International Journal of Modern Electronics and Communication Engineering (IJMECE) ISSN: 2321-2152
Volume No.-7, Issue No.-3, May, 2019

Performance analysis of OFDM using Clipping and PTS as PAPR reduction techniques

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Abstract: There has always been discussion on peak to average power ratio (PAPR) which is a major drawback of orthogonal frequency division multiplexing (OFDM) and multiple-input multiple-output (MIMO) OFDM systems. A high PAPR OFDM signal always leads to distortion in non-linear devices. These non-linear devices can be High power amplifier (HPA), Analog to digital convertor (ADC) etc. Therefore, a number of PAPR reduction schemes are identified and available in literature. Some of them are Selective Mapping (SLM), Partial Transmit Sequence (PTS), Clipping, Tone Reservation and Tone injection, Coding schemes etc. In this paper, we have discussed about Clipping and Partial transmit sequence (PTS) and their effects on OFDM signal. The simulation results are also presented for better understanding of our findings.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Partial Transmit Sequence (PTS), Clipping, Peak to Average Power ratio (PAPR), IFFT, Selective Mapping (SLM)

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is found to hold great significance in Long Term Evolution (LTE) and upcoming 5G systems. Its high spectral efficiency and low interference always makes it preferable among other schemes available in literature. OFDM when combine with Multiple input and Multiple output (MIMO) antennas provides high spatial diversity. Even with a number of advantages, there are many drawbacks attached to OFDM. Out of which, Peak to Average Power Ratio (PAPR) is the major drawback. It has its inherent detrimental aspects that are difficult to handle [5].

Large PAPR causes signal distortion if the transmitter contains non-linear components like power amplifiers (PAs), Analog to Digital convertor (ADC) etc. Due to high peaks, the PA at transmitter enters into saturation region instead of being in linear region which causes distortion to the transmitted signal. This will further result in increased Bit error rate (BER) at the receiver. In other words, the nonlinear distortion will cause both in-band and out-of-band interference to signals. Therefore, the PAs requires a back off should be approximately equal to the PAPR for distortion-less transmission. This decreases the efficiency of amplifiers [1]. In literature, a number of techniques are presented to overcome this PAPR problem such as Tone Reservation (TR), selective mapping (SLM), clipping, Partial transmit sequence (PTS), etc.

In this paper, we are discussing about PAPR which affects the performance and efficiency of Power Amplifier (PA). Two PAPR reduction techniques: Partial transmit sequence (PTS) and Clipping technique are broadly discussed. Further, the simulation results are analyzed wherein the performance of OFDM system in the form of PAPR value is discussed with and without using these techniques followed by Conclusion.

II. PAPR

In simple words, PAPR is the relation between maximum power and average power of an OFDM transmit symbol. It occurs when different OFDM subcarriers are out-of-phase with respect to each other. This means that every instant of time they are different with different phase values. Whenever all of the OFDM subcarriers achieve their maximum value at the same time, the output envelope shoots up to a very high value which causes a peak in output envelope. Sometimes this peak value of the OFDM system is very high as compared to the average of the whole system. This ratio is termed as Peak to Average Power ratio.

The Peak power and Average power can be easily interpreted from Figure 1 as shown below. Peak power is the maximum power of an OFDM signal. The ratio of peak and average power must be kept as minimum as possible.

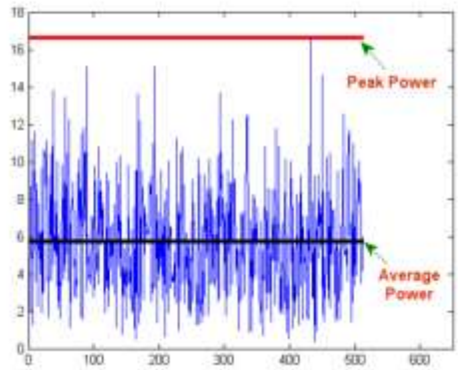

Fig. 1. Peak and Average power of an OFDM signal

For a signal x(t), the PAPR is defined as follows:

$$papr = \frac{\max[x(t)x^*(t)]}{E[x(t)x^*(t)]}$$

where $x^*(t)$ is the conjugate of x(t)

