PTS) [23-25].

One major disadvantage of OFDM is big Peak to Average Power Ratio (PAPR). It is caused nonlinear distortions after amplified by power amplifier. Numerous methods to decrease PAPR have been projected. These



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methods have been known as amplitude clipping [26]-[27], clipping & filtering [26]-[27], coding [26]-[27], tone reservation (TR) [26]-[27], tone injection (TI) [26]-[27], active constellation extension (ACE)[27], & multiple signal representation methods, such as selected mapping (SLM) [27], partial transmit sequence (PTS) [27]

PAPR reduction with a small extent of redundancy [28]-[33]. With selective mapping (SLM) [28]-[30], multiple sequences are created from the original data block & the system with the lowest PAPR is designated for transmission. In the partial transmit sequence (PTS) method [30]-[33], disjoint subblocks of OFDM subcarriers are phase shifted distinctly after the IFFT is calculated. If the sub blocks are optimally phase shifted, they show minimum PAPR & subsequently decrease the PAPR of the compound signal. The amount of subblocks & their separating system determine the PAPR reduction. The examine for optimum sub block phase features is computationally difficulty, but this can be condensed with adaptive PTS [32] or sphere decoding [33]. Usually, the receiver needs side data equivalent to the optimal phases in PTS & the transmitted sequences in SLM. Methods for avoiding explicit side information transmission are accessible in [29], [30].

One of the main disadvantage of PTS arises from the computation of multiple IFFTs, causing in a high complexity proportional to the number of sub blocks. In an effort to decrease this complexity, intermediate signals within the IFFT using decimation in time (DIT) have been used to attain the PTS sub blocks.

It is known that the PAPR reduction systems can be mainly categorized into two groups, i.e. distortion-less systems such as SLM & PTS & the pre-distortion systems such as clipping & *companding*. In this paper, we demonstrate the performance of three methods for PAPR reduction in OFDM system namely partial transmit sequence method (PTS), Clipping technique and Selected Mapping Technique (SLM).

In the performance assessment of the projected detection algorithm, no oversampling at the transmitter is used because oversampling method is useful for appropriately computing PAPR but has no result on BER unless a HPA is used at the transmitter. To make the scheme simple, the HPA is absent from the transmitter. Additionally, only a stationary channel (i.e., AWGN Channel) is measured throughout this simulation. Channel estimation is not accomplished here.

The enlightening stages of this paper are as follow: Chapter II contain a thorough literature review of overall PAPR reduction methods in OFDM system. Projected comparative study (details of individual method) is described in Chapter III. An overview of simulation consequences along with comparative analysis is shown in Chapter IV. And finally, the conclusion & references are pointed in Chapter V and VI.

Review of Literature

Fernando & Foomooljareon (2002) proposed about the PAPR difficulty in OFDM schemes. They presented two algorithms to decrease the PAPR. The first algorithm is passed out by choosing the input sequence correctly using a lookup table & the second by scaling the input envelope for subcarriers before they are changed to the time domain by Inverse Fast Fourier Transform (IFFT).

Jung Chieh Chen & Chao-Kai Wen (2010) expresses the PAPR reduction with TI system as a certain combinatorial optimization difficulty. Following they projected the presentation of the cross entropy technique to explain the difficulty.

The partial transmit sequence (PTS) method has established much devotion in decreasing the high PAPR of Orthogonal Frequency Division Multiplexing (OFDM) signals. However, the PTS method needs an extensive search of all groupings of the permissible phase issues & the search complexity increases exponentially with the amount of sub-blocks. The Parametric Minimum Cross Entropy Technique (PMCE) is projected by Yajunwang (2010) to search the optimal grouping of phase features. The PMCE algorithm not only decreases the PAPR considerably but also reduce the computational difficulty

Most of current works have concentrated on reducing the PAPR of OFDM signals. However, after connecting this problem with the definite features of high power amplifier (HPA), Dong-Hyun Park et al (2007) suggest a



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novelsystem based on iterative partial transmit sequence systemthat uses the amount of OFDM signal where the nonlinear distortion is to be produced by high power amplifier (HPA) as a novelation.

Chin-Liang Wang & Yuan Ouyang (2005) present a Selected mapping technique (SLM). The SLM methodoffers good performance for PAPR reduction, but it needs a bank of Inverse Fast Fourier Transforms (IFFTs) to create a set of candidate transmission signals, & this condition usually consequences in high computational difficulty.

Stephane Y. Le Goff et al (2009) suggest a novel SLM technique for which no side information desires to be sent. By seeing the illustration of numerous OFDM schemes using either QPSK or 16- QAM modulation, the projectedtechniqueachieves very well both in terms of PAPR reduction & bit error rate at the receiver output with hugeamount of sub carriers.

