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Effective Performance Analysis of Peak Power Reduction in Orthogonal Frequency Division Multiplexing System

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***Abstract*-Orthogonal Frequency Division Multiplexing (OFDM) is a digital transmission method developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments. Coding, Phase rotation and Clipping are among many PAPR reduction schemes that have been proposed to overcome this problem. In this paper, we are analysed on three different PAPR reduction methods e.g. Partial Transmit Sequence (PTS) and Selective Mapping (SLM) are used to reduce PAPR. Significant reduction in PAPR has been achieved using these techniques. The performances of the two methods are then compared. Next, Clipping and Filtering (CAF) techniques are presented which reduce substantially the complexity of clipping algorithms by using novel methods to calculate the magnitude, avoiding the use of multiplication. A novel idea is presented to show the effect of HPA and noise on the OFDM signal and introduction of clipping as PAPR reduction method to reduce the power amplifier effect. Comparison between data phase representation of clipped and unclipped OFDM signal can also be seen.**

I. INTRODUCTION

With the advance of communications technology comes the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links. New modulation schemes are required to transfer the large amounts of data which existing 3rd generation schemes such as Global System Mobile (GSM), its enhanced version Enhanced Data Rates for Global Evolution (EDGE), and Wideband Code Division Multiple Access (WCDMA) cannot support. These new modulation schemes must be able to act over point to point links and in broadcast mode, support bi-directional communications, and be able to adapt to different requirements of individual services in terms of their data rate, allowable Bit Error Rate (BER), and maximum delay[1]. One new modulation scheme which has received significant attention over the last few years is a form of multicarrier modulation called Orthogonal Frequency Division Multiplexing (OFDM). OFDM has been used for Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) in Europe, and for Asymmetric Digital Subscriber Line (ADSL) high data rate wired links. OFDM has also been standardized as the physical layer for the wireless networking standard 'HIPERLAN2' in Europe and as the IEEE 802.11a, g standard in the US, promising raw data rates of between 6 and 54Mbps. OFDM has various properties that make it desirable over existing single carrier systems, the main advantage is OFDM's immunity to frequency selective fading**.** Single carrier systems can increase their data rate by shortening the symbol time, thereby increasing the occupied bandwidth.[2] Wideband channels are sensitive to frequency selective fading which require complex equalizers in the receiver to recover the original signal. OFDM overcomes this problem by dividing the wideband channel into a series of narrowband channels which each experience flat fading. Therefore only 1 tap equalizers are required in the receiver, reducing complexity greatly. Other factors such as advances in silicon and Digital Signal Processing (DSP) allow the use of efficient Fourier transforms in the transmitter and receiver to perform the modulation, demodulation respectively. Due to the orthogonality of the subcarriers the transmission bandwidth is used efficiently as the subcarriers are allowed to overlap each other and still be decoded at the receiver. Despite the many advantages of OFDM it still suffers from some limitations such as sensitivity to carrier frequency offset and a large Peak to Average Power Ratio (PAPR). The large PAPR is due to the superposition of N independent equally spaced subcarriers at the output of the Inverse Fast Fourier Transform (IFFT) in the transmitter. A large PAPR is a problem as it requires increased complexity in the word length at the output of the IFFT and the Digital to Analog Converter (DAC). Perhaps the most serious problem is the reduced efficiency of the High Power Amplifier (HPA) which must cater for these low probability large peaks. If the high PAPR is allowed to saturate the HPA out of band radiation is produced affecting adjacent channels and degrading the BER at the receiver. As portable devices have a finite battery life it is important to find ways of reducing the PAPR allowing for a smaller more efficient HPA, which in turn will mean a longer lasting battery life.

II. OFDM SYSTEM MODEL

A. MODULATION

OFDM symbol consists of N subcarriers which have constant spacing Δf. Bandwidth of that signal is $B = \Delta f \cdot N$ and symbol time $T = 1/\Delta f$, This leads to sum of N sinusoids in the time domain, that have exactly an integer number of cycles in the interval T. Each subcarrier is modulated by complex value $X_{m,n}$, where m denotes symbol index and n subcarrier index. M-th OFDM symbol can be written as:

$$x_m = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_{m,n}\, g_n(t - mT) \qquad (1)$$

where $g_n(t)$ means: $g_n(t) = \exp(j2\pi n\Delta ft)$, for $0 \le t \le T$ and $g_n(t)=0$, for other t.

