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An Improved DSI-PTS for PAPR Reduction of OFDM System

Chhavi Sharma, A.K.Gupta, S.K Tomar

Abstract— Peak-to- average power ratio (PAPR) is one of the major problems of orthogonal frequency division multiplexing (OFDM). The larger PAPR signal may cause high out-of-band radiation, when the OFDM signal is passed through a radio frequency power amplifier. In literatures, many researchers proposed various methods to reduce PAPR. Among those, Dummy sequence Insertion (DSI) and partial transmit sequence (PTS) are well-known PAPR reduction techniques for OFDM signals,however, it results a huge amount of computation complexity.This paper proposes an improved DSI-PTS scheme that is able to carry out improved PAPR performance with lesser system complexity than the conventional methods. In addition to that, this scheme requires no side information.

Index Terms— OFDM, PAPR, Dummy Sequence, PTS

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1 INTRODUCTION

IN modern wireless communications, orthogonal frequency Division Multiplexing (OFDM) has been widely used because of its inherent robustness to frequency selective fading channels [1]. One of the major drawbacks of any OFDM system is that the signal has a nonconstant envelope exhibiting peaks that exceeds the mean power and the signal is said to have a high peak-to-average power ratio (PAPR). Inter-modulation among subcarriers and undesired out-of-band radiation occurs due to the high signal peaks. Therefore, it is highly desirable to reduce the PAPR [2].Various techniques have been proposed to reduce the PAPR comprising clipping and filtering [3], coding schemes[4], phase optimisation [5],Tone reservation (TR), tone injection (TI) [7], Active Constellation extension (ACE)[8],multiple signal representation techniques such as interleaving [9], selective mapping (SLM)[10] ,partial transmit sequence (PTS) [11]. In the PTS scheme, the number of subblocks and their partitioning determine the extent of PAPR reduction. Nevertheless, this approach still needs many IFFTs and the number of optional phase factor sequences is very large. Hence, it is very difficult to determine which phase factor sequences are employed in the optimization process [12].

- *Chhavi Sharma is currently pursuing Phd. from National institute of Technology,Kurukshetra,Haryana,India, E-mail: yash_naina @yahoo.com*
- *A.K Gupta is Professor in National institute of Technology, Kurukshetra, India.*
- *S.K Tomar is Associate Professor in IET M.J.P.Rohalkhand University Bareilly,India.*

Dummy signal insertion (DSI) is another technique for PAPR reduction proposed in [13].This method is simpler than SLM and PTS because it does not require side information.
DSI method reduces PAPR **by** increasing the average power of the signal. In this method, after converting the input data stream into parallel through the serial to parallel converter a, dummy sequence is inserted in the input signal. Therefore, the average value of signal is increased and the PAPR is subsequently reduced. It is concluded in [13] that DSI method is not much better than conventional PTS and block coding methods in respect of the PAPR reduction performance but it improves the BER performance than conventional PTS and has higher transmission efficiency (TE). Then the idea of DSI-PTS was proposed in [14]. It is claimed in [14] that by using DSI-PTS technique not only PAPR is reduced but also the complexity and processing time is reduced.
This paper proposes an improved DSI-PTS scheme with Riemann sequence. Riemann Sequence achieves good PAPR reduction capability by producing an amplitude change in the modulated data symbols [15] .Simulation results show that the proposed technique outperforms existing techniques by offering very low PAPR.
The paper is organized as follows: In Section II, OFDM system and conventional PTS are described. Section III introduces a new DSI-PTS with Riemann sequence. The simulation results are shown in section IV, and finally, the concluding remarks are given in section V.

2 OFDM SYSTEM WITH CONVENTIONAL PARTIAL TRANSMIT SEQUENCE

2.1 OFDM systems and PAPR definition

In an OFDM system with N subcarriers, the discrete-time transmitted signal is represented as

$$x_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j\frac{2\pi nk}{N}}, k = 1, 2, ...N-1 \quad (1)$$

Where $j=\sqrt{-1}$, X_n are the input symbols modulated by QPSK such that $X_n \in \{1, j, -1, -j\}$

