Analysis of the Techniques for Reducing PAPR in the OFDM System.

Medha Vijayvargia ,Mamta Sood, Varsha Rajoria

Abstract – Orthogonal Frequency Division Multiplexing (OFDM) is an efficient method of data transmission for high speed communication. It is a wireless application. PAPR reduces the system efficiency and hence increases the cost of the radio frequency (RF) power amplifier. In this paper, we analysis PAPR reducing method that include STM, PTS,clipping and differential by using simulation and result comparisons in a table.

Key Words - OFDM, PAPR, Selective Mapping (SLM), Partial Transmit Sequence (PTS), Cumulative Distribution Function (CCDF), Clipping and Differential Method.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation (MCM) technique which seems to be an attractive candidate for Fourth Generation (4G) wireless communication System. Orthogonal Frequency Division Multiplexing (OFDM) posses several desirable attributes, such as immunity to the inter-symbol Interface(ISI), robustness with respect to multi-path fading, and ability for high data rates. Thus OFDM has been proposed in various wireless communication standard such as IEEE 802-11a standard for wireless Local Area Network (WLAN), IEEE-16a Standard for wireless Metro politician Area Network (WMAN), digital audio/video broadcasting, Terrestrial Digital Video Broadcasting, Terrestrial Digital Video Broadcasting HIPERLAN/2 Standard and high speed cellular data[1].

However OFDM System suffers from serious problem of high PAPR which arises as a consequence of the coherent addition of Multiple Sub-carrier Amplitudes & Phases from the System. A large PAPR limits the range of Linear[1].Operation of power amplifier in transmitter; this reduces the efficiency of the system. It also increases the complexity of Analogue-to-digital and digital-to-analogue convertors in wireless system [1], [2].

Several researchers have proposed schemes for reducing Peak amplitude such as clipping, companding, interleaving, Active constellation Extension (ACE), Partial Transmit Sequence Turbo Coded OFDM etc. The transmitted signal is the combination of a number of sinusoids which can add coherently and result in a high peak magnitude but the average value of the signal might be low due to destructive interference and therefore the PAPR ration is high[3]

PAPR results in high power consumption and lower efficiency and is hence undesirable.

The scheme of mitigating PAPR that have been explain in this paper is -

A. Selective Mapping (SLM)
B. Partial Transmit Sequence (PTS)
C. Clipping and differential

The paper is organized as follows-

In section (II) we discuss the basic OFDM System and PAPR. In section (III), we explain the Techniques for Reducing PAPR. Section (A) elaborated selective Mapping (SLM), Section (B) explains Partial Transmit Sequence (PTS) and clipping with Differential Method is discuss in Section (C). Section (IV) includes the simulation results and comparison of these techniques. In section (V) the conclusion is drawn.

II. OFDM System and PAPR Reduction

Orthogonal Frequency division multiplexing is a form of multi carrier modulation technique with high data rate efficiency, robustness to channel fading, immunity to impulse interference. Owing to these features it is being widely used in wireless communication and being considered for upcoming 4G [2].

In OFDM system, the data stream is broken into a number of sets, each being modulated onto a separate orthogonal carrier. The signals are then converted to time domain by suing Inverse Fourier Transform [IFFT]. IFFT also

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ensures orthogonality of the carriers. A cyclic prefix is added in order to reduce inter-symbol interference.[2]

A basic OFDM transmitter is shown is shown in fig.1. The baseband modulated symbols are passed through S/p converter which generates complex vector of size N & Let use define N symbols in OFDM as $\{x_n,\ n=0,1,\ldots\ldots\ldots\ldots,N-1\}$[10]

OFDM Diagram

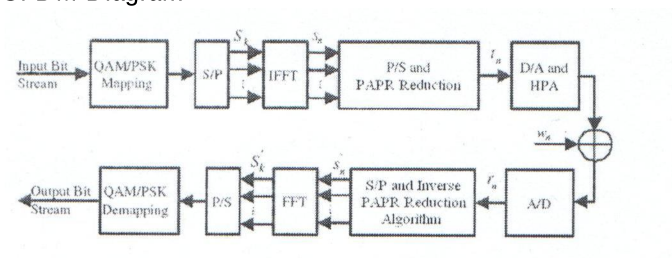


Fig. 1. OFDM system model with PAPR reduction block

The complex baseband representation of a multicarrier signal consisting of N subcarriers is given by :

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0} X_n e^{j2\pi n \Delta f t};\ 0 \le t < NT$$

where j is the subcarrier spacing and NT denotes the useful data block period. In OFDM system the subcarriers are assumed to be mutually orthogonal

The PAPR is defined by :