A typical OFDM transmission system is shown in Fig. 1. At the transmitting end, first of all, input binary serial data stream is first processed by channel encoder, constellation mapping and serial to parallel (S/P) conversion. A single signal is divided into N parallel routes after N -point inverse fast Fourier transform (IFFT). Each orthogonal sub-carrier is modulated by one of the N data routes independently. By definition the N processed points constitute one OFDM symbol

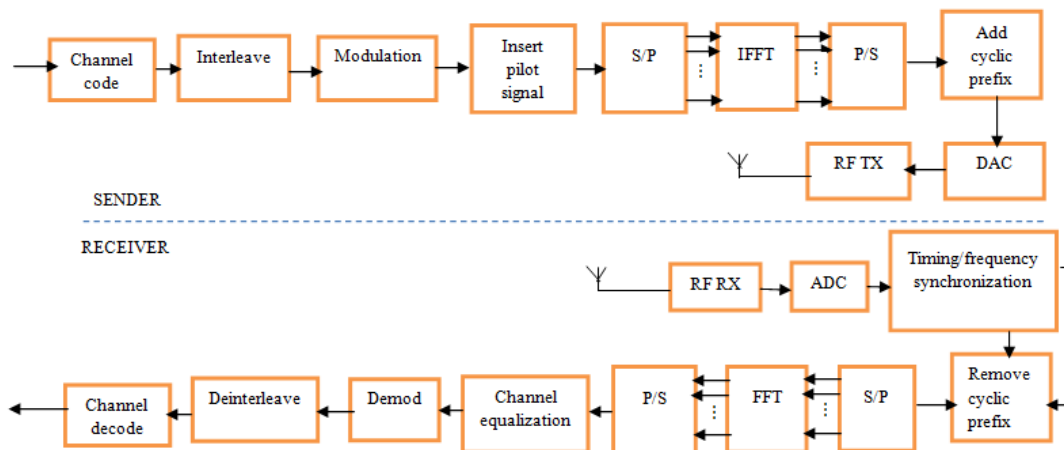


Fig. 1: Basic structure of OFDM system

Next, convert modulated parallel data to serial sequence and then copy the last L samples of one symbol to the front as cyclic prefix (CP). At last, arrive at transmitter after process of digital to analog (D/A) conversion and radio frequency (RF) modulation. To recover the information in OFDM system, reception process is converse and self-explanatory. At the receiving end, digital down conversion is carried out, demodulate receiving signals. At last, demodulated signals are fed into an analog to digital (A/D) converter, sample output and take timing estimation to find initial position of OFDM symbol. The CP added in transmission process is removed and N -Points fast Fourier transform (FFT) transformation will be conducted on the left sample points to recover the data in frequency domain. The output of baseband demodulation is passed to a channel decoder, which eventually recover the original data.

ChusitPradabpet&KobchaiDejhan (2008) proposed a novelPAPR reduction technique using a PTS combined with adaptive peak power reduction approaches. In order to decrease PAPR, the order of input data is rearranged by the PTS for the reduction of PAPR & then fed to the adaptive peak power reduction process in the proposed system. The comparison among SLM & PTS was projected by Anil Singh Rathore & Neelam Srivastava (2010). Theystudied that the SLM algorithm is more appropriate if scheme can receive more redundant information.

The investigation of side information difficulty in SLM method has been protracted by Kasiri&Dehghani



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(2009). Certain subcarriers have been reserved in the OFDM frame which is to be replaced with one of the probable phases according to the amount of phase order blocks in SLM algorithm.

Houshou Chen & Hsinying Liang (2007) investigated with BPSK subcarriers by joining SLM & binary cyclic codes. The author decomposes the binary cyclic codes into direct sum of two cyclic sub codes: the correction sub code used for error correction & the scrambling sub code for PAPR reduction. The communicated OFDM signal is designated that attains minimum PAPR, from the set of binary cyclic code words.

Daoud and Alani (2009) enhanced the performance of the OFDM scheme by using Low-Density Parity-Check codes as an alternative to turbo coding in modifying the PAPR difficulty which has been used in the preceding works of the authors. Simulation consequences presented that using LDPC has led to improved performance than the earlier issued turbo encoding in terms of PAPR reduction proportion.

In a turbo coded OFDM, low PAPR can be attained by relating SLM. Yung-Chih Tsai & Yeong Ueng (2007) projected to create multiple applicants used in SLM by employing the tail-biting bits in a tailbiting turbo code. In this technique, no clear side information is required & no error propagation is detected. Low PAPR can also be attained by distortion-based methods such as thoughtful clipping.