$\max[x(t)x^*(t)]$ is the peak power value of signal

$E[x(t)x^*(t)]$ is the mean square value or average power of signal

The PAPR is expressed in decibels as

$$PAPR(dB) = 10\log_{10}(PAPR)$$

The high PAPR leads to lower power efficiency and strongly affects the performance of power amplifier (PA). The high PAPR value of the transmitted signal also highly affects the power amplifiers complexity. High PAPR require linear amplifier but it is difficult to maintain linearity of the amplifier which produces nonlinear characteristic. This non-linearity plays a great role of undesired distortion like out of band radiation. The power amplifier of transmitter essentially requires operating in linear region. It is not possible to maintain specific limit to keep out of band power, if high power amplifier (HPA) do not operate in linear region with high back off. This condition is not suitable for amplification and the transmitter becomes expensive. Using a large linear range also results in saturation of the HPA. This saturation will create both in band distortion, increasing the BER and out of band distortion [1].

III. BACKGROUND

A. CLIPPING

This is the simplest technique used for PAPR reduction. In this technique, the amplitude of the input signal is clipped or reduced to a fixed value/level. The basic idea behind this technique is to clip the parts of signal which is outside the allowed range (region). It is expressed from as:

$$Y(t) = \begin{cases} -L & if\ x(t) < -L \\ x(t) & if\ -L \le x(t) \le L \\ L & if\ x(t) > L \end{cases}$$

Where x(t) is OFDM signal, Y(t) is Clipped (OFDM) signal and L is the fixed level used for clipping.

The main advantage of this technique is its high PAPR reduction capability. Also, no side information is required. The main drawback of this technique is that it introduces distortion and degrades BER performance [4]. The clipping of OFDM signal amplitude is clearly seen in figure 2 below.

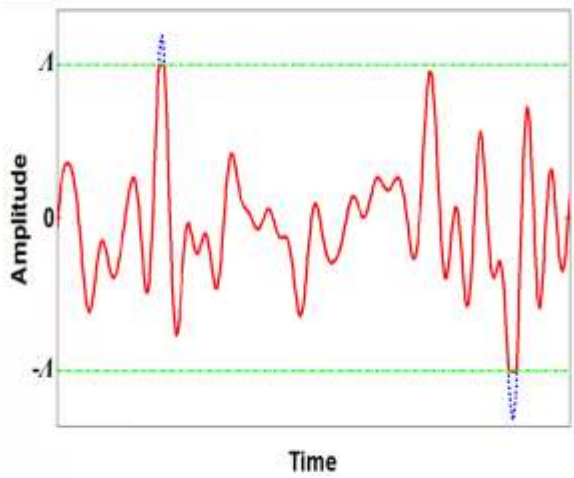

Fig.2 Clipped signal

B. SELECTIVE MAPPING

Selective Mapping is a distortion-less Signal Scrambling technique which is used to reduce the PAPR in OFDM system without increasing the power requirement and causing data rate loss. In this technique, the input OFDM signal is first converted to parallel signal. The phase rotation of the modulated data is performed before IFFT operation to obtain candidate signals [2]. And after performing phase rotations, the candidate signal with lowest PAPR is selected [3]. Figure 3 shows the various steps of selective mapping method. Side information related to phase rotation vectors is also transmitted along with the OFDM signal. This will reduce system efficiency.

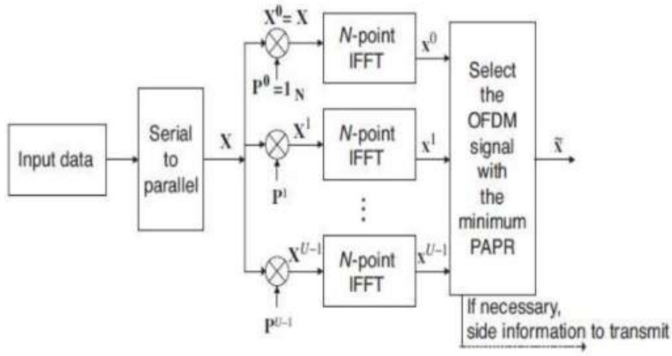

Fig. 3. SLM Block Diagram

The main advantage of this technique is that it does not affect the system performance in terms of Bit Error Rate (BER) and there is no distortion. The disadvantage of this technique is its high implementation complexity and it also requires side information to be transmitted along with lowest PAPR signal. The complexity of this technique increases exponentially upon increasing the number of phase sequence and number of subcarriers in OFDM system.