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]}$$

where E[.] denotes expectation. The complementary cumulative distribution function (CCDF) of the PAPR is one of the most frequently used performance measurers for PAPR a reduction techniques. The CCDF of the PAPR denotes the Probability that the PAPR of a data block exceeds a given threshold. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold. The cumulative distribution function(CCDF) of the Amplitude of a signal sample is given by [1]:

$$F(z) = 1 - exp(z)$$

The CCDF of the PAPR of a data block with Nyquist rate sampling is desired as:

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

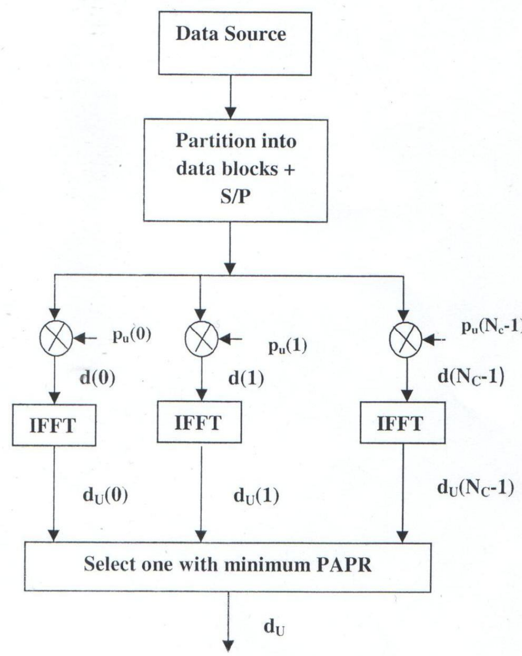
III. TECHNIQUES FOR REDUCING PAPR

A. Selective Mapping (SLM)

The selective Mapping[SLM] scheme is one of the most effective PAPR reduction scheme in OFDM system. SLM scheme can achieve several decibel of PAPR reduction and hence significantly improves the transmission power efficiency [7].

SLM technique is a probabilistic technique for PAPR reduction with the aim of reducing the occurrence of peaks in a signal [2]. In this technique a set of candidate signals is generated. Before transmitting the signal, its PAPR is calculated and the one with least value of PAPR is transmitted. This technique can handle any number of carriers but the only disadvantage is increased computational complexity and increased over heads side information [2]

A block diagram of SLM technique is shown in fig 2.



.fig.2

The transmitted data vector represented by D=[D(0),D(1)........................D(N-1)]where N is the number of subcarriers, are generated by multiplexing a phase codes represented by.

P=[P(0), P(1)]................................P(N-1)]element wise in frequency domain to the original input data modulated vector.

d=[d(0), d(1)............................d(N-1)]. Finally the OFDM signal with least PAPR is transmitted[2].

As shown in the fig.2

Stephane and samer [8] have proposed a SLM technique without side information. This method takes into account the increase in average energy with PAPR reduction which is identical to that of classical SLM. A recursive selected Mapping (RSLN) for PAPR reduction has been proposed by Lingying and Yewen[8],where the PAPR reduction has been a Little better than that of SLM with high reduction in computational complexity. Xiaowen and Siungmin[8] have proposed a look-up table method (LUT) by making use of the feature that the PAPR performance is independent of modulation Schemes in normal OFDM. This method shows the regulations of selective efficient phase rotation Factors. It proves a way of achieving the most efficient PAPR performance for SHM-OFDM, but limited to FFT size 8.

B. Partial Transmit Sequences (PTS)

Partial Transmit Sequence (PTS) algorithm is a technique for improving the stactics of a multicarrier signal. The basic idea of Partial transmit sequences algorithm is to divide the original OFDM sequence[6] into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen[6].

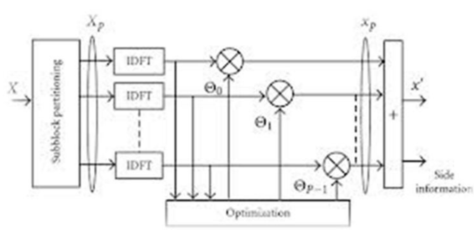


Fig.3 Block Diagram of PTS Techniques.

The data stream is partitioned into non-overlapping sub blocks of equal size. each sub block is multiplied by a weight. The weight is chosen as per convince and a hit and trial method is used to obtain the weights to optimize the algorithm. The side information must be provided at the receiver [2].it is described in [2] as:

Let {Xn:n=0,1,2....................N-1} be a vector, then X=[x0,x1.........................M], such that x is the union of all these sets[]. A block diagram is shown in fig.

$$X = \sum_{m=1}^{M} X_m$$

The objective of this approach is to form a weighted combination of the M clusters.

$$X' = \sum_{m=1}^{M} b_m X_m$$

Where {bm, m=1,2........................M} are weighting factors. The time domain transform IFFT of X is x:

$$x' = \sum_{m=1}^{M} b_m x_m$$

X_m is called the partial transmit sequence. The phase factors are then chosen to minimize the PAPR [3].

