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Selective Mapping and Partial Transmit Sequence Based PAPR Reduction for OFDM Applications

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Abstract: *Although orthogonal frequency division multiplexing (OFDM) has many advantages but still it suffers high PAPR which is considered as its major drawback. To overcome this problem an amplifier with high dynamic range can be used but it will cause high cost to the system. In this paper two existing techniques are applied to decrease the peak to average power (PAPR) in orthogonal frequency division multiplexing (OFDM) system. These two techniques are selective mapping (SLM) and partial transmit sequence (PTS). Firstly, these two basic techniques are analysed and then SLM technique is modified with the use of Riemann matrix to optimize the phase sequence for the SLM technique. Later in the paper both SLM and PTS techniques are combined and the peak to average power ratio is analysed. Although SLM and PTS both provide reduction in the peak to average power (PAPR), but proposed techniques can offer better PAPR than individual PTS and SLM as shown using computer simulation detail analysis of these techniques furnished in this paper. The results show that the reduction in PAPR in case of proposed technique decreases as number of sub blocks increases. The PAPR reduction in case of two sub blocks is estimated 13.42% and 17.19% for SLM-riemann and proposed technique where as it is maximum in case of sixteen sub blocks i.e. 43.07% and 46.74% respectively as compared to basic PAPR.*

Keywords: *Orthogonal frequency division multiplexing (OFDM), Peak to average power (PAPR), Partial transmit sequence (PTS), Riemann-selective mapping (SLM), Selective mapping (SLM).*

I. Introduction

Orthogonal frequency division multiplexing (OFDM) is a modulation technique that consists multicarrier. It is bandwidth efficient schemethatis used in communication systemshaving higher data rate. Orthogonal Frequency Division Multiplexing has been the preferred candidate for broadband wireless communications over the years [1]. It has many advantages like robustness against frequency selective fading channel, higher spectral efficiency, easy equalization and flexibility. It has been widely used in many communication systems such as IEEE 802.11a standard for WLAN and IEEE 802.16a [2].OFDM is a special case of multicarrier transmission in which a single information bearing stream is transmitted over many lower rate sub channels [3]. Consider an N sub-carriers OFDM system. Take a vector X that denotes a block containing N frequency domain sub-carriers, where $X = [X_0, X_1, . . ., X_{N-1}]$ is the input data in a block. Each symbol in X modulates a sub-carrier. Let, $f_p = p\Delta f, where\ p = 0,1,\ldots,N-1$, denotes the pth sub-carrier frequency. Note that the sub-carriershould be Orthogonal to adjacent sub-carriers, i.e. $f_p = p\Delta f$ where $\Delta f =$ 1/NTand T denotes the duration of the symbol. Therefore, the OFDM signal to be transmitted is

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi k\,\Delta f} \ ,0 \le t < NT \tag{1}$$