Time domain signal can be written as sum of symbols:

$$x = \frac{1}{\sqrt{N}} \sum_{m=0}^{\infty} X_{m,n} \sum_{n=0}^{N-1} X_{m,n}\, g_n(t-mT) \quad (2)$$

The complex value $X_{m,n}$, depends of partial modulation. Usually M-PSK or M-QAM is used.

B.PEAK PROBLEM

OFDM consists of lots of independent modulated subcarriers (without considering coding). That leads to problem with peak to average power ratio. If N subcarriers are in phase (same symbols modulated on all subcarriers), the peak power is N times average power. For sampled signal, PAPR is defined:

$$\text{PAPR}=\frac{P_{peak}}{P_{average}} = \frac{\max[|S_n|^2]}{E[|S_n|^2]} \quad (3)$$

Where P_{peak} represents peak output power, $P_{average}$ means average output power and $E[|S_n|^2]$ is average power of transmitted symbol. To get proper values of PAPR oversampling is necessary. Oversampling can be performed by padding IFFT source data with zeros. The time domain signal is usually oversampled by factor of four or greater. For an OFDM system with N sub-carriers, the peak power of received signals is N times the average power when phase values are the same. The PAPR of baseband signal will reach its theoretical maximum at (dB) =10log N.

Another commonly used parameter is the Crest Factor (CF), which is defined as the ratio between maximum amplitude of OFDM signal $s(t)$ and root-mean-square (RMS) of the waveform. The CF is defined as

$$CF(S(t)) = \frac{\max[|S_n|^2]}{E[||S_n|^2|]} = \sqrt{PAPR} \quad (4)$$

In most cases, the peak value of signal s(t) is equals to maximum value of its envelope (t).

In practice, it is preferred to take the probability of PAPR exceeding a threshold as measurement index to represent the distribution of PAPR. This can be described as "Complementary Cumulative Distribution Function" (CCDF), and its mathematical expression as:

$$(PAPR > z) = 1 - P\,(PAPR \le z) = 1 - F(z)^N = 1-(1-\exp -z)^N \quad (5)$$

In this paper, we will use CCDF to evaluate the performance of various PAPR reduction techniques

III. PAPR REDUCTION TECHNIQUES

Several PAPR reduction techniques have been proposed in the literature. These techniques are divided into two groups. These are signal scrambling techniques and signal distortion techniques.

A. PEAK TO AVERAGE POWER SOLUTIONS-DISTORTIONLESS

Distortionless techniques do not corrupt the data and encode it in such a way that it can be completely recovered at the receiver, however they are usually more complex.

(i) *SELECTED MAPPING METHOD*

In selected mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks $\boldsymbol{S}_m=[S_{m,0},S_{m,1},\ldots,S_{m,N-1}]^T$, $m=1,2,\ldots,M$ are then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols $\boldsymbol{x}_m=[x_1,x_2\ldots,x_N]^T$ in discrete time-domain are acquired, and then the PAPR of these M vectors are calculated separately. Eventually, the sequences x_d with the smallest PAPR will be elected for final serial transmission.Fig.3.1,[17] illustrates the basic structure of selected mapping method for suppressing the high PAPR.

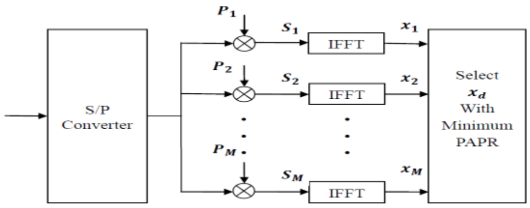

FIG. 3.1 BASIC PRINCIPLES OF SELECTED MAPPING

This method can significantly improve the PAPR performance of OFDM system. The reasons behind that are: Data blocks $\boldsymbol{S}_m=[S_{m,0},S_{m,1},\ldots,S_{m,N-1}]^T$, $m=1,2,\ldots,M$ are statistical independent, assuming that for a single OFDM symbol, the CCDF probability of PAPR larger than a threshold is equals to p. The general probability of PAPR larger than a threshold for k OFDM symbols can be expressed as p^K. It can be verified that the new probability obtained by SLM algorithm is much smaller compared to the former. Data blocks $\boldsymbol{S}_m$ are obtained by multiplying the original sequence with M uncorrelated sequence $\boldsymbol{P}_m$. In the reality, all the elements of phase sequence P_1 are set to 1 so as to make this branch sequence the original signal. The symbols in branch m is expressed as[8]

$$\boldsymbol{S}_m=[X_0P_{m,0},X_1P_{m,1},\ldots,X_{N-1}P_{m,N-1}]^T,\ m=1,2,\ldots,M \quad (6)$$

And, then transfer these M OFDM frames from frequency domain to time domain by performing IFFT calculation.

