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PAPR Reduction Schemes in OFDM Systems using Selected Mapping (SLM) and Partial Transmit Sequence (PTS)

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) has gained a lot of interest for high speed data transmission in wireless communication. OFDM provides high spectral efficiency and robustness against Inter Symbol Interference (ISI) and channel fading. OFDM is widely used in several modern applications of wireless communication such as HDTV, DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting) etc. Although, OFDM has several attractive features, it has few drawbacks. Peak-to-Average Power Ratio (PAPR) is one of the main drawbacks in OFDM system. An OFDM scheme consists of a large number of subcarriers. The peak value of the transmitting signal makes the system inefficient. Selected Mapping (SLM) and Partial Transmit Sequence (PTS) are two well-known techniques to reduce PAPR efficiently. This paper shades light on a comparative study of the result in OFDM system, using both SLM and PTS techniques to reduce PAPR.

Key words: PAPR, OFDM, ISI, ICI, DVB, DAB, IFFT

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1. INTRODUCTION

In any wireless application, high speed data transmission is the demand of time. The efficiently the data is transmitted with minimum loss and to minimize the noises are the goal of any wireless communication system. Inter Symbol Interference (ISI), multipath delay spread, fading, shadowing etc. are the common phenomena which decrease the wireless communication system's performance. There are various approaches to solve these problems to increase the quality of performance of the system such as: several equalization and diversity techniques, channel coding etc. But these approaches may have different complexity. For example, many techniques may have high cost in hardware implementation and so on (Seshadri et al., 1993).

Orthogonal Frequency Division Multiplexing (OFDM) is a kind of multi carrier technique (Zhang & Cheng, 2004). It's well suited for high speed data transmission. It divides high data stream into a number of low data stream which are transmitted in parallel over narrowband channels which are easily equalized. Additionally, OFDM provides high spectral efficiency. It reduces ISI (Inter Symbol Interference) and ICI (Inter Carrier Interference) (Chen & Zhu, 2004).That's why OFDM is widely used in modern wireless communication field such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), and wireless Local Area

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Networks (LANs) (IEEE 802.11a, IEEE 802.11g). It will also be used in fourth generation cellular systems, such as Third Generation Partnership Project-Long-Term Evolution (3GPP-LTE) and WiMAX etc. (Goldsmith, 2004).

In spite of such attractive features, OFDM technique is not free from drawbacks. Peak to Average Power Ratio (PAPR) is one of the major drawback of OFDM system (Nik et al., 2006). For any communication system, PAPR is an important property. In the case of OFDM, it degrades the system quality. An OFDM system, when transmitting signals, many subcarrier components are added via the IFFT operation (Rahman et al., 2016). So, the transmitted signals may have high peak values in time domain. The linear region operation of power amplifier requires to avoid signal distortion, so the peak value is included in this region. For maximum efficiency of the power amplifier operation, it is desired that the peak and average values are as close as possible. A high resolation is required by high PAPR for reciever A/D converter because for high PAPR signals, dynamic range of the signal is much larger. It brings complexity and power burden on reciever end. So, low PAPR is essential for the transmit power amplifier to operate efficiently (Goldsmith, 2004).

There are several reports related to the concept of Power Ratio Reduction Techniques for OFDM Signals. In a recent report, two PAPR reduction schemes based on Zadoff-Chu Matrix Transform (ZCT) precoding and postcoding in OFDM systems were proposed. It was found that PAPR of both proposed systems is equal to the PAPR of M-QAM itself. Hence, it is concluded that the proposed pre/postcoded OFDM systems introduce no PAPR or BER degradation. Where the ZCT precoding and postcoding based OFDM systems for PAPR reduction do not require any power increment, complex optimization and side information to be sent for the receiver thus improving the overall system performance in a significant manner (Baig & Jeoti, 2010). In another statement, one of the serious drawbacks of OFDM systems was tested. It was found that composite transmit signal displays a very high PAPR when the input sequences are highly correlated. Five typical techniques to reduce PAPR were also analyzed, all of which have the potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation, computational complexity increase, and so on (Jiang & Wu, 2008).In another research, different low-complexity conversions technique was introduced to replace the IFFT blocks in the traditional SLM method. It was found that, as compared to the conventional SLM scheme, the first proposed approach technique has slightly worse PAPR reduction performance and the second proposed one reaches almost the same PAPR reduction performance (Wang & Ouyang, 2005). So, from the recent findings we saw that reducing PAPR is an ongoing process in the communication engineering sector. This paper shades light on a comparative study of the result in OFDM system, using both SLM and PTS techniques to reduce PAPR.