Where$j = \sqrt{-1}$, Δf is the sub-carrier spacing, and NT denotes the useful data block period. In OFDM the sub-carriers are chosen to be orthogonal$(i.e., \Delta f = 1/(NT\,))$. The total bandwidth is given as $BW = N.\Delta f$. Due to the frequency selective fading of channels, few sub-carriers are enhanced while others suffer fading. If N is large enough, each sub-carrier is narrow compared to the coherence bandwidth of the channel and even under severe fading conditions they suffer flat fading. The signal is built in frequency domain but the actual data transmission takes place in time domain. A OFDM symbol is consists of N sub carriers containing output samples converted into time domain using IFFT. Added up constructively these sub-carriers result in power that is much higher as compared to the average power of the OFDM signal. This results in a very large peak and this value increases with the increase in number of subcarriers therefore, causing a very high peak to average power ratio. High PAPR is an important drawback of orthogonal frequency division multiplexing systems. The major problems associated with transmitted signal in orthogonal frequency division multiplexing beside peak to average power ratio reduction as discussed above are sensitivity to frequency error and inter carrier interference (ICI) between subcarriers [4]. But this paper concerns of high peak to average power ratio. Typically, at transmitter sidein order to boost the signal strength a power amplifier is used and large peak to average power ratio (PAPR) can cause the signal go beyond the linear region of the amplifier which leads to saturation state. This results in signal distortion which increases demodulation error [5]. A higher peak to average power reduction (PAPR) also increase the complexity of analog to digital (A/D) and digital to analog (D/A) converter [1]. It is clear that it's useless to send signal such high peaks to transmitter without reducing. Many approaches have been presented in literature to overcome PAPR problem. These approaches include amplitude clipping, filtering [6,7], tone injection and rejection [8,9], active constellation extension [9], partial transmit sequence(PTS) [10,11] and selective mapping (SLM) [12,13] technique etc. These techniques have their own advantages but the main approach to use these techniques is to reduce PAPR. There is reduction in PAPR but these techniques also cause some negative effects like BER increase, computational complexity, increase in transmitted signal or increase in data rate loss [14]. In this paper the focus is on SLM and PTS techniques for PAPR reduction. Both these techniques are discussed and compared. Further the phase sequences used in SLM technique are modified based on normalized Riemann matrix. Note that SLM and PTS can reduce the PAPR without degrading the BER performance but the computational complexity of increases and also additional side information is needed at the receiver [15]. PAPR signifies dynamic range of orthogonal frequency division multiplexed signal. And can be defined as a ratio of maximum peak power to average power during a symbol period. Therefore, PAPR is given as

$$\mathrm{PAPR} = \max_{0 \le n \le T} \frac{|x(n)|^2}{E[|x(n)|^2]} \qquad (2)$$

Where A [.] represents average power. As already described dynamic range of the time-domain OFDM signal can be given by the peak-to-average power ratio which is the most popular parameter [16,17,18,19]. Minimize max|x(n)| the major concern inPAPR reduction techniques. PAPR is random in nature because it depends on random input data. Therefore, PAPR can be obtainedby using level crossing rate theorem and done by calculating the complementary cumulative distribution function of PAPR values.

II. Basic techniques

2.1 Partial Transmit Sequence (PTS) Technique

PTS technique was proposed by the Muller and Hubber in 1997. Figure 4 shows the PTS scheme. The first step is to partition the main data stream into multiple sub sequences. Then every symbol is applied with IFFT.The resulting signals are then multiplied by rotating vectors. After that these sub sequences are summed up. Now PAPR of respective sequence is obtained and lowest PAPR signal selected for transmission [13].

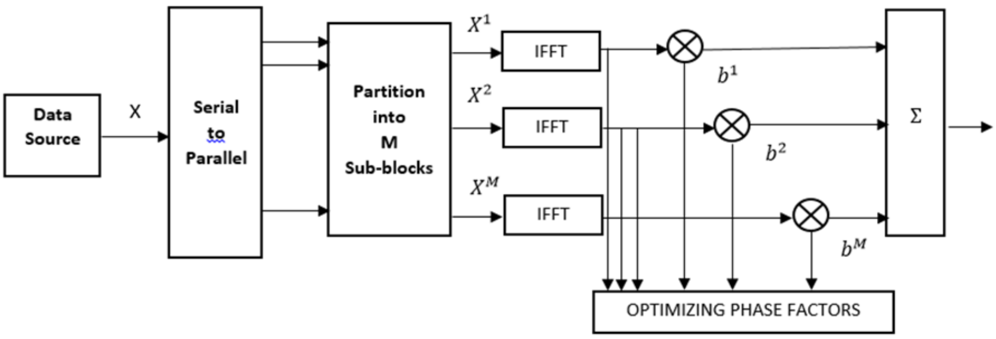

Fig.1 Block diagram of PTS technique

In this scheme, at first stage the input data (X) is divided into sub-blocks (M). In each sub block there is a weighing factor(phase factor) for corresponding subcarrier. The phase factors are selected in such a way that the resultant signal becomes of havingleast PAPR [6]. The disjoint sub-blocks generated by dividing input data is

$$X^m = [X_0^m, X_1^m, X_2^m \ldots\ldots\ldots\ldots. X_{N-1}^m]; \quad m = 1,2, \ldots . M \qquad (3)$$