Paper Reduction Techniques Used For Comparison

OFDM is multicarrier multiplexing access Technique for Transmitting Large data over Radio waves. Next mobile Generation system is expected to provide high data rate to meet the requirement for future multimedia application. Minimum data rate required for the 4G System is 10-20Mbps & at least 2Mbps in moving vehicles. And modulation technique adopted by 4G mobile system is OFDM. One of the major problems observed in OFDM system is PAPR (Peak to Average Power Ratio). This PAPR must be Reduce for efficient transmission. Different techniques can be used for reduce PAPR in OFDM system.

A large peak-to-average power ratio (PAPR) would source the power amplifier used in an OFDM system to be determined in the saturation area, thus important to signal alteration. The traditional remedy for this PAPR difficulty is to use a linear amplifier with a large dynamic range. This answer, however, executes a stringent condition on the analog devices in both the transmitter & receiver, & therefore, rises the cost of the system. The PAPR reduction technique should be chosen with awareness according to various system requirements.

TABLE 1: Comparison of PAPR Reduction Techniques

Reduction Technique	Parameters			Operation required at Transmitter (TX)/ Receiver (RX)
	Decrease distortion	Power raise	Defeat data rate	
Clipping and Filtering	No	No	No	TX: Clipping RX: None
Selective Mapping (SLM)	Yes	No	Yes	TX: M times IDFTs operation RX: Side information extraction, inverse SLM
Block Coding	Yes	No	Yes	TX: Coding or table searching RX: Decoding or table



				searching
Partial Transmit Sequence(PTS)	Yes	No	Yes	TX: V times IDFTs operation RX: Side information extraction, inverse PTS
Interleaving	Yes	No	Yes	TX: D times IDFTs operation, D-1 times interleaving RX: Side information extraction, de-interleaving
Tone Reservation (TR)	Yes	Yes	Yes	
Tone Injection (TI)	Yes	Yes	No	

A. Partial Sequence Reduction

Transmit for PAPR

The partial transmit sequence method is a phase optimization method which can offer remaining PAPR reduction with a small amount of redundancy. With this method, separate subblocks of OFDM subcarriers are phase shifted distinctly after the IFFT is calculated. If the subblocks are optimally phase shifted, they display minimum PAPR & accordingly decrease the PAPR of the combined signal. The number of subblocks (V) & the partitioning arrangement define the PAPR reduction. The main difficulty of PTS ascends from the computation of multiple IFFTs, subsequent in a high computational difficulty proportional to the amount of subblocks.

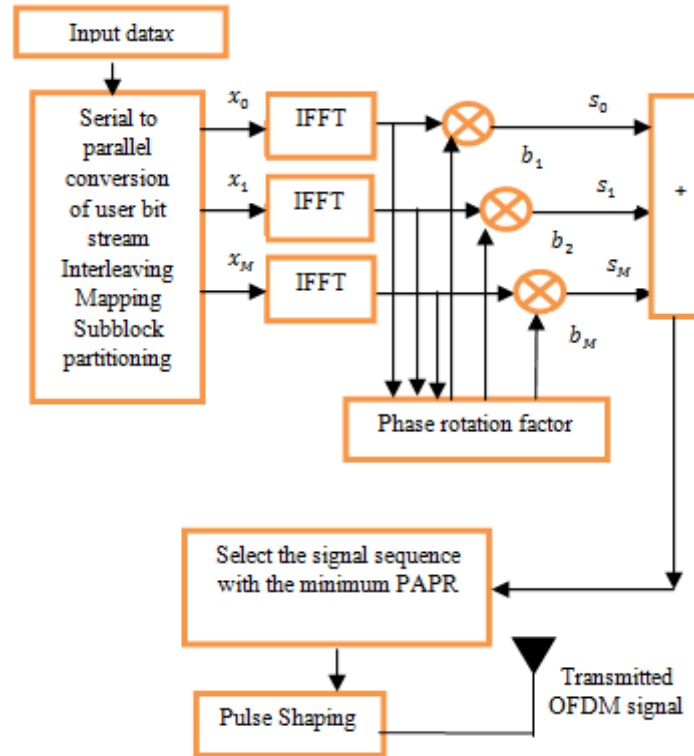


Figure 2: A typical structure of transmitter for PTS combined with interleaved OFDM signal

Sub-block partition for PTS OFDM is a technique of separation of subbands into multiple disjoint subblocks. Generally, it can be categorized into 3 groups; interleaved partition, adjacent partition, & pseudo-random partition. For the interleaved technique, each subblock signal spread out is allotted at the similar subblock. In the adjacent system, consecutive subblocks are allocated into the similar subblock consecutively. And all subblock signal is allocated into any one of the subblocks arbitrarily in the pseudo-random arrangement. It can be distinguished that the computational difficulty of the interleaved sub-block partitioning arrangement is condensed widely as compared to that of the adjacent & pseudo-random partition system.