The PAPR of the transmitted signal in (1) is defined as the ratio of the maximum to the average power, can be expressed as

$$PAPR = 10\log_{10} \frac{\max_k |x_k|^2}{E\left[|x_k|^2\right]} (dB) \quad (2)$$

where E [.] denotes expectation operation

2.2 OFDM with conventional PTS

The objective of the PTS scheme is to design a rotation phase vector ϕ that minimizes the PAPR. The functional block diagram of an OFDM system with conventional PTS scheme is shown in Fig.1 as that in [11]. The data block X is partitioned into U disjoint sub blocks X_u, where $u = 1, 2, ...U$ such that

$$X = \sum_{u=1}^{U} X_u \quad (3)$$

Here, it is assumed that the sub blocks X_u consist of a set of subcarriers of equal size. The partitioned sub-blocks are converted from the frequency domain to the time domain using N point IFFT. After taking IFFT, the representation of the block in the time domain is given by

$$x = IFFT\left\{\sum_{u=1}^{U} X_u\right\} = \sum_{u=1}^{U} IFFT\{X_u\} = \sum_{u=1}^{U} x_u \quad (4)$$

The goal of the PTS is to form a weighted combination of the U time-domain partial sequences x_u by a rotation vector $b = \{b_1 b_2 ......b_U\}$ to minimize the PAPR, which is given as:

$$x'(b) = \sum_{u=1}^{U} b_u x_u \quad (5)$$

To minimize the peak power of x', each partial sequence x_u should be properly rotated. Let $b_u = e^{j\varphi_u}$ where φ_u can be chosen freely within $[0, 2\pi]$.Now equation (5) can be expressed as

$$x'(\phi) = \sum_{u=1}^{U} e^{j\phi_u} x_u \quad (6)$$

where $\phi = [\varphi_1 \varphi_2 ....\varphi_U]$.PAPR reduction with the PTS technique is related to the problem of minimizing $\max|x'(\phi)|$ subject to $0 \le \varphi_u \le 2\pi$, $u = 1, 2, ..., U$,but it requires an exhaustive search and an enormous amount of computations to search all possible rotation phase vectors.

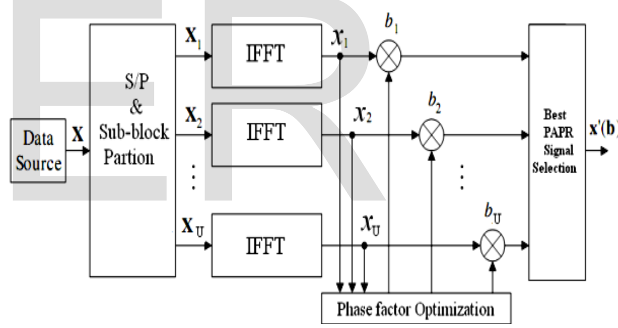

Fig. 1 Block diagram of conventional PTS Technique

2.3 Riemann sequence

If any row, except the first row is used for PAPR reduction in PTS-OFDM system of Riemann matrix B as phase sequence, it results not only in phase change but also in amplitude change of the modulated data symbols. Therefore, average energy of the OFDM signal after multiplication with phase sequence increases and PAPR is improved [14].The Riemann matrix (B) of size NN is obtained by removing the first row and first column of Matrix A of size $(N+1)(N+1)$ [14].

$$A(i,j) = \begin{cases} i-1 & \text{if i divides j} \\ -1 & \text{otherwise} \end{cases} \quad (7)$$

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Using Equation (7), Riemann Matrix (B) of order, four can be written as:

$$B = \begin{bmatrix} -1 & -1 & -1 & -1 \\ -1 & 2 & -1 & -1 \\ -1 & -1 & 3 & -1 \\ -1 & -1 & -1 & 4 \end{bmatrix} \quad (8)$$

It can be observed that the elements of p^{th} row in Riemann matrix (B) are either p or one for $1 \le p \le N$.

3 PROPOSED METHOD

The block diagram of proposed method is shown in Fig.2. Information data is converted in serial to parallel of length $L = N - S$ where N is the length of data subcarriers and S is the length of dummy sequence. Then a vector of dummy signals $\left[D_s\right]$ is generated and added to the vector of data subcarriers $\left[X_l\right]$, where $D_s = \left[D_{s,1}, D_{s,2}, ...D_{s,S}\right]$, $s = 1, 2, ..., S$ and $X_l = \left[X_{l,1}, X_{l,2}, ...X_{l,L}\right]$, $l = 1, 2........L$ *and* L and S are the length of data vector and dummy sequence vector respectively.
Now the new vector Y in frequency domain is then constructed as

$$Y = \left[X_l, D_s\right]$$

Now to generate dummy sequence, initially all -1s are used as dummy sequence then the bit flipping method is used for generating each dummy sequence for next branch. After generation of ***Y***, the PAPR of the signal is checked with the threshold value that is predefined before. If the PAPR is less than the threshold PAPR then the OFDM signal will be

transmitted, otherwise the dummy sequence is generated again and the process continues until the desired PAPR (threshold) is achieved. In this process, the processing time will increase.