All the sub-carriers position which are presented in other sub-blocks must be zero so that the sum of all the sub-blocks constitutes the original signal, i.e.

$$X = \sum_{m=1}^{M} X^{m} \qquad (4)$$

The set of phase factors denoted as Vector b = [b1; b2……; bM] are introduced. Aphase factor is multiplied to each sub block and then summed up. It can be given as

$$X' = \sum_{m=1}^{M} \mathrm{IFFT}(b^{m}.X^{m}) = \sum_{m=1}^{M} b^{m}.\mathrm{IFFT}(X^{m}) = \sum_{m=1}^{M} b^{m}.x^{m} \qquad (5)$$

$$b^{m} \subseteq \ominus, \ominus = [e^{j\theta 1}, e^{j\theta 2}, \dots \dots \dots . e^{j\theta v}]$$

where x(m) represents the Partial Transmit Sequence and the set of phase factors denoted by $\ominus$. Now the target is to find the phase factors in such a way that resultant signal having minimum PAPR comes out. Note that with the increase in the number of sub blocks the search complexity increases exponentially [20]. The PTS algorithm is described as follow:

1. Disjoint sub-blocks are created by dividing OFDM sub-carriers.
2. IFFT of each sub-block is taken to generate the OFDM signals.
3. Using optimizing algorithm weighting factors are generated and combined with the output signals.

2.2 Selective Mapping (SLM) Technique

Block diagram of selective mapping is shown in Figure 2. In this technique, lowest PAPR signal is selected from a set of different signals representing same information. Among these same information sharing signals the one which is having the least PAPR is selected and the transmitted along with the side information.

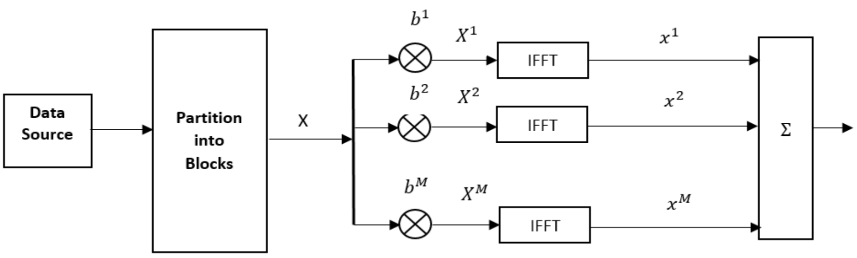

Fig 2. Block diagram for SLM technique

The SLM performsbetter than PTS in PAPR reduction for the same number of subcarriers but note that computational complexity also increases by doing so [21]. The SLM algorithm can be given using following steps:

1. Different phase sequences are multiplied to input signal.
2. For each signal the OFDM signal is generated.
3. OFDM signal having lowest PAPR is selected.

III. Proposed Technique

Normally in basic SLM technique described above uses the phase sequences which is generated by producing random numbers. These numbers are the phase values of the SLM technique. The rows of the normalized Riemann matrix are used in the Selective Mapping (SLM) as phase sequence set for PAPR reduction. The simulation results show that this technique provides better results than PTS and SLM. [2]. The Riemann matrix is obtained by removing the first row and first column of matrix A, where

$$A(i,j) = \begin{cases} i-1 & \text{if } \ \text{i divides j}, \\ -1 & \text{otherwise} \end{cases} \qquad (6)$$

In the proposed technique the first the rows of the normalized Riemann matrix are used in selective mapping scheme as phase sequence is applied and output data having minimum PAPR is selected. This data which is having minimum PAPR is then applied as the input of the PTS technique which results in the least PAPR data. From simulation results as shown in figures it is clear that PAPR reduction of the proposed technique is better than the techniques discussed above. The block diagram for the proposed technique is shown below:

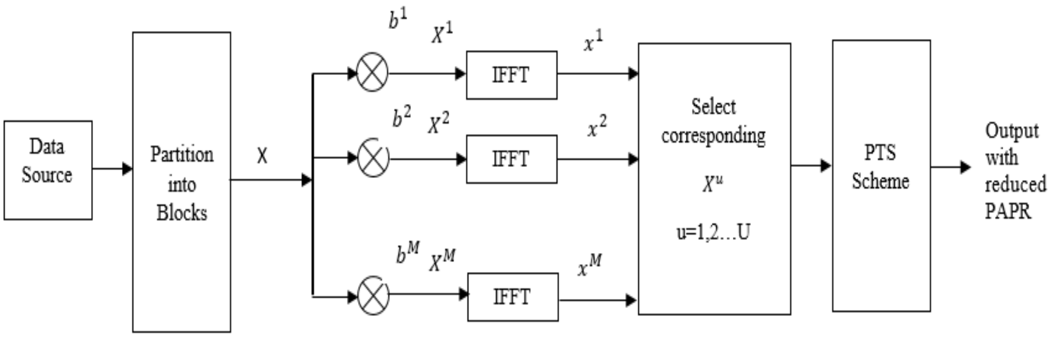

Fig 3. Proposed Technique block diagram

The proposed technique algorithm is described in follows:
1. Different phase sequences based on rows of normalized Riemann matrix are multiplied to input signal.
2. For each signal the OFDM signal is generated.
3. OFDM signal having lowest PAPR is selected.
4. Disjoint sub-blocks are created by dividing OFDM sub-carriers.
5. IFFT of each sub-block is taken to generate the OFDM signals.
6. Using optimizing algorithm weighting factors are generated and combined with the output signals.

IV. Simulation Results

In this section, we present simulation results to show the performance of the proposed scheme and compare the proposed scheme with Original, PTS, SLM, SLM combined with PTS and SLM with new phase sequence schemes. Simulation has been done in MATLAB and simulation carried out using 256 subcarriers with BPSK modulation scheme. Other parameters taken are oversampling rate equal to 4 and no of sub blocks. The four values: 2,4,8 and 16 are taken for this parameter. The 5000 iterations are taken for the simulation. The phase factor takenis [1, -1]. the complement cumulative distribution function (CCDF) of PAPR in original, partial transmit, selective mapping, selective mapping with new phase sequence as rows of normalized Riemann matrix and proposed schemes for the different values of sub blocks are shown in Fig. 4 to 7 respectively. Here CCDF describes the probability that the PAPR of given data exceeds a predefined fixed threshold PAPR. For M=2 the CCDFs of PAPR in various schemes is given in Fig. 4. The result graphs show that the proposed scheme gives better PAPR reduction in PAPR than the partial transmit, selective mapping and selective mapping combined with partial sequence butis more complex than the all other. When the number of sub-blocks is four the CCDFs of PAPR in various schemes is given in figure 5. From the figure 5 it can be seen that the performance of proposed, SLM, SLM and PTS combined schemes is much better than that of the previous case (M=2), Fig. 6 illustrates the case of M=8 sub-blocks. In this case, some more changes are observed as compared to the previous case and there is further reduction in PAPR. From the figure 4 to 6 it is concluded that with the increase in number of sub-blocks performance of the schemes increases. Therefore, the proposed schemes offer better reduction in PAPR with increase in the number of sub-blocks. When M=16 the proposed scheme offers better reduction in PAPR than previous cases. Therefore, Simulation results, shows that proposed schemesgives more PAPR reduction as compared to other techniques discussed in this paper.

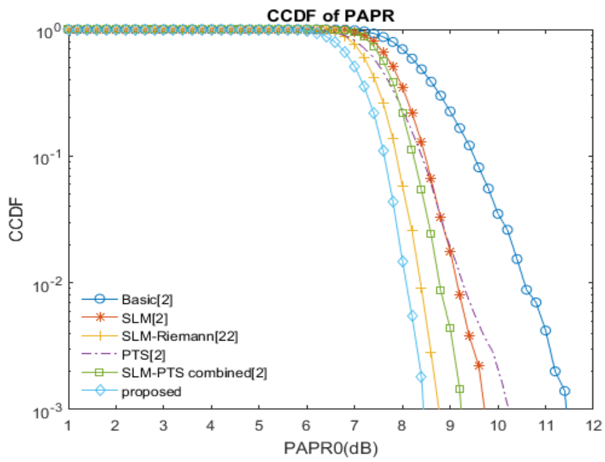

Figure 4. CCDFs of PAPR in Proposed, SLM and PTS combined, PTS, SLM, and original Scheme with 8 sub-blocks