B. Paper Calculation

OFDM signal is the sum of the multiple sinusoidal having frequency separation (1/T) where each sinusoidal gets modulated by the independent information a_k . Mathematically, the transmit signal is

$$x(t) = \sum_0^{k-1} a_k e^{\frac{j2\pi kt}{T}} \dots (1)$$

Due to the large number of sub-carriers in typical OFDM systems, the amplitude of the transmitted signal has a large dynamic range, leading to in-band distortion and out-of-band radiation when the signal is passed through the nonlinear region of power amplifier.

Peak Power

$$\text{Max}[x(t)x^*(t)] = \text{Max} \left[\sum_0^{k-1} a_k e^{\frac{j2\pi kt}{T}} \sum_0^{k-1} a_k^* e^{-\frac{j2\pi kt}{T}} \right] = K^2 \dots (2)$$

Average Power

$$E[x(t)x^*(t)] = E \left[\sum_0^{k-1} a_k e^{\frac{j2\pi kt}{T}} \sum_0^{k-1} a_k^* e^{-\frac{j2\pi kt}{T}} \right] = K \dots (3)$$



So, mathematically PAPR is given by,

$$PAPR = K^2 / K = K \quad \dots (4)$$

TABLE 2: Comparison of the reduction techniques

Technique	Implementation Complexity	Bandwidth Expansion	BER Degradation	Distortion
Clipping	Low	No	Yes	Yes
CODING	Low	Yes	No	Yes
PTS	High	No	No	No

C. Technical Description of PTS Method

The basic idea of partial transmit sequence arrangement is to distribute the original OFDM order into numerous sub sequences & for each sub sequence increased by dissimilar weights until anbest value is chosen. For executing PTS scheme possible phase features or weights are to be created depending on the mapping used. Every subsequence is increased with every weights created& PAPR is considered each time. The phase issues for which subsequence-weight product signals with minimum PAPR is acquired is selected as the best values for weight. Thus the signals with low PAPR is attained.

Let X is the random input signal in frequency domain with a length of N. X is divided into V disjoint sub blocks.

$$X_v = [X_{v,0}, X_{v,1}, \dots, X_{v,N-1}]^T \quad \dots (5)$$

Where $v = 1, 2, \dots, v$. The dividing of input signal in to sub blocks is such that the summation of these sub blocks provides the input signal X, ie.

$$\sum_{v=1}^V X_v = X \quad \dots (6)$$

Then these sub blocks are common in time domain. The sub block partition is based on interleaving in which the computational difficulty is less associatedto adjacent & Pseudo-random, however it has the worst PAPR performance between them. Then apply the phase rotation factor ' b_v ' to the IFFT of each of the sub blocks.

$$b_v = e^{j\theta_v} \quad \dots (7)$$

Where $v = 1, 2, \dots, V$. The time domain signal after merging is given by:

$$x'(b) = \sum_{v=1}^V b_v x_v \quad \dots (8)$$

Where $x'(b) = [x'_0(b), x'_1(b), \dots, x'_{NL-1}(b)]^T$ and L is the over sampling issue. The optimum signal $x'(b)$ with the lowest PAPR is to be found out.

Both b and x can be shown in matrix form as follows:

$$b = \begin{bmatrix} b_1, b_1, \dots, b_1 \\ \vdots \\ b_V, b_V, \dots, b_V \end{bmatrix}_{V \times N} \quad \dots (9)$$

$$x = \begin{bmatrix} x_{1,0}, x_{1,1}, \dots, x_{1,NL-1} \\ \vdots \\ x_{V,0}, x_{V,1}, \dots, x_{V,NL-1} \end{bmatrix}_{V \times NL} \quad \dots (10)$$

It should be distinguished that all the basics of each row of matrix b are of the similar values in this technique. In direction to have exact PAPR calculation, at least 4 times over sampling is essential. As the over sampling of x, add zeros to the vector, hence the amount of phase sequence to increase to matrix x will continue the similar.