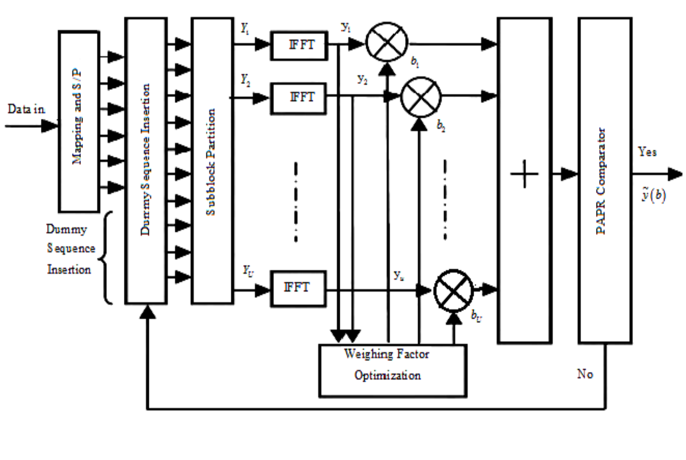

Fig. 2 Block diagram of improved DSI-PTS technique

Now signal Y is partitioned into U disjoint blocks, using adjacent sub block partitioning

$$Y_u = \left[Y_1, Y_2, ...Y_U\right] \text{ such that}$$

$$Y = \sum_{u=1}^{U} Y_u \quad (9)$$

These subblocks are then combined to minimize the PAPR in time domain by taking IFFT of each block. In the proposed method, after partitioning the signal and performing the IFFT, each subblock is multiplied with rows of normalized Riemann's matrix B as phase sequence vectors $B^{(u)}$, where $B^{(u)}$, $u = 1, 2, ...U$. In the time domain, the OFDM signal can be expressed as

$$\tilde{y}(b) = \sum_{u=1}^{U} b_u y_u \quad (10)$$

The objective is to optimally combine the U subblocks to obtain the time domain OFDM signal $\tilde{y}(b)$ with lowest PAPR. Now again PAPR of $\tilde{y}(b)$ is compared with $PAPR_{th}$. If PAPR of $\tilde{y}(b) > PAPR_{th}$ the signal is transmitted, otherwise, it is returned to the DSI block to generate the dummy sequence again and the process will continue until we get lesser PAPR than the $PAPR_{th}$.

4 COMPUTATIONAL COMPLEXITYAND SIDE INFORMATION

4.1 Computational complexity of the Improved DSI-PTS technique and the conventional PTS for N=128

In this section, the complexity analysis of conventional PTS (CPTS) and proposed Riemann sequence based DSI-PTS for N=128 subcarriers are compared. In general, when the number of subcarriers is $N=2^n$ and oversampling factor is 1, the number of complex multiplication and complex additions of the conventional PTS scheme are given by $2^{n-1}nU$ and

$2^n nU$ respectively, where U is the number of subblocks. One of the major issues in the proposed DSI-PTS method is to reduce the complexity of the OFDM system. The complexity of improved DSI-PTS can be reduced in terms of the number of subblock partition because only half IFFT operations are required and this is due to the addition of dummy sequence to the OFDM symbols. The computational complexity reduction ratio (CCRR) of improved DSI-PTS technique over the conventional PTS [13] is defined as

$$CCRR = \left(1 - \frac{Complexity \text{ of improved } DSI-PTS \text{ scheme}}{Complexity \text{ of conventional PTS}}\right) \times 100\% \quad (11)$$

Table 1

Computational Complexity of the improved DSI-PTS technique and the conventional PTS for N=128

Complex Calculations	No. of subblocks	C-PTS	Improved DSI-PTS	CCRR %
Multiplications	U=2	896	448	50
Additions	U=2	1792	896	50
Multiplications	U=4	1792	896	50
Additions	U=4	3584	1792	50

Table1 gives the CCRR of the proposed DSI-PTS technique over the conventional PTS when N =128. The table shows that, the computational complexity is reduced to half by applying improved DSI- PTS with Riemann sequence technique if it is compared with conventional PTS and remains same if it is compared with conventional DSI-PTS reported in [16].

4.2 Side information

In conventional PTS, the side information is necessary to transmit to the receiver for recovery of original information but it is not necessary to send this information to the receiver using the proposed method. This is because the Riemann matrix has a specific structure and receiver can easily regenerate it to recover the signal.