Partial Transmit Sequence (PTS) method is a well known method which can reduce the OFDM PAPR value. A major drawback of PTS method is its high computational complexity due to the necessity of Large number of inverse Fast Fourier Transform (IFFT) [7].

HSA Harmony Search Approach: The researchers introduce HSA approach to PAPR reduction based on the PTS. The HSA is inspired from musical process of searching for a perfect state of harmony [6]. This search algorithm had been very successful in a wide variety of optimization problems, presenting several advantages with respect to traditional optimization technique [6]. The privilege of HSA is its few mathematical requirements and not requiring initial value settings of the decision variables.

An improved harmony Annealing (HAS-PTS) method is proposed to search the sub optimal combination of phase factors, thus achieve the signal with Low PAPR. Its simulations results shows that HAS-PTS technique could achieve perfect balance between PAPR reduction Performance and computational complexity compared with the conventional PTS techniques [6]

D. Clipping and differential (C & D)

Clipping: In clipping, we can perform time-domain based clipping or frequency-domain based coding. The Simplest approach for PAPR reduction is to deliberately clip the amplitude of the signal to a predefined valued for amplification. However, there are several drawbacks of this approach, such as signal distortion and spectral re-growth. Hence simple clipping is not enough, we have to use coding techniques that are applied to OFDM signals is order to find the optimum threshold for every specific signal[12] However, this technique works well only when the number of sub carriers is small, because at higher sub carriers the clipping ratio is to be very low which will lead to more distortion and deterred the BER[9][12]

Clipping & diffrential scaling is proposed in [13] which author[ ] proposed that instead of clipping the signal further to reduce the PAPR, we consider a reversible process- Differential scaling which would reduce the PAPR but not deteriorate the BER, Since different ranges of amplitudes of the signal are scaled in a different ranges of amplitudes of the signal are scaled in a different ranges of amplitudes of the signal are scaled in a different manner, it is called differential scaling[13] They have consider three types of scaling –

1. Scale up
2. Scale down
3. Scale up and down

1. Scale up : In this method, we scale up the lower amplitudes of the signal by a factor of B. This leads to increase the average value without affecting the peak values. Therefore, the resulting PAPR reduces [13].The PAPR reduction function can be defined as

$$\begin{aligned} h(x) &= \alpha x_p, && if\ x > \alpha x_p \\ &= \beta x, && if\ x < A \\ &= x, && if\ A \le x \le \alpha x_p \end{aligned}$$

where as x_p is the amplitude peak value, a is the factor deciding the clipping threshold β is the scaling factor for the range[o, a] whose value is greater than one.

2. Scale Down: In this method, we scale down the higher amplitudes of the signal by a factor of Y. This leads to decrease the peak value. Although the average value would also fall down, the resulting PAPR reduces [10] Because the reduction in peak power is greater than the reduction in the average power [12][13] The PAPR reduction function can be defined as

$$\begin{aligned} h(x) &= \alpha x_p, && if\ x > \alpha x_p \\ &= \gamma x, && if\ B \le x \le \alpha x_p \\ &= x, && if\ x < B \end{aligned}$$

where xp is the amplitude peak value occurring in an OFDM symbol block, x is the factor deciding the clipping threshold in terms of percentage of the peak value and Y is the scaling factor whose value is less than one.

3. Scale up and Down : In this method, we combine both the above mentioned approach i.e. up-scaling and down -scaling. This method exploits the advantages of both the methods [13][12]Hence, a PAPR can be reduced considerably. The PAPR reduction function can be defined as

$$\begin{aligned} h(x) &= \alpha x_p, && if\ x > \alpha x_p \\ &= \gamma x, && if\ B \le x \le \alpha x_p \\ &= \beta x, && if\ x < A \\ &= x, && if\ A \le x \le B \end{aligned}$$

where x_p is the amplitude peak value occurring in an OFDM symbol block, x is the factor deciding the clipping threshold in terms of percentage of the peak value, bita is the scaling factor for the range[O,A] [12] [13].

It has been studied that the BER of clipping technique is 7 times higher than that of the proposed technique at 10dB SNR[12]. Thus the clipping & Differential scaling is better as compare to the other clipping or companding technique in terms of the PAPR reduction achieved at the corresponding BER performance.