C. PARTIAL TRANSMIT SEQUENCE

Partial Transmit Sequence (PTS) is one of the promising technique that provides good PAPR reduction for OFDM systems [3]. The original data block is partitioned into V disjoint sub blocks. The subcarriers present in each of these sub blocks are rotated by the equal phase factor, so the PAPR of the combination is minimized. Also, the reverse operation is performed at the receiver, to recover the original data block. The conventional PTS has high complexity, as it extensively searches for all the combinations of allowed phase factors. Figure 4 shows the main steps of using Partial transmit sequence with OFDM. After phase rotation, PTS involves selection of an optimized combination of phase factor with minimum PAPR. And then the parallel signal is converted to serial output [6].

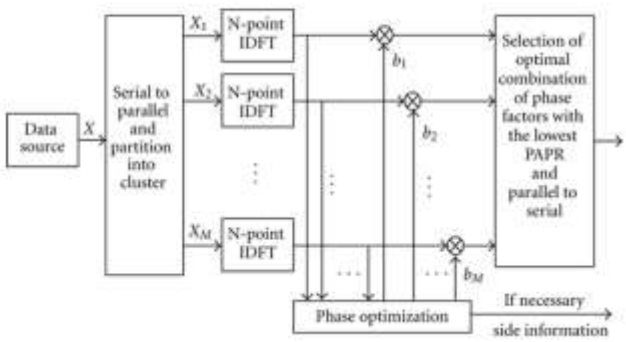

Fig. 4. PTS Block Diagram

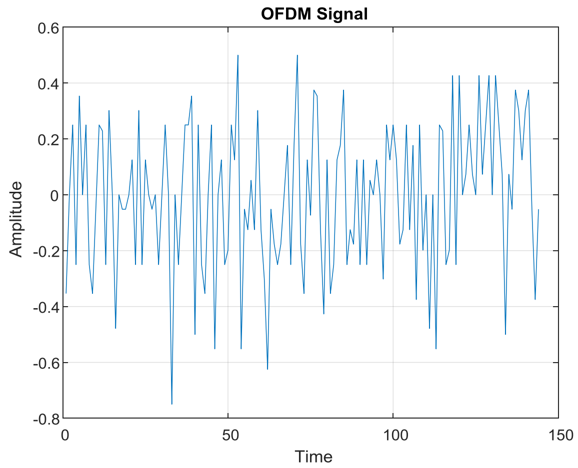

Fig. 5. Original OFDM signal

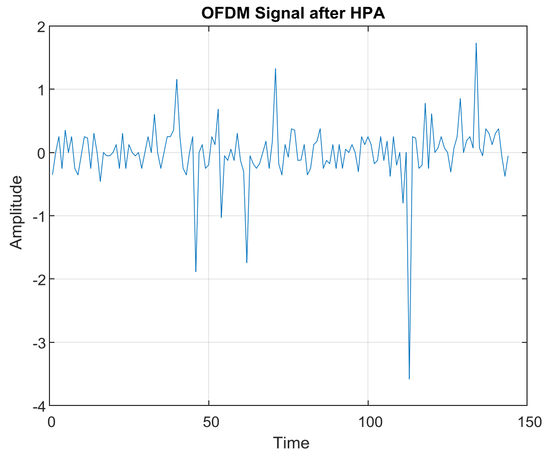

Fig. 6. OFDM signal after High power amplifier

IV. SIMULATION RESULTS

In this paper, we performed simulation of clipping technique and Partial transmit sequence (PTS). In our simulation results, it is clear from plots that the PAPR performance improves for Clipping and PTS technique when it is compared to the conventional techniques in ordinary OFDM or MIMO OFDM systems. Figure 5 shows the normal OFDM signal. When normal OFDM signal passes through High power amplifier it starts to behave non-linearly as seen in Figure 6. There are many high peaks in the signal which will lead to high PAPR.