5 SIMULATION RESULTS

MATLAB simulations have been performed to evaluate and compared the PAPR performance of CPTS, DSI-PTS and improved DSI-PTS. Here QPSK format is considered with 256 subcarriers with oversampling factor four. All the simulation results have been performed for 10 iterations and the length of Dummy sequence S in the simulation is taken as 55.

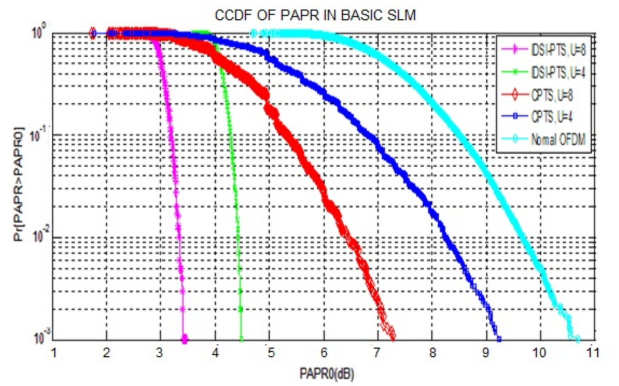

Fig.3 CCDF of PAPR of improved DSI-PTS (IDSI-PTS) for sub blocks U=4&8 with conventional PTS for N=128

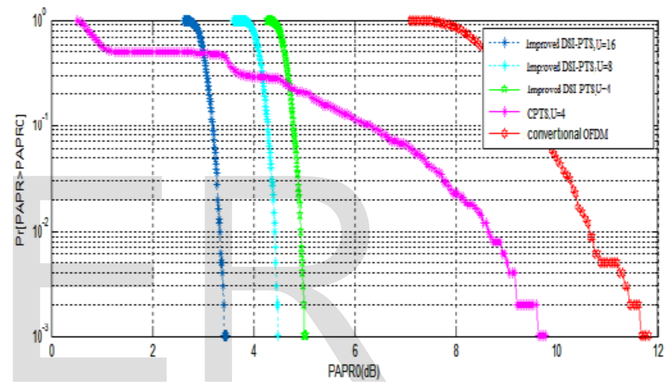

Fig.4 CCDF of PAPR of improved DSI-PTS(IDSI-PTS)) for sub blocks U=4, 8&16 with conventional PTS for N=256

Fig.3 shows the CCDF comparison curves of improved DSI-PTS (IDSI-PTS), Conventional PTS (CPTS) and conventional OFDM. It is clear that by applying the proposed DSI-PTS for U=4, the PAPR is reduced up to 4.7dB as compare to CPTS and 6.4dB is reduced as compare to conventional OFDM at CCDF 10^{-3}. Furthermore PAPR reduction is possible for U=8&16. Similarly,Fig.4 shows the CCDF comparison of improved DSI-PTS (IDSI-PTS), Conventional PTS (CPTS) and conventional OFDM. From the results it is clear that by applying the proposed DSI-PTS for U=4, the PAPR is reduced up to 5dB as compare to CPTS and 7 dB is reduced as compare to conventional OFDM at CCDF 10^{-3}. Furthermore PAPR reduction is achieved for U=8 & 16.

Fig.5 shows BER performance of normal OFDM, CPTS, IDSI-PTS for subblocks U=2 & 4. Results show that the proposed IDSI-PTS method outperforms than the conventional PTS method.

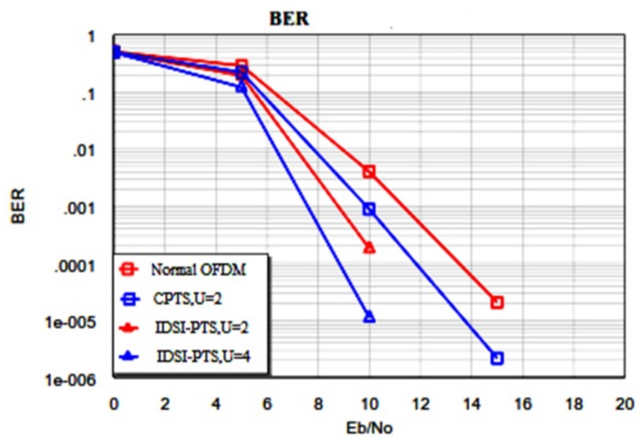

Fig.5 BER performance of normal OFDM, CPTS, IDSI-PTS for sub-blocks U=2&4

6 CONCLUSION

The technique applied in the proposed work is able to carry out improved PAPR performance with lesser system complexity than the conventional PTS methods. In addition to that, this scheme requires no side information if the simulation results are compared with conventional DSI-PTS.

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