The entire process is given by

$$Xm(t) = \frac{1}{\sqrt{N}} \sum_0^{N-1} X_n P_{m,n} \cdot e^{j2\pi n \Delta f t},\ 0 \le y \le NT,\ m = 1,2,\ldots M$$

(7)

Finally, the one which possess the smallest PAPR value is selected for transmission. Its mathematical expression is given as

$$x_d = arg\ min_{1 \le m \le M}(PAPR(xm)) \quad (8)$$

Where, argmin (·) represent the argument of its value is minimized.

At the receiver, in order to correctly demodulate the received signal, it is necessary to know which sequence is linked to the smallest PAPR among *M* different candidates after performing the dot product.

(ii) *PARTIAL TRANSMIT SEQUENCE*

The crucial idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequence, multiplied by different weights until an optimum value is chosen. Let the sub-blocks have the same size and no gap between them, the sub-block vector is given by:

$$\hat{X} = \sum_{v=1}^{V} b_v X_v \quad (9)$$

Where, $b_v = e^{j\varphi v}$ ($\varphi_v \in [0,2\pi]$){ $v=1,2,\ldots,V$} is a weighting factor been used for phase rotation .The signal in time domain is obtained by applying IFFT operation on X_v , that is

$$\hat{X} = IFFT(X) = \sum_{v=1}^{V} b_v IFFT(X_v) = \sum_{v=1}^{V} b_v X_v \quad (10)$$

Select one suitable factor combination **b**= [b_1, b_2, ..,] which makes the result achieve optimum. The combination can be given by

$$b = [(b_{1,2}, \ldots, b_v)] = \operatorname{argmin}(b_1, b_2, \ldots, b_v)\left(\max_{1 \le n \le N}\left|\sum_{v=1}^{V} b_v X_v\right|^2\right) \quad (11)$$

Where argmin (·) is the judgment condition that output the minimum value of function. In this way we can find the best **b** so as to optimize the PAPR performance. The additional cost we have to pay is the extra *V*-1 times IFFTs operation.

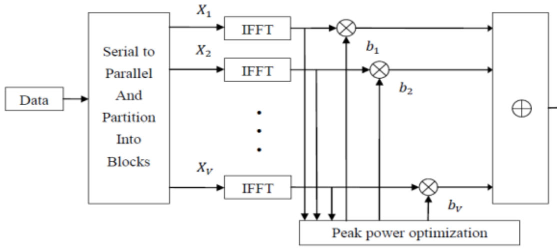

FIG. 3.2 BLOCK DIAGRAM OF PTS ALGORITHM.

In conventional PTS approach, it requires the PAPR value to be calculated at each step of the optimization algorithm, which will introduce tremendous trials to achieve the optimum value [9]. Furthermore, in order to enable the receiver to identify different phases, phase factor **b** is required to send to the receiver as sideband information (usually the first sub-block b_1, is set to 1). So the redundancy bits account for (晦−1) $\log_2 W$, in which *V* represents the number of sub-block, *W* indicates possible variations of the phase. This causes a huge burden for OFDM system, so studying on how to reduce the computational complexity of PTS has drawn more attentions, nowadays. The optimization is achieved by searching thoroughly for the best phase factor. Theoretically, **b**= [$b_{1,2,\ldots,}b_v$] is a set of discrete values, and numerous computation will be required for the system when this phase collection is very large. For example, if φ_v contains *W* possible values, theoretically, **b** will have W^V different combinations, therefore, a total of $V \cdot W^V$ IFFTs will be introduced.

By increasing the *V*, *W*, the computational cost of PTS algorithm will increase exponentially. For instance, define phase factor b_v contains only four possible values, that means $b_v \in [\pm 1, \pm j]$, then for each OFDM symbol, $2 \cdot V-1$ bits are transmitted as side information. Therefore, in practical applications, computation burden can be reduced by limiting the value range of phase factor **b**= [$b_{1,\ 2,\ldots,}$] to a proper level. At the same time, it can also be changed by different sub-block partition schemes.

B. *PEAK TO AVERAGE POWER SOLUTIONS-DISTORTION TECHNIQUES*

Signal distortion techniques are Peak Windowing, Envelope scaling, Peak Reduction Carrier, Clipping and Filtering.