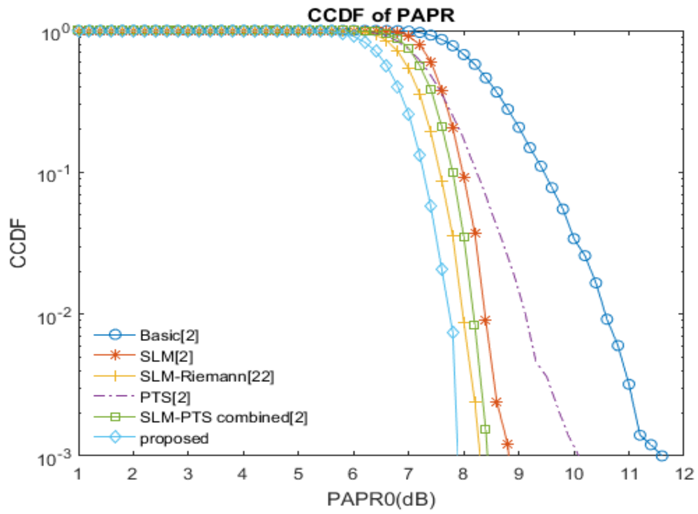

Figure 5. CCDFs of PAPR in Proposed, SLM and PTS combined, PTS, SLM, and original Scheme with 8 sub-blocks

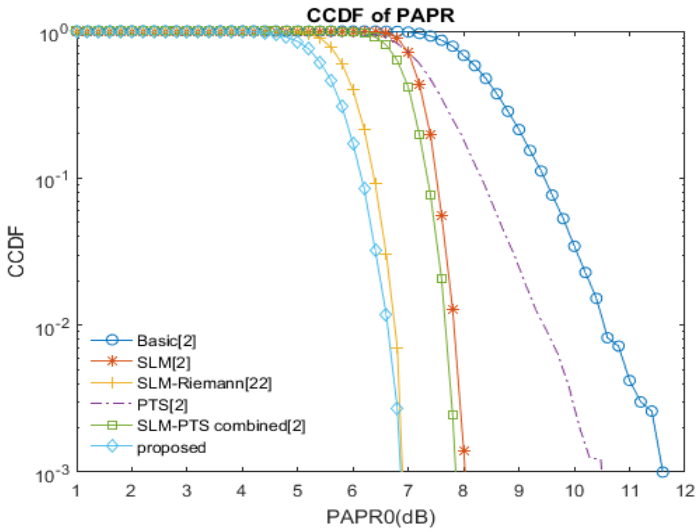

Figure 6. CCDFs of PAPR in Proposed, SLM and PTS combined, PTS, SLM, and original Scheme with 8 sub-blocks

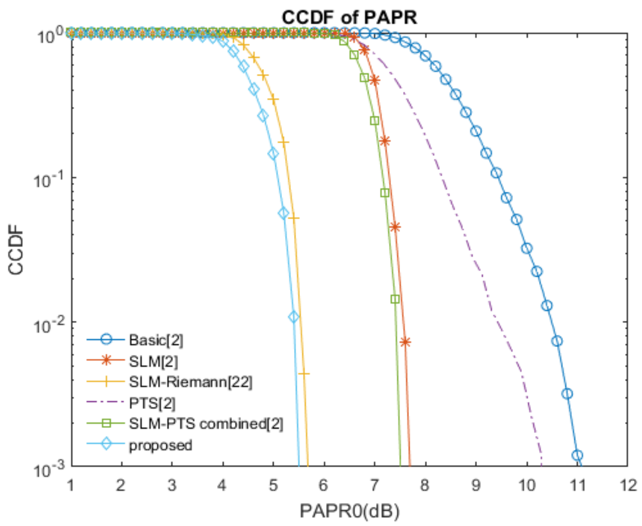

Figure 7. CCDFs of PAPR in Proposed, SLM and PTS combined, PTS, SLM, and original Scheme with 8 sub-blocks