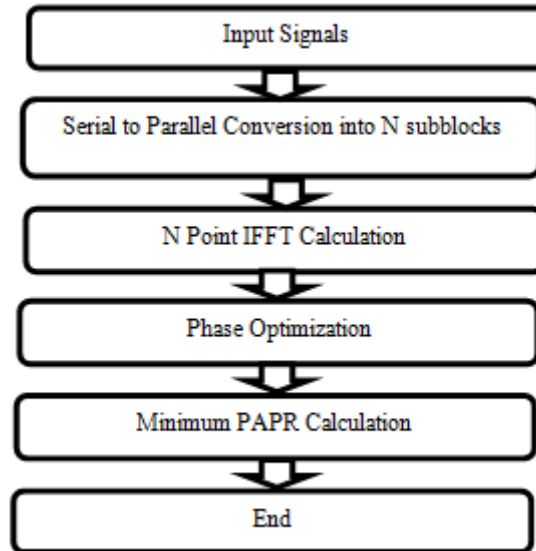


Figure 3: Flowchart for the PTS

The PTS contain of numerous inverse fast Fourier transform (IFFT) operations & complicated designs to obtain best phase sequence which consequences in growing the computational difficulty of PTS.

D. Selective Mapping Technique

In SLM technique, from a single OFDM sequence D having a length of N , number of sequences are generated that represent the same information using some rotation factors and the sequence with lowest PAPR is transmitted. If the number of generated new sequences is U , called the SLM length, then all these sequences are the result of multiplying the incoming original OFDM sequence D by U different rotation factors. These factors are given in vector form as

$$B^{(i)} = [b_0^{(i)}, b_1^{(i)}, \dots, b_{N-1}^{(i)}] \quad \dots (11)$$

where $i = 1$ to U and represents the indices of these factors and B is the represent the rotation factor in vector form. After multiplying these factors by the original OFDM sequence D , we get:

$$X^{(i)} = [d_0 b_0^{(i)}, d_1 b_1^{(i)}, \dots, d_{N-1} b_{N-1}^{(i)}] \quad \dots (12)$$

The multiplication factors are phase rotations selected appropriately such that multiplying a complex number by these factors results in rotation of that complex number to another complex number representing a different point in the constellation. Hence,

$$b_n^i = e^{-j\theta_n^i} \text{ where } \theta_n^{(i)} \in [0, 2\pi) \quad \dots (13)$$

Where θ is the angle of rotation. The rotation vectors are used as side information which are transmitted for signal recovery.

The efficiency of SLM approach depends on the amount of scrambling done by these rotation factors on the original OFDM sequence and the length of SLM U . As we increase number of SLM sequences, PAPR performance becomes better but at the expense of increase in system complexity.

Although SLM technique has moderate implementation complexity, this complexity increases as U increases. For this reason, many researchers devoted their work in this field towards improving the complexity computation of conventional SLM. The complexity of a typical SLM method considering no oversampling (i.e. $J = 1$) in terms of complexity additions are:

$$\text{Complexity} = UN \log_2 N \quad \dots (14)$$



E. Amplitude Clipping Technique

A high PAPR brings disadvantages like increased complexity of the ADC and DAC and also reduced efficiency of radio frequency (RF) power amplifier. One of the simple and effective PAPR reduction techniques is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. In Clipping, the amplitudes of the input signal are clipped to a predetermined value. However, clipping yields distortion power, which called clipping noise, and expands the transmitted signal spectrum, which causes interfering. Clipping and filtering technique is effective in removing components of the expanded spectrum. Although filtering can decrease the spectrum growth, filtering after clipping can reduce the out-of-band radiation, but may also cause some peak re-growth, which the peak signal exceeds in the clip level. The technique of iterative clipping and filtering reduces the PAPR without spectrum expansion. However, the iterative signal takes long time and it will increase the computational complexity of an OFDM transmitter. But without performing interpolation before clipping causes it out-of-band. To avoid out-of-band, signal should be clipped after interpolation.