(i) *CLIPPING AND FILTERING*

One of the simple and effective PAPR reduction techniques is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. However, clipping yields distortion power, which called Clipping noise, and expands the transmitted signal spectrum, which causes interfering. Clipping is nonlinear process and causes in-band noise distortion, which causes degradation in the performance of bit BER and out-of-band noise, which decreases the spectral efficiency [4]. 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 [9]. 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 [8].But without performing interpolation before clipping causes it out-of-band. To avoid out-of-band, signal should be clipped after interpolation. However, this causes significant peak re-growth. So, it can use iterative clipping and frequency domain filtering to avoid peak re-growth.

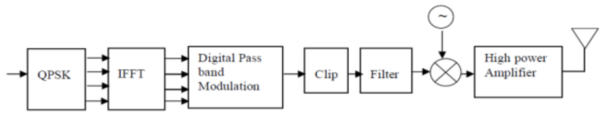

FIG. 3.3 BLOCK DIAGRAM OF A PAPR REDUCTION SCHEME USING CLIPPING AND FILTERING.

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IV. SIMULATION AND RESULTS

A. *SIMULATION OF SLM SCHEME*

Fig. 4.1 shows the theoretical CCDF curves as a function of PAPR distribution when SLM method is used. The number of *N* sub-carriers is 128. *M* takes the value of 1 (without adopting SLM method), 2, 8, 32 and 128. It is seen in Fig. 4.1 that with increase of branch number *M*, PAPR's CCDF distribution gets smaller and smaller.

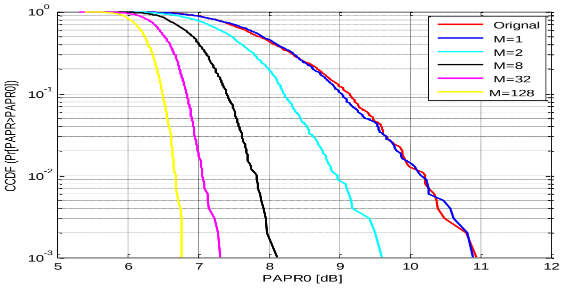


FIG. 4.1 THEORETICAL PAPR'S CCDF CURVES USING SLM METHOD.

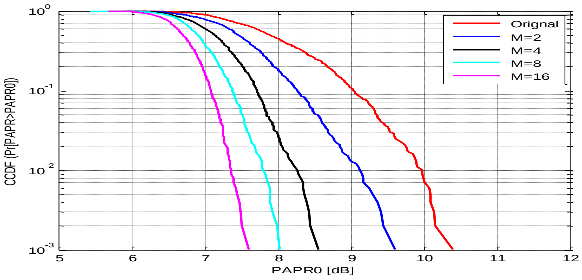


FIG. 4.2 COMPARISON OF PAPR REDUCTION PERFORMANCES WITH DIFFERENT VALUES OF *M*

In fig.4.2, it seems that that the ability of PAPR reduction using SLM is affected by the route number *M* and subcarrier number *N* [9]. Therefore, simulation with different values of *M* and *N* and the results exhibits some desired properties of signals representing same information. Comparison of PAPR reduction performance with different values of *M* while *N* is fixed at 128. Rotation factor is defined as *Pm*, ∈[±1,±*j*]. This reduces calculation complexity dramatically compared to performing miscellaneous complex multiplication. The algorithm executes 10000 times, over-sampling factor is 8 and QPSK mapping is adopted as modulation scheme in each sub-carrier. Route numbers *M*=2, *M*=4, *M*=8, *M*=16 and *M*=32 are used. From Fig. 4.2, it can be observed that the proposed SLM method displays a better PAPR reduction performance than the original OFDM signal which is free of any PAPR reduction scheme. The probability of high PAPR is significantly decreased. Increasing *M* leads to the improvement of PAPR reduction performance. If the probability is set to 1% and then the CCDF curves with different *M* values are compared. The PAPR value of case *M*=2 is about 1dB smaller than the unmodified one *M*=1. Under the same condition, the PAPR value of case *M*=16 is about 3dB smaller than the original one *M*=1. However, from the comparison of the curve *M*=8 and *M*=16, we learned that the performance difference between these two cases is less than 0.5dB. This proves that we will not be able to achieve a linear growth of PAPR reduction performance with further increase the value of *M* (like *M*>=8), the PAPR reduction performance of OFDM signal will not be considerably improved.

B. *SIMULATION OF PTS SCHEME*

We realized from the above discussion that in PTS approach, there are varying parameters impact the PAPR reduction performance, these are: (1) The number of sub-blocks *V*, which influences the complexity strongly; (2) The number of possible phase value *W*, which impacts the complexity as well; and (3) The sub-block partition schemes. In our simulation, two parameters will be considered. They are sub-block sizes *V* and different sub-block partition proposals.