When clipping technique is applied on normal OFDM signal with a clipping factor of 0.4, the amplitude signal is clipped. It can be seen in Figure 7. When this clipped signal is passed through HPA, the resulting signal is shown in Figure 8. It can be observed from Figure 8 that the Clipped OFDM signal behaves linearly even on passing through HPA. It does not show irregularity or high peaks.

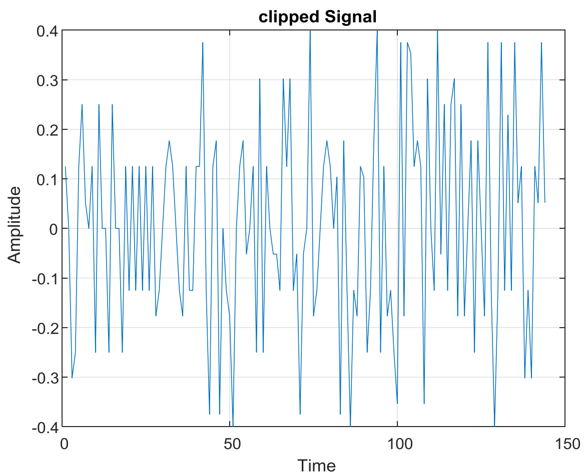

Fig. 7. Clipped OFDM signal

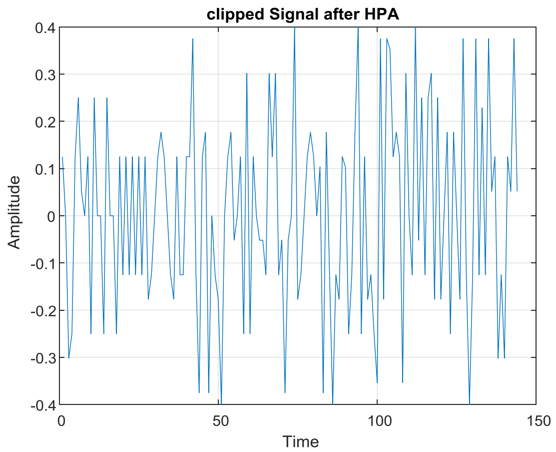

Fig.8. Clipped OFDM signal after High power amplifier

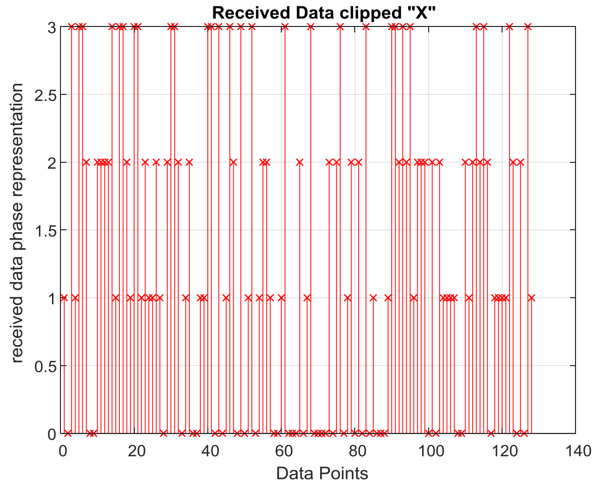

Fig. 10. Received Clipped OFDM signal

Figure 9 and 10 respresents the transmitted and received Clipped OFDM signal respectively. As we can see, there is a consistency in signal phase with respect to the data points. The transmitted and received signal looks somewhat similar which means the amount of error is low.

After performing analysis on Clipping technique, we performed simulation using PTS technique with OFDM. Figure 11 and 12 shows the input OFDM signal used for PTS analysis and OFDM signal after using PTS technique respectively.