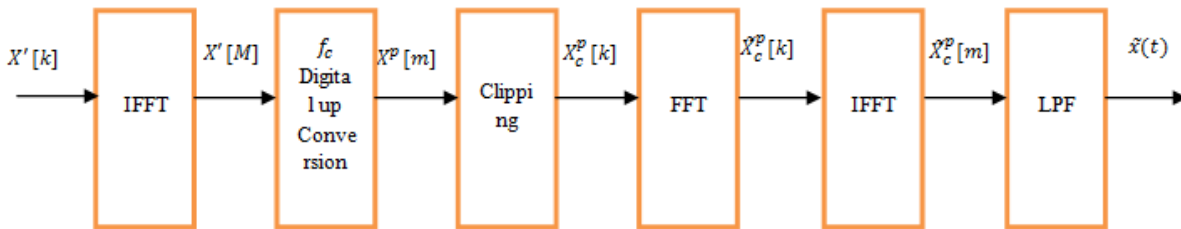


Figure 4: Clipping and Filtering Technique

However, this causes significant peak re-growth. So, it can use iterative clipping and frequency domain filtering to avoid peak re-growth. In the system used, serial to parallel converter converts serial input data having different frequency component which are base band modulated symbols and apply interpolation to these symbols by zero padding in the middle of input data. Then clipping operation is performed to cut high peak amplitudes and frequency domain filtering is used to reduce the out of band signal, but caused peak re-growth. This consists of two FFT operations. Forward FFT transforms the clipped signal back to discrete frequency domain. The in-band discrete components are passed unchanged to inputs of second IFFT while out of band components are null. Clipping introduces in band distortion and out of-band signals, which can be controlled by proper filtering

$$x_c^p[m] = \begin{cases} x^p[m] & \text{if } |x^p[m]| < A \\ \frac{x^p[m]}{|x^p[m]|} \cdot A & \text{Otherwise} \end{cases} \dots (15)$$

Where, A is the pre-specified clipping level. Note that Equation (16) can be applied to both baseband complex-valued signals and pass band real-valued signals be applied only to the passband signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS values of OFDM signal, such that

$$CR = \frac{A}{\sigma} \dots (16)$$

Results & Analysis

In this section, the practical PAPR performance of the proposed scheme has been evaluated. It is known that the PAPR reduction schemes can be mainly classified into two categories, i.e. distortion-less schemes such as SLM and PTS and the pre-distortion schemes such as clipping and *companding*.

In this sub section, we illustrate the performance of different algorithms which has been compared with the existing PAPR reduction methods using MATLAB simulations. The simulation has been done with an OFDM system which had 1024 symbols and uses M-QAM constellation modulation scheme on each sub carrier under Gaussian noise. The oversampling rate factor 4 to approximate the continuous time peak signal.



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The Complementary Cumulative Distribution Function (CCDF) is used to measure of PAPR reduction in OFDM system. Generally, the original OFDM system has the PAPR of 12dB. And it is well known by us that the 12dB is the conventional OFDM PAPR without applying any PAPR reduction methods to OFDM system. Comparison considers three algorithms: Amplitude Clipping, Selective Mapping, and PTS method for different values with their complimentary cumulative distributed function (CCDF). The auto-correlation function is a standard method to measure the degree of correlation within the sequence or periodic nature. In OFDM, the high peak occurs at the output of IFFT when the input data sequence applied at the input of IFFTs is strongly correlated. Therefore, to reduce the auto correlation at the input of IFFT, the input data sequences are multiplied with another sequence with low autocorrelation magnitude.

To make the system simple, the HPA is omitted from the transmitter. In addition, only a static channel (i.e., Additive White Gaussian Noise (AWGN) Channel) is considered throughout this simulation. Channel estimation is not performed here. Our aim is to just detect the symbols and see the effect of wrong detection on overall BER and in terms of results we proved that proposed PAPR reduction perform much better than standard methods. The OFDM receiver performance employing Proposed comparative analysis, partial transmit sequence are (dividing OFDM symbols into sub-blocks) are calculated from OFDM symbol after interleaving and phase shifting is analyzed with benefit of simulation factors listed in Table 2. LS channel estimation is employed to analyse the receiver performance in terms of MSE and BER. The PAPR performance of the OFDM system for $N=250$ and different sub blocks is shown in results. At CCDF between 0 to 1, the reduction in PAPR is about 28.18%, 40.91%, 54.55% and 62.73% for $V=2, 4, 8$ and 16 when compared to OFDM system without PAPR reduction. In this proposed comparison result analysis is based on these parameters.

TABLE 3: Lists the simulation parameters used.
Simulation parameters *Type value*

<i>Size of FFT</i>	1024
<i>Symbols per Carrier</i>	50
<i>Number of carriers 'N'</i>	200
<i>Number of sub blocks 'V'</i>	2,4,8 and 16
<i>Phase factors</i>	$+i, -i, +j, -j$
<i>Interleaving factor 'S'</i>	4
<i>Pulse shaping filter</i>	Raised cosine
<i>SNR</i>	10

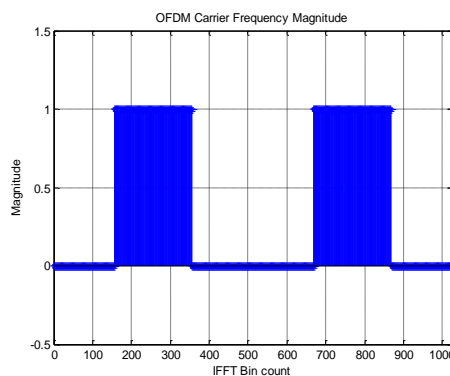


Figure 5: Figure shows the Magnitude of signal with respect to IFFT bin count for transmitted OFDM signal.