(a) PAPR reduction performance effects by number of sub-blocks *V*

Simulation evaluates the PAPR reduction performance using PTS algorithm with different V, in which simulation configuration, QPSK is applied, *N* = 256 and V = 0, 2, 3, 4, respectively. From Fig. 4.3, it can be seen that PTS algorithm undeniably improve the performance of OFDM system, moreover, with the increasing of V, the improvement of PAPR reduction performance becomes better and better. Assume that we fix the probability of PAPR at 1%, and compare the CCDF curve with different V values. Form the figure, we notice that the CCDF curve has nearly 1.5dB improvement when V = 2, compared to the conventional OFDM system. When V = 4, the 1% PAPR is about 6.6dB, so an optimization of more than 3 dB is achieved. However, the downward trend of CCDF curve is tended to be slow when we keep on increasing *V*, which means too large sub-block numbers *V* will result in small improvement of PAPR reduction performance, but pay for the tremendous hardware complexity. Therefore, practically, we prefer to choose a suitable value of *V* to achieve a trade off in the use of PTS.

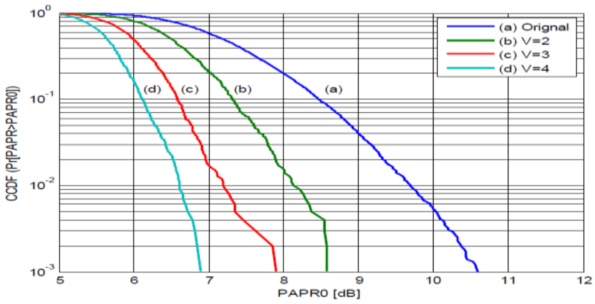


FIG. 4.3 COMPARISON OF PAPR REDUCTION PERFORMANCES WITH DIFFERENT VALUES OF *V*.

(b) PAPR reduction performance effects by different value range

The simulation result in Fig. 4.4 shows the varying PAPR reduction performance with different *W* (collection range of weighting factor *bv*) when using PTS reduction scheme. Simulation specific parameters are: the number of sub-carriers *N* = 128, QPSK constellation modulation, oversampling factor takes *L* = 8, the number of sub-block *V* = 4. From the figure we notice that the CCDF curve has nearly 1dB improvement when *W* = 4, compared to *W* = 2, the 1% PAPR is about 7.5 dB. We conclude that in a PTS-OFDM system, the larger *W* value takes, the better PAPR performance will be obtained when the number of sub-block *V* is fixed.

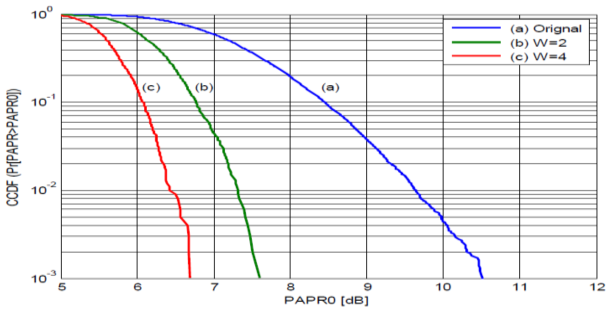


FIG.4.4 COMPARISON OF PAPR REDUCTION PERFORMANCES WITH DIFFERENT VALUES OF *W*.

C. *COMPARISON OF SLM AND PTS ALGORITHM*

(a) COMPARISON OF AUXILIARY INFORMATION

SLM and PTS algorithms are two typical non-distortion techniques for reducing PAPR in OFDM system. In order to have error-free demodulation in the receiving end, side information must be sent to the receiver, correctly. Hence, in practical application often requires the use of some coding measures to protect information from being disturbed. Since this thesis only focuses on studying PAPR reduction performance in OFDM system with different algorithms, and does not reflect on the modulation in receiving end. Thus, we will look at the redundancy of auxiliary information rather than coding redundancy.

In PTS method, if the collection range of weighting factor is *W*, then for *V* sub-blocks, the system exists W^{V-1} types of auxiliary information sequence, so the number of redundant bits is $R_{ap}=(V-1)\log_2 W$. By the same token, in SLM method, if the length of sequence *Pm* is *M*, then in SLM-OFDM system, it requires redundant bits $R_{ap}=\log_2(M-1)$. As can be seen from Table 4.1, under the same circumstances, PTS method requires a higher information redundancy, compare to SLM algorithm.