!V. SIMULATION AND COMPARISION

In our MATLAB Simulations we have considered a system with a bit stream of 16384 bits and the modulation technique used is BPSK. In case of PAPR simulation for normal OFDM, the bit stream is divided into 64 carriers with 256 bits per carrier. The CCDF (Complementary Cumulative Distribution Function) plot for this is shown in fig.4

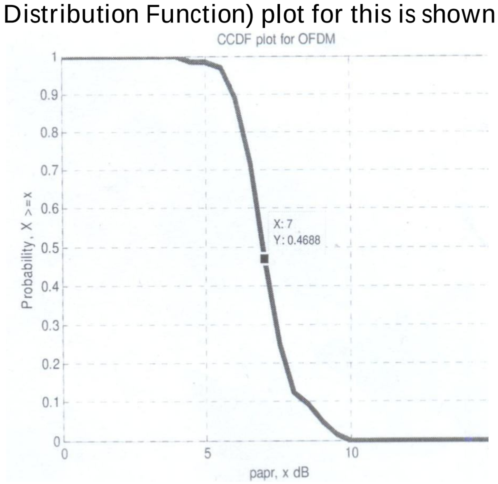


Fig.4. CCDF Plot for OFDM

In case of SLM, the bit stream is divided into 64 carriers with 256 bits per carrier. Each carrier is further divided into 4 sub carriers with 64 bits each

The CCDF plot of this technique is shown in fig.5

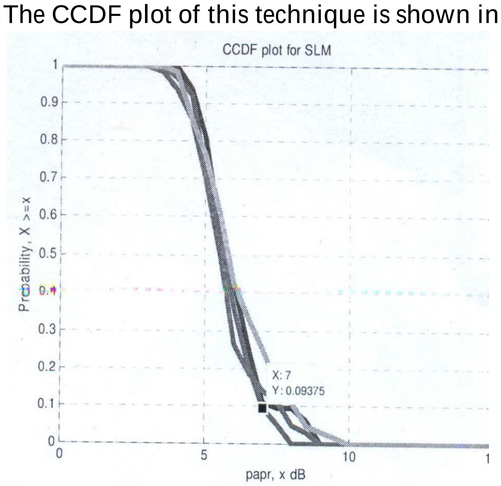


Fig.5. CCDF plot for SLM

PTS is also similar to OFDM in terms of the number of carriers and bit per carrier. The CCDF plot to this technique is shown in fig.6.

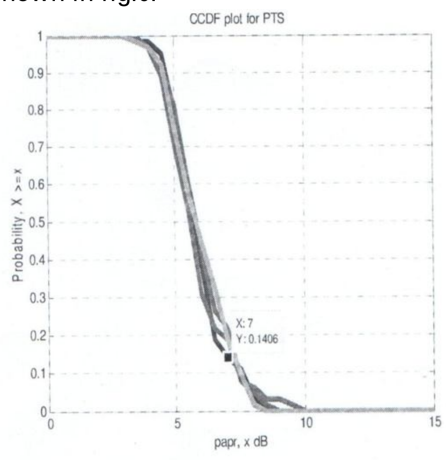


Fig.6.CCDF plot for PTS

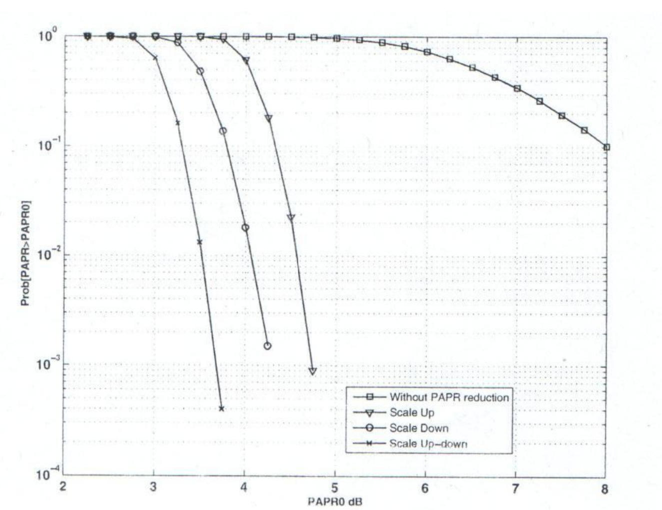


Fig.7. Comparison of PAPR performance (CCDF) of clipping and Differential Scaling with the CCDF of original OFDM Signal

Table:1. Comparison of SLM, PTS, CLIPPING, CLIPPING AND DIFFERENCIAL techniques of PAPR reduction.

Technique	Distortion	Data loss	Complexity	Prob. **of** PA PR> 7DB
OFDM	No	No	Low	0.4688
SLM	No	Yes	Medium	0.0937
PTS	No	Yes	Medium	0.1406
Clipping	Yes			
Clipping & Differential Scaling	up down		medium	8.5 db from 12db PAPR

V1. CONCLUSION

We analyzed various techniques for reducing PAPR in OFDM and compared their characteristics. In case of normal OFDM the probability of PAPR greater than 7db is 46.88%.whereas in case of SLM the probability of PAPR greater then 7db falls down to 9.37% .

It has been studied that the BER of clipping technique is 7 times higher than that of the proposed technique at 10dB SNR[2]. Thus the Clipping & Differential scaling is better as compare to the other clipping or companding technique in terms of the PAPR reduction achieved at the corresponding BER performance.

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