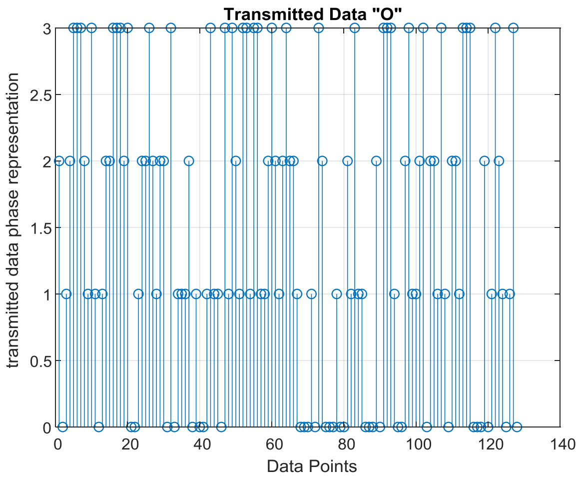

Fig. 9. Transmitted Clipped OFDM signal

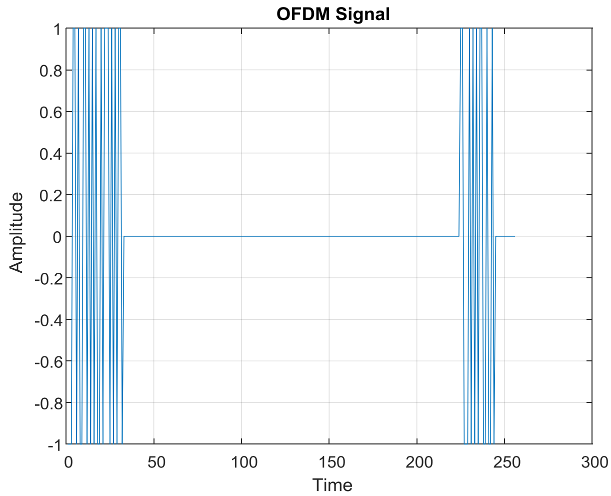

Fig. 11. Input OFDM signal used for PTS

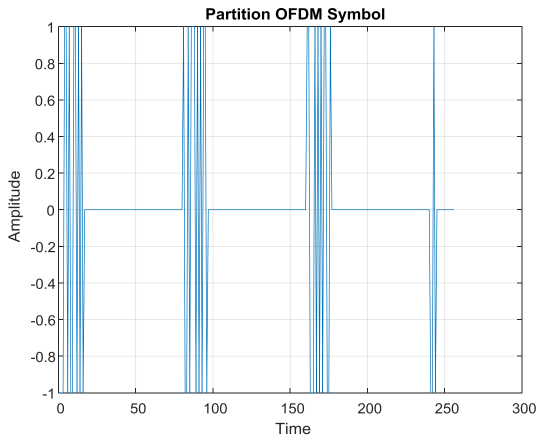

Fig. 12. OFDM signal using PTS technique

From simulation results, we have found that the PAPR of OFDM signal without using Clipping technique is 8.6852 dB and the PAPR of OFDM with using Clipping is 7.0223 dB. So, there is a 1.6629 dB improvement by using this Clipping technique.

Similarly, on performing analysis on PAPR using Partial transmit sequence, we have found that the conventional OFDM signal (without PTS) gives a PAPR value of 10.8158 dB which is very high. When this signal is combined with PTS technique, the PAPR is reduced to 4.0178 dB. There is a straightforward 6.798 dB improvement in PAPR on using PTS which is significant.

V. CONCLUSION

In conventional OFDM systems, PAPR is found to have many detrimental effects. This problem is investigated in detail. In this paper, we have compared the PAPR performance of Clipping technique and PTS technique. It is observed that the PAPR performance of conventional OFDM system is very high as compared to the results achieved on using other two techniques. We have also analyzed the results after passing through high power amplifier. There is a 1.6629 dB improvement on using Clipping technique and 6.798 dB improvement in PAPR on using PTS which is quite significant.

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AUTHOR'S BIOGRAPHIES

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