TABLE 4.1 THE NUMBER OF REDUNDANT BITS USED IN PTS AND SLM METHOD WITH DIFFERENT *V* AND *M*

		V=M=2	V=M=4	V=M=8	V=M=16
PTS	W=2	1	3	7	15
	W=4	2	6	14	30
	W=8	3	9	21	45
SLM		0	1.58	2.81	3.91

(b) *COMPARISONF PAPR REDUCTION PERFORMANCES BETWEEN SLM AND PTS METHOD*

Fig. 4.5 shows the simulation result of using SLM and PTS method to an OFDM system, separately. In PTS method, we set the number of sub-carriers *N* = 128 and applying pseudo-random partition scheme, for each carrier, adopting QPSK constellation mapping, weighting factor $b_v \in [\pm1,\pm j]$; In SLM method, rotation factor $P_{m,n} \in [\pm1,\pm j]$. Based on the theory, we know that the IFFT calculation amount of these two methods is same when *V* = *M*, but for PTS method, it can provide more signal manifestations, thus, PTS method should provide a superior performance on PAPR reduction. In fact, this deduction is confirmed by simulation result. From the Figure 4.5, we learned that with the same CCDF probability 1%, the PAPR value equals to 7dB when PTS is employed, while the PAPR raise up to 8.2dB when SLM is employed under the same circumstance.

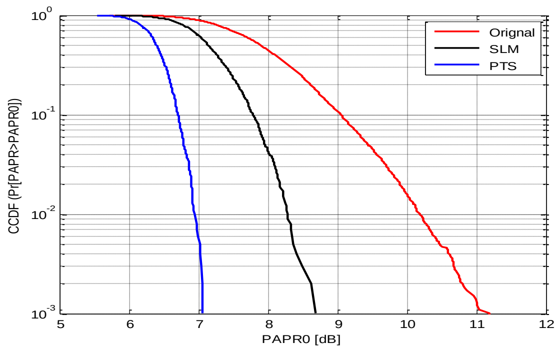


FIG.4.5 COMPARISON OF PAPR REDUCTION PERFORMANCES BETWEEN PTS ALGORITHM AND SLM ALGORITHM FOR PTS-OFDM SYSTEM.

It shows clearly that PTS method provides a better PAPR reduction performance compared to SLM method. Nevertheless, the cost is also payed for sacrificing transmission efficiency and rising complexity. Thus, in practical applications, a trade off should be made between good performance and auxiliary information. From the discussion above, we can say that SLM algorithm is more suitable if system can tolerate more redundant information, otherwise, PTS algorithm is more acceptable when complexity becomes the first considering factor. In brief, compromise will be made for a reliable system.

D. *CLIPPING AND FILTERING*

(1) *CLIPPING*

Our investigation with the help of MATLAB CODING (m-file) depends on the analysis of the various subsections as stated below:-

A: Parameter specifications

B: Transmitter section

C: Clipping as a PAPR reduction method

D: Analyzing of effect of high power amplifier

E: Generation of complex multipath channel

F: Receiver section

The detailed analysis of these sections is being listed below:

A: *PARAMETER SPECIFICATIONS*

In this section we have assumed an OFDM signal with following specifications:

1. QPSK signal constellation i.e. M=4;
2. No _of _data_points=128;
3. Size of each OFDM block i.e. block_size=8;

   Length of cyclic prefix i.e. cp_length=

   ceil(0.1*block_size);

Note:-where "ceil" rounds the element to the nearest integer towards infinity.

4. no_of _ifft _points and no_of_fft_points is considered to be equal to" block _size".
5. Clipping of transmitted signal is done so that a signal remains between +0.4 to -0.4 average value.

B: *TRANSMITTER SECTION*

Initially 1*128 random data points are generated and then QPSK modulation technique is performed which provides the complex envelope of modulating the message signal using the phase shift keying.

Message signal consists of integer values between zero (0) to M-1.Inverse Fast Fourier Transform (IFFT) is now performed on each block by finding out the number of columns that will exist after reshaping an empty matrix is created to put the IFFT data and it operates column wise by appending cyclic prefix which leads to the creation of OFDM block. Data is converted to serial stream for the purpose of transmission and actual OFDM signal to be transmitted is generated.

C: *CLIPPING AS A PAPR REDUCTION METHOD*

OFDM signal suffers from high PAPR or crest factor which may require a large amplifier power back-off.