2. RESEARCH METHODOLOGY

In this paper, PAPR reduction schemes in OFDM system are implemented by using MATLAB as simulation tool. After implementing necessary MATLAB code, projected plot can be obtained. Here, only the transmitting portion of OFDM system has been simulated since PAPR is in the transmitting side. First of all, default PAPR is calculated before applying the SLM. Then, PAPR is calculated after applying SLM and finally, after applying PTS. OFDM simulation is performed for 64, 128, 256 subcarriers.

2.1. Peak-to-Average Power Ratio (PAPR)

PAPR is the ratio of the maximum power to the average power. It can be expressed by the following equation (Dwivedi, S. K. & Patel, P. 2016):

$$\text{PAPR} = 10log_{10}\frac{\max|x[n]|^2}{E[|x[n]|^2]} \quad \text{(1)}$$

Where, x[n] denotes an OFDM signal after IFFT and expectation operator is denoted by E [.]. So, the time domain OFDM samples output from the IFFT for N subcarriers:

$$x[n] = \frac{1}{\sqrt{N}}\sum_{i=0}^{N-1} X[i]e^{j\frac{2\pi in}{N}},\ 0 \le n \le N-1 \quad \text{(2)}$$

Practically, it can be shown that, the probability that the PAPR exceeds a threshold, P_0 to represent the distribution of PAPR as the measurement index:

$$p(PAPR \ge P_0) = 1-(1-e^{-P_0})^N \quad \text{(3)}$$

This is known as Complementary Cumulative Distribution Function (CCDF). Here, N is the number of subcarrier.

2.2. PAPR Reduction Techniques

There are different techniques to reduce PAPR such as (Soocho,Y., Kim,J., Yaag,W. Y., Kang,C., 2006):

- Clipping technique
- Coding technique
- Probabilistic or scrambling technique
- Adaptive predistortion technique
- DFT spreading technique

Selected Mapping (SLM) and Partial Transmit Sequence (PTS) approaches are included in probabilistic technique. In this technique, an input block of data of OFDM symbols are scrambled. Then, one of them is transmitted with minimum PAPR so that the probability of incurring high PAPR is reduced. Tone Reservation (TR) and Tone Injection (TI) are also included in Probabilistic technique (Soocho et al., 2006).

Theoretically Both SLM and PTS has the capability to reduce PAPR. In SLM, pre decided phase sequences are multiplied with information bearing signals. Among these resulting multiple generated signals, the lowest PAPR signal is selected to transmit. On the other hand, In PTS, the input data block is portioned in equal size sub blocks. Sub blocks in PTS is an important parameter. If the number of sub blocks increases, the probability of PAPR reduction is also increased. Here, we motivated to investigate the comparative performance of SLM and PTS to reduce PAPR and also

observe the comparative results of PAPR reduction ability by increasing number of sub blocks for PTS schemes.

a. Selected Mapping(SLM)

The principle of SLM technique can be explained by the following block diagram shown in Fig. 1(Nik et al., 2006).

- First, the input data is sent to serial to parallel converter. N sequence of parallel data block, X[0],X[1],……X[N-1] is multiplied by different phase sequence U.
- Then IFFT algorithm is implemented on this product sequence.
- Among the resulting sequence of symbols, one symbol is chosen to transmit As minimum PAPR.
- Selected phase sequence should also be transmitted as side information it may contain the minimum PAPR symbol.