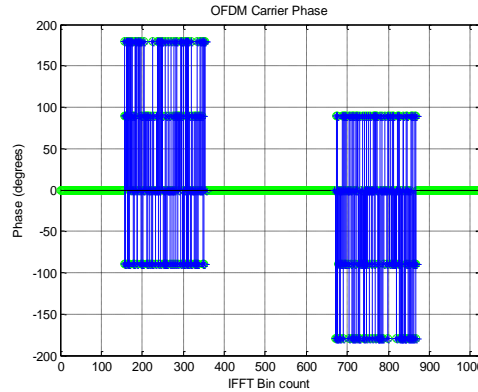


Figure 6: Shows the OFDM carrier phase, in which phase in degrees of OFDM signal is extracted with respect to IFFT bin count for transmitted OFDM signal.

To illustrate the performance, an N subcarrier OFDM system with M-QAM modulation is considered. For an accurate estimation of PAPR, the signal is oversampled by a factor of 4 ($L = 4$), and the 1024 random OFDM blocks have been generated to obtain the numerical results. The results are illustrated using the CCDF, and PAPR is measured with and without the proposed PAPR reduction technique.

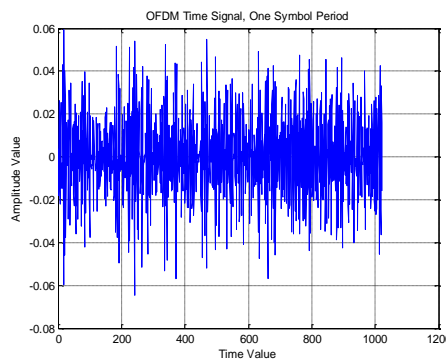


Figure 7: The graph above shows Amplitude value of signal with respect to time slot (1024) taken for transmitted OFDM signal.

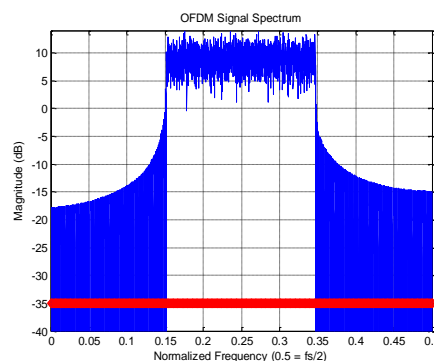


Figure 8: The graph obtained shows a signal spectrum of Proposed OFDM system. X axes shows the normalized frequency defined for proposed system and Magnitude in dB is shown in Y axes for transmitted OFDM signal.

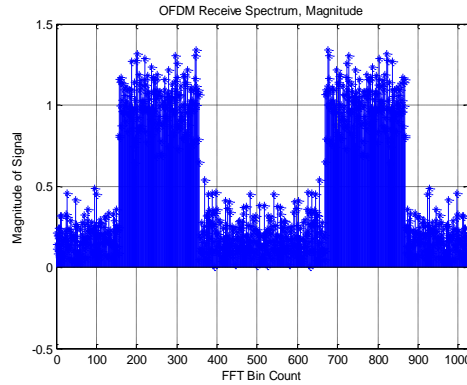


Figure 9: Figure above shows a OFDM received signal spectrum. It shows the magnitude of signal received with respect to the FFT bin count for the signal received at Receiver.

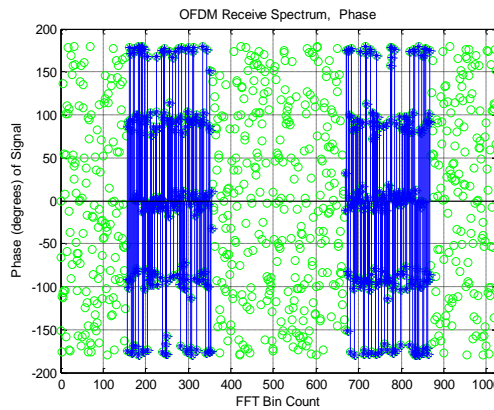


Figure 10: Figure above shows phase information of received signal spectrum. In figure, phase of the received signal is plotted with respect the FFT bin count for the signal received at the receiver after adding noise within the channel.