V. Result comparison

Table 2 shows the average PAPR obtained by using the proposed and other techniques discussed in this paper. Please note that the input is the random in nature and this makes PAPR random in nature too. The PAPR results shown in the table 2 are in reference to the parameters considered in table 1. If the parameter changes the PAPR also gets affected. For example, if the no of subcarriers increases the PAPR also increases. For each technique the given PAPR is the average value obtained from an array of PAPR values which are generated for different random inputs and the number of such inputs are equal to the number of the total iteration run which is 5000 in this case. From table 2 it is clear that proposed techniques perform better than the other techniques discussed. However, the results comparison of all discussed techniques is given in table 3. Table 3 lists the comparison of PAPR among the proposed and other discussed techniques with respect to the basic PAPR i.e. PAPR without any scheme. It can be noted from the table 2 that proposed techniques provides better results as compared to other techniques and also its performance increase as the number of sub locks increases. For easy observation of the comparison shown in table 3 bar chart is drawn in figure 8.

Table 2. PAPR Analysis

PAPR (dB)						
	Paper [2]					
sub blocks	Basic	PTS	SLM	SLM and PTS	SLM-Riemann [22]	Proposed
2	8.45	7.8008	7.8304	7.679	7.3161	6.9976
4	8.4178	7.6448	7.5011	7.2684	7.0338	6.6636
8	8.4281	7.6491	7.1546	6.9004	5.8897	5.5229
16	8.4238	7.6565	6.9766	6.7696	4.7958	4.4864

Table 3. Results Comparison

	Paper [2]				
sub blocks	PTS	SLM	SLM and PTS	SLM-Riemann [22]	Proposed
2	7.68	7.33	9.12	13.42	17.188
4	9.18	10.89	13.65	16.44	20.84
8	9.24	15.11	18.13	30.11	34.47
16	9.11	17.18	19.64	43.07	46.74

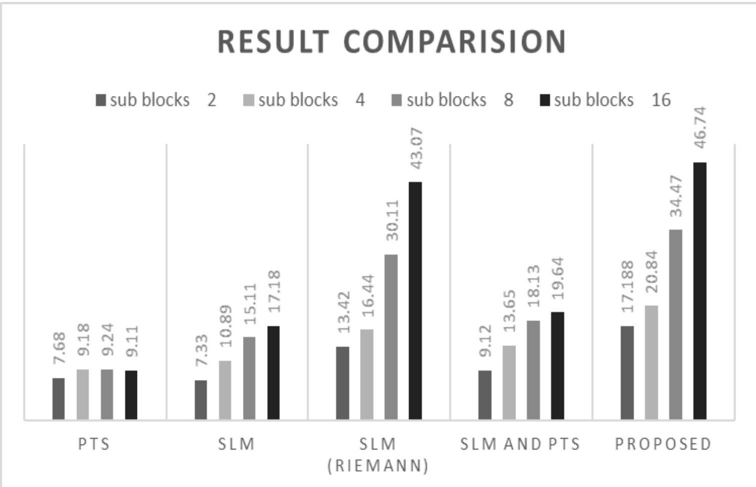

Figure 8. Results Comparison Bar Chart

VI. Conclusion

In this paper, proposed technique used for PAPR reduction in OFDM system is compared the selective mapping, partial transmit, selective mapping combined with partial transmit and selective mapping with new phase sequences rows of normalized Riemann matrix. It is observed that all discussed schemes lower the PAPR but proposed scheme gives better reduction in PAPR. Simulation result leads to the conclusion there is improvement in performance as the number of sub blocks increases. The results show that the proposed scheme gives better reduction in PAPR than all other schemes discussed. The PAPR reduction of proposed scheme in case of two sub blocks is estimated 6.99 dB where as it is minimum in case of sixteen sub blocks i.e. 4.48 as compared to basic PAPR. Even though the proposed schemes give better reduction in PAPR, still more work can be done to reduce the computational complexity. Riemann matrix is usedin this paper but further work can be done by using other test matrices.

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