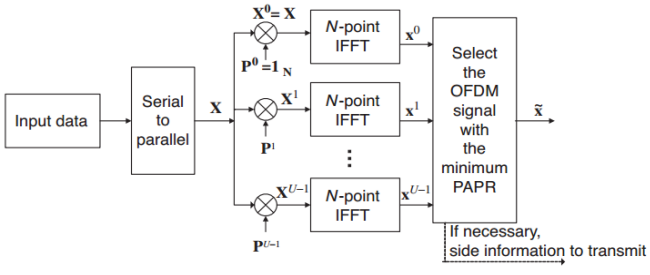

Fig.1.The block diagram of selective mapping to reduce PAPR in OFDM system (Soocho et al., 2006).

b. Partial Transmit Sequence (PTS)

In PTS, the input data block is portioned in equal size sub blocks. The main difference between SLM and PTS is, in SLM the scrambling is applied to all the subcarriers. In PTS, scrambling is applied to each sub blocks. Scrambling means rotating its phase independently. The principle of PTS technique is shown in Fig. 2. (Femila & Jisha, 2018).

- After converting serial to parallel, the N input data block is portioned into disjoint sub blocks, each of them are equalize and they are located consecutively.
- After taking the IFFT of each sub block, each partitioned sub block is multiplied by corresponding a complex phase factor $b^v = e^{j\emptyset v}$.

Now, x= IFFT

$\{\sum_{v=1}^{V} b^v X^v\}=\sum_{v=1}^{V} b^v .\ IFFT\ \{X^v\}=\sum_{v=1}^{V} b^v .\ x^v$ ..... (4)

Where, $\{ x^v\}$ is a partial transmit sequence. Like SLM, the chosen phase factor is transmitted as side information.

2.3. Simulation Parameters

Various PTS schemes are investigated by increasing the sequence numbers or sub blocks. First PTS is implemented for 4 sub blocks and finally for 8 sub blocks. Fig. 6 & 7 show the PTS schemes for the sequence number 4, 8. The parameters for simulation are specified in Table 1.

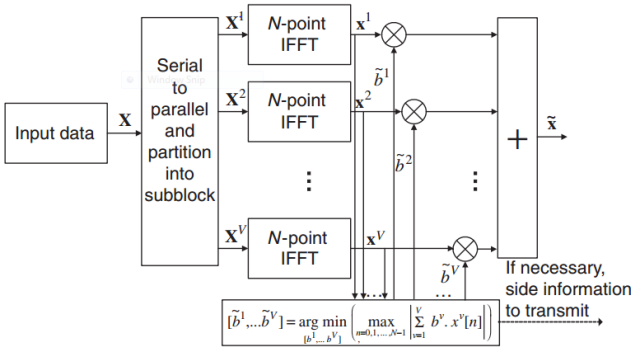

Fig.2. The block diagram of PTS technique in OFDM system (Soocho et al., 2006).

Table 1: Important parameters for simulation.

Parameters	Values used
Number of subcarriers (N)	64,128,256
Number of bits	52*100,104*100,204*100
Number of sequence (C)	4,8
Number of bits per symbol (n Bit Per Symbol)	52,104,204
Modulation technique	BPSK
Phase factor combination	256

3. RESULTS

Fig. 3, 4, 5 showed that the probability of PAPR Vs PAPR (dB) plots for 64,128,256 carriers respectively. This figure is plotted as the probability of PAPR is in Y-axis and PAPR (dB) is in X-axis. These plots are based on how the probability of PAPR is varied on the PAPR (dB).

From Fig. 3, it is realized that SLM reduces about 2dB while PTS reduces about 2.9 dB which indicates the better performance of PTS over SLM in PAPR reduction. We then further investigate about PAPR reduction in Fig. 4 and 5.

In Fig. 4, same simulation is performed for 128 carriers where SLM is found to reduce about 2dB PAPR and PTS is 3dB as compared to SLM that attested the better performance of PTS over SLM. In Fig. 5, the probability of PAPR Vs PAPR (dB) plot is implemented for 256.

Here, PTS reduces about 2.5dB and SLM reduces about 2dB. From Fig. 3, 4 and 5, it is clear that PTS technique is better approach than SLM technique for PAPR reduction in OFDM systems.

Now, PTS schemes are implemented in OFDM system for 4 sequences or sub blocks. From Fig. 6, it clear that, for 64 carriers, about 3dB PAPR is reduced by PTS technique. If number of subblocks are increased for same OFDM system and PTS system is implemented, then it is found to be reduced about 4.2dB by PTS schemes.