Hence, clipping of transmitted signal is done so that a signal remains between +0.4 to -0.4 average value.

D: *ANALYZING OF EFFECT OF HIGH POWER AMPLIFIER*

In order to show the effect of power amplifier, random complex noise is generated and then clipped signal and original OFDM signal (unclipped) are passed through high power amplifier.

E: *GENERATION OF COMPLEX MULTIPATH CHANNEL*

The signals are transmitted through complex multipath channel to the receiver for the purpose of demodulation.

F: *RECEIVER SECTION*

In the receiver section clipped and unclipped data is converted back to parallel form in order to perform Fast Fourier Transform (FFT). Cyclic prefix is removed and data is again converted to serial stream and demodulated.

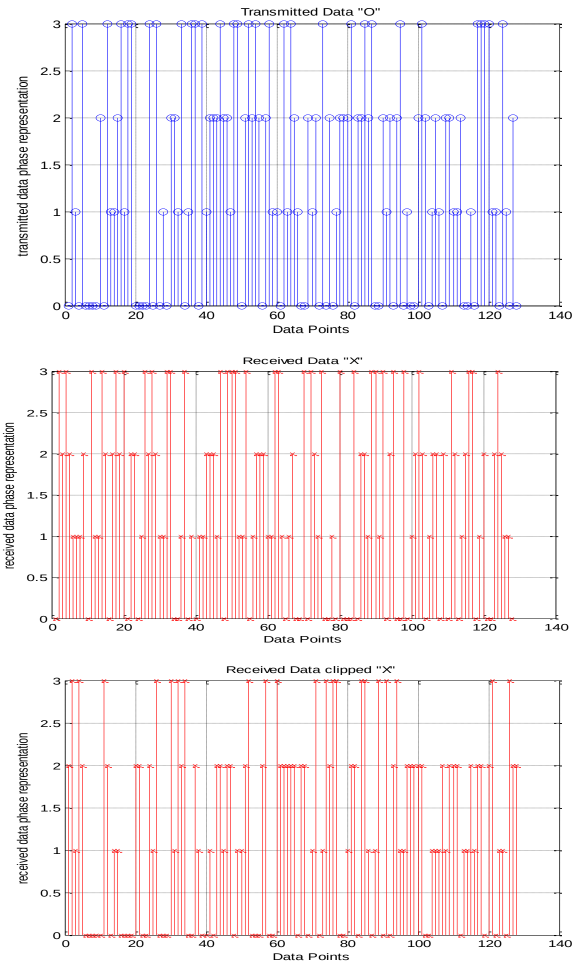


FIG. 4.6 COMPARISON BETWEEN DATA PHASE REPRESENTATION OF TRANSMITTED OFDM SIGNAL AND RECEIVED UNCLIPPED AND CLIPPED OFDM SIGNAL.

(2) *CLIPPING AND FILTERING*

One of the simplest methods to reduce PAPR is by clipping the peak. Clipping is nonlinear process so that it causes in-band distortion and out-of-band emission. Out-of-band emission can be handled by filtering. Thus, it is common that clipping is followed by filtering. The principle of clipping is shown in figure below.

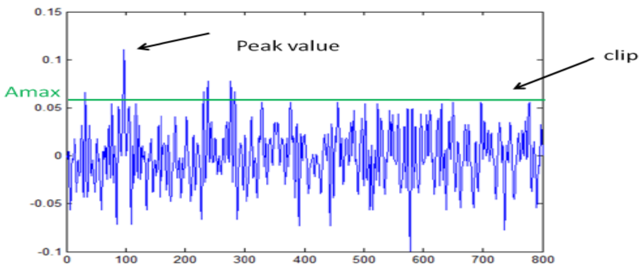
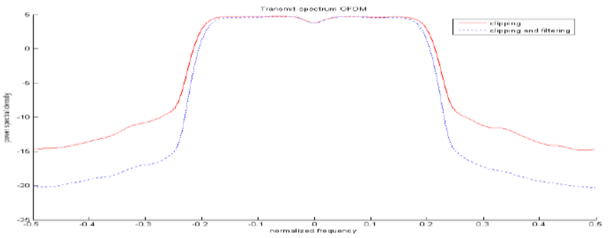
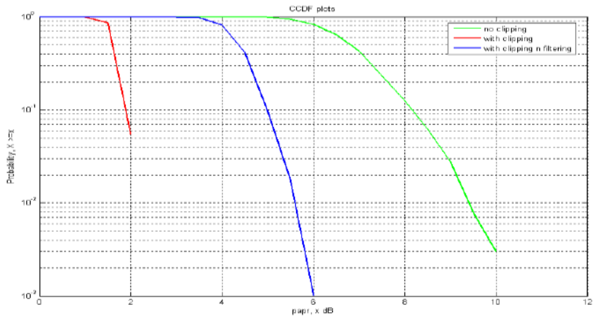


FIG. 4.7 PRINCIPLE OF CLIPPING

As stated above, filtering can reduce the out-of-band emission caused by clipping. However, filtering may increase PAPR (peak regrowth). Figures below explain those statements.