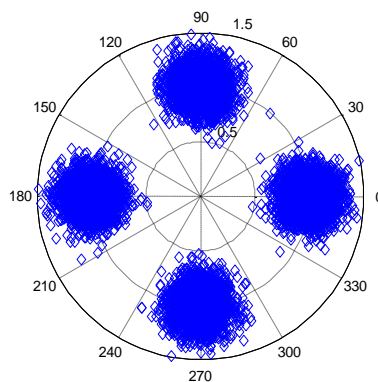


Figure 11: Figure above shows the polar plot of the received signal spectrum with respect to the channel information. It shows distribution of signal spectrum across a polar spectrum.



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TABLE 4: PAPR values with respect to CCDF for all the techniques considered in simulation.

CCDF	Value of PAPR			Original PAPR
	Clipping	SLM	PTS	
0.8	9.3582	9.4254	3.3695	10.8653
0.6	9.1956	9.7881	3.1974	10.7844
0.4	10.1647	9.8752	3.1526	10.9672
0.2	20.4691	10.7383	3.2648	11.8564
0.0	20.7095	21.1958	3.9167	27.7624

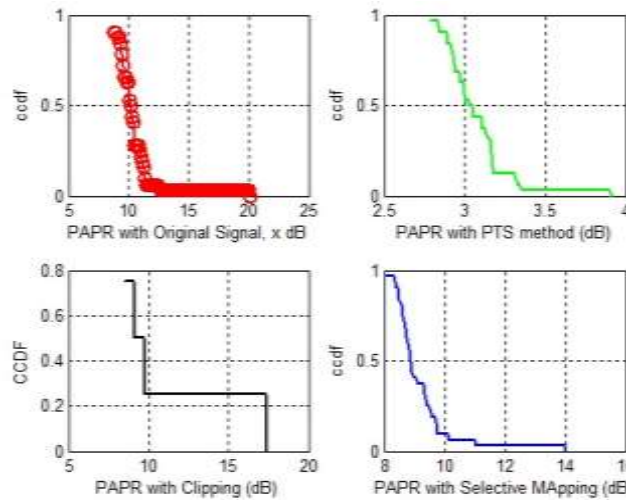


Figure 12: Comparative view of PAPR values with respect to CCDF for all the techniques used for the simulation. It is clear from the figure that line shown in green for the PTS having lower values of PAPR for all values of CCDF.

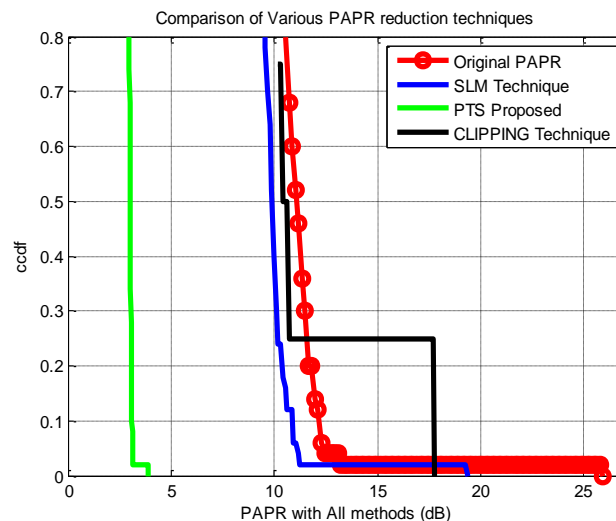


Figure 13: Figure above shows a comparative view of PAPR with respect to different values of CCDF for all 3 techniques used for the simulation.

From figure, it is clear that the PTS method for PAPR reduction technique perform much better than other techniques. We are getting a very lower value of PAPR of approximately ~4 dB by using standard PTS method.



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From figure 12 and figure 13, this section conclude that and also here results shows that, this proposed PAPR reduction technique successfully extends the stable region to more than ~ 3 dB & the PAPR reduced to less than ~ 4 dB and outperformed successfully other techniques considered in simulation.

Conclusion

Peak value of the independently modulated sub-carriers in the OFDM system is actual high compared to the average value. Ratio of this value is called the peak-to-average power ratio (PAPR). Though the OFDM has many benefits such as the high spectral efficiency, robustness to the channel fading, immunity to impulse the interference, capacity to handle very robust echoes & the less non-linear distortion it also has disadvantage of high PAPR. The Complementary Cumulative Distribution Function (CCDF) is used to measure of PAPR reduction in OFDM system. Generally, the original OFDM system has the PAPR of 12dB. And it is well known by us that the 12dB is the conventional OFDM PAPR without applying any PAPR reduction methods to OFDM system. Comparison considers three algorithms: Amplitude Clipping, Selective Mapping and PTS for different values with their complimentary cumulative distributed function (CCDF). Our aim is to just detect the symbols and see the effect of wrong detection on overall BER and in terms of results we proved that PTS method PAPR reduction perform much better than standard methods.

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