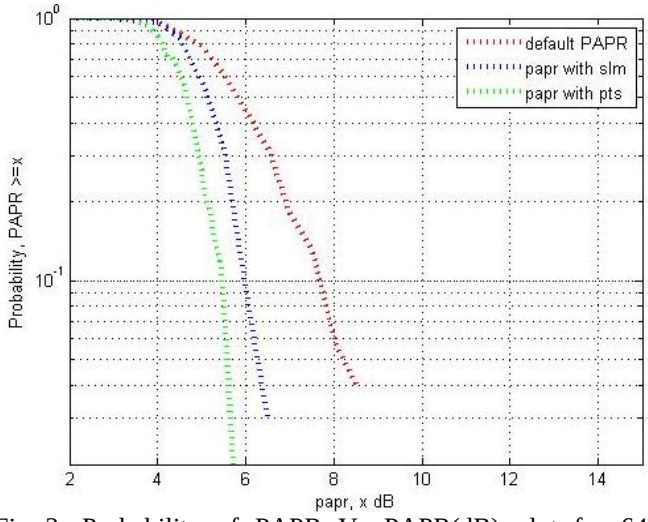

Fig 3: Probability of PAPR Vs PAPR(dB) plot for 64 carriers

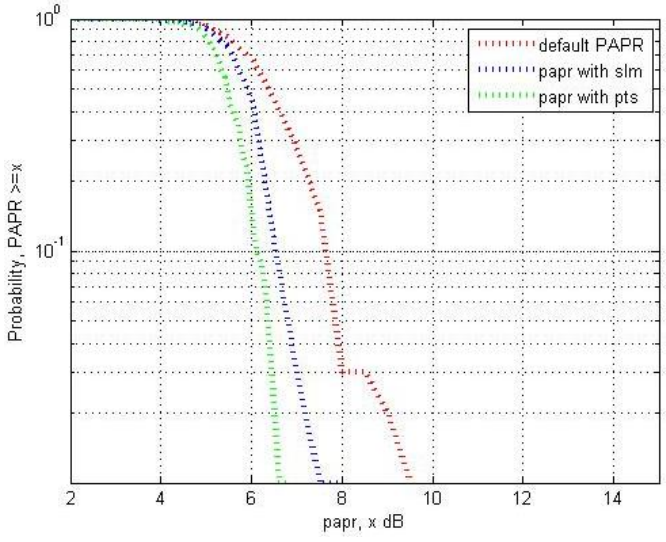

Fig 4: Probability of PAPR Vs PAPR(dB) plot for 128 carriers

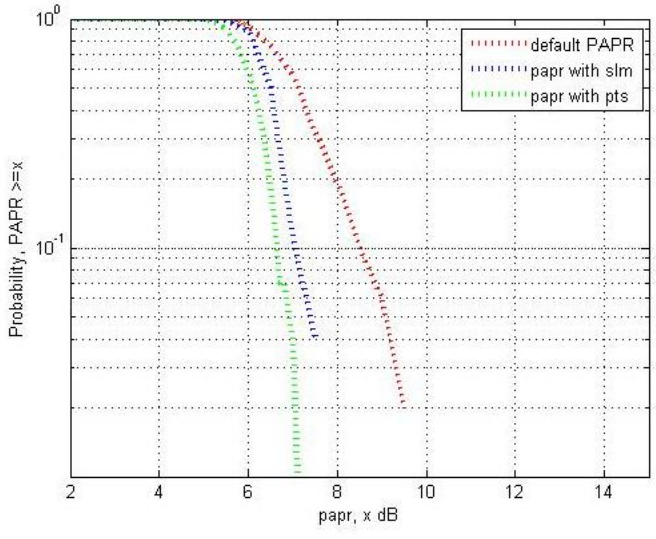

Fig 5: Probability of PAPR Vs PAPR(dB) plot for 256 carriers

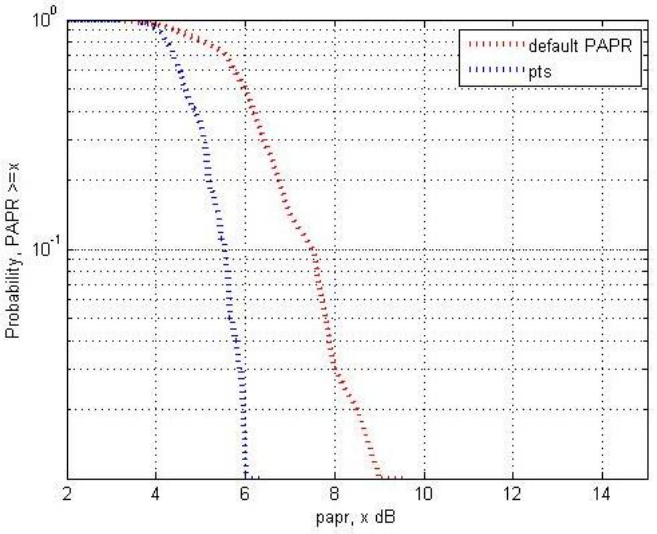

Fig 6.Probability of PAPR Vs PAPR plot for 4 sequences.

In both cases, PTS is implemented for 64 carriers. BPSK modulation technique is used for all cases. From Fig. 6 and 7, it is investigated that by increasing number of sequences or sub blocks of PTS, the amount of PAPR reduction is increased. Here, 3dB and 4.2dBPAPR reduction is obtained for 4 and 8 sub blocks in PTS schemes respectively. So, about (4.2-3) dB=1.2dB more PAPR is reduced when number of sub blocks are increased from 4 to 8.

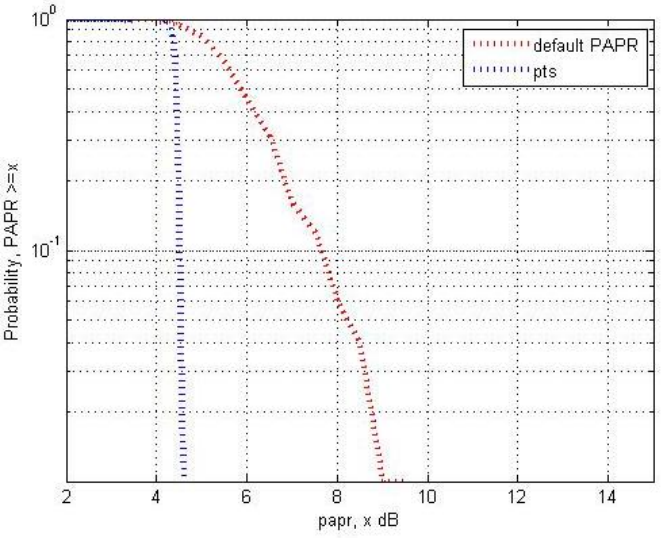

Fig.7.Probability of PAPR Vs PAPR plot for 8 sequences.

4. DISCUSION

Various methods were evaluated over the years to reduce the PAPR in OFDM based systems including clipping (O'Neill & Lopes, 1995), coding schemes (Jones et al., 1994), phase optimization (Tarokh & Jafarkhani, 2000), nonlinear companding transforms (Wang et al., 1999). Tone Reservation (TR) and Tone Injection (TI) (Singh, et al., 2009), constellation shaping (Kou, 2004), along with SLM

and PTS. These are basically signal scrambling techniques, such as block codes and PTS etc., and signal distortion techniques such as clipping. A comprehensive review is still required including some motivations of PAPR reductions, like power saving. An effective PAPR reduction method should exhibit the best tradeoff between the capacity of PAPR reduction and transmission power, data rate loss, implementation complexity and Bit-Error-Ratio (BER) performance etc.

5. CONCLUSION

In spite of many attractive features of OFDM, PAPR degrades the system performance. In an OFDM system, peak values are shown in transmitted signals. From the various figures we got a comparative idea about the more effective technique between SLM and PTS. PTS reduces more PAPR than SLM. So, PTS is more efficient technique to reduce PAPR for any OFDM based Communication system. A comparative observation is also obtained in the case of PTS schemes for 4 and 8 sub blocks which provide the idea that PTS scheme of 8 sub blocks has better performance of about 1.2dB than PTS scheme of 4 sub blocks. More research must be done to improve the OFDM system.

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