Xiaodong Li took CR value of 1.4 as optimal value. CR = 1.4 means that clipping level is 3 dB higher than Rms level.

(3) *ITERATION CLIPPING AND FILTERING METHOD*

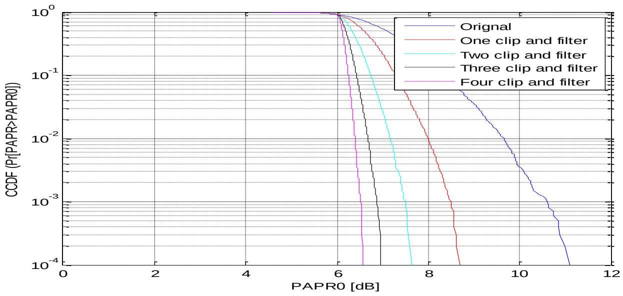


Fig.4.8 Cumulative Distributions For Signal After Papr Reduction

The fig4.8 shows the complementary cumulative distribution function of the oversampled signal after one to four stages of clipping and filtering. In this case N=128, the modulation used is QPSK and CR is chosen to be 6dB. It is seen from the graph that repeated clipping and filtering significantly reduces the PAPR and the performance in the table 4.2 indicates the reduction in PAPR value

.

TABLE 4.2 PAPR REDUCTION USING CLIPPING & FILTERING

	CCDF Pr[PAPR>PAPR0])	**PAPR0(dB)**
Original	10^{-3}	10.5
After one clip and filter	10^{-3}	9
After two clip and filter	10^{-3}	8.5
After three clip and filter	10^{-3}	7
After four clip and filter	10^{-3}	7.5

Clipping causes in-band noise, which is approximately white, and this causes degradation in the BER performance. This degradation is investigated by plotting the BER versus SNR for various clipping ratio as shown in Fig. 4.7**.** BER performance of the system improves with increase in CR from 0.6 to 0.9.

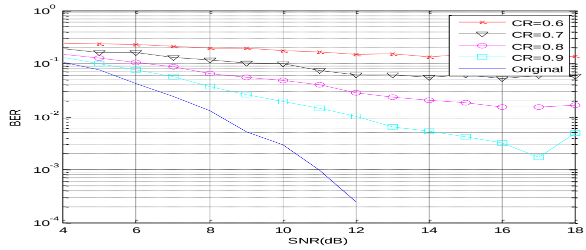


Fig.4.9 Ber Performance Varying Clipping Ratio (Cr= 0.6, 0.7, 0.8, 0.9) For N=64

CONCLUSION

The bottleneck problems that exist in OFDM wireless communication system – high peak-average power ratio (PAPR) of OFDM signal, and discuss how to reduce it by different effective algorithms. We have analysed the performance of three different algorithms viz. Selective Mapping, Partial Transmit Sequence, Clipping and Filtering to reduce High PAPR of OFDM Signal. In this paper to reduce PAPR we are analysed SLM and PTS which are signal scrambling techniques. From the comparison curve of the SLM and PTS techniques, SLM algorithm is more suitable if system can tolerate more redundant information otherwise PTS algorithm is more acceptable when complexity becomes first considering factor and we have analysed a clipping and filtering method to reduce PAPR in OFDM system. We observed that Amplitude Clipping and Filtering reduce complexity as compared to Selected Mapping (SLM) and Partial Transmit Sequence (PTS)is shown in table below and also we have also analysed a iterative clipping and filtering method to reduce PAPR and its performance is much better as compared to novel clipping scheme but it has distortion is obatained. We have analysed no efficient method to reduce PAPR in OFDM system because it is depend on system requirements.

Table Comparison Between Different PAPR Reduction Techniques

	Distortion	**Power Increase**	**Data Rate Loss**	**Complexity**
Clipping and Filtering	YES	NO	NO	LOW
Selected Mapping	NO	NO	YES	LOW HIGH
Partial Transmit Sequence	NO	NO	YES	LOW HIGH

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