

Single IFFT Block Based Reduced Complexity Partial Transmit Sequence Technique for PAPR Reduction in OFDM

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Abstract – This paper discusses a novel, reduced complexity implementation of the Partial Transmit Sequence technique (PTS) for reducing the Peak to Average Power Ratio (PAPR) of OFDM signals. The original PTS provides good PAPR reduction at the cost of computational complexity. The use of large number of IFFT blocks in PTS has been replaced by a single IFFT block. The parallel processing of the PTSs has been replaced by serial processing. Reducing the number of IFFT blocks and replacing parallel processing by serial processing reduces the computational complexity. The simulation results demonstrate that the proposed technique provides performance as good as standard PTS.

Keywords – PAPR, PTS, IFFT, OFDM

I. INTRODUCTION

Single carrier transmission has been in vogue in the world of wired and wireless communication for several decades. They suffer from the limitation of narrow bandwidth and hence only a limited data rate can be achieved. The new communication technologies such as IEEE 802.11g/n (Wi-Fi), IEEE 802.16 (WiMAX) and IEEE 802.20 (MBWA) have evolved as today's standard using multicarrier transmission, particularly the Orthogonal Frequency Division Multiplexing (OFDM) technique [1]. OFDM provides high data rates and high immunity to interference and frequency selective fading in wireless channels. But the biggest problem with OFDM is the high Peak To Average Power Ratio (PAPR). High PAPR affects power amplifier (PA) performance in the transmitter and causes intercarrier interference and signal distortion due to saturation of the PA.

In order to reduce the PAPR of OFDM signal, several techniques [2] have been proposed and tested till date. These include amplitude clipping, clipping and filtering, coding, tone reservation, tone injection, active constellation extension, partial transmit sequence,

selected mapping and interleaving. PAPR reduction using partial transmit sequences (PTS) [3] has proved effective due to its superior performance. However the technique suffers from a very high computational complexity and a loss in data rates. Several modified versions of the PTS technique have been proposed over the time to address the problem of high computational complexity.

Some of the popular techniques for PTS include reducing the number of candidate signals [4], using the correlation among the candidate signals [5] and using dummy signals [6]. However in most of the modified techniques, the basic algorithm has been the same. Thus the number of IFFT blocks being used is large and is equal to the number of sub-blocks. Moreover the number of candidate signals to be generated also increases exponentially with an increase in the number of sub-blocks and the number of allowed phase factors. This has led to new research for better PTS implementation.

This paper presents a PTS technique that uses only one IFFT block. The OFDM symbol is formed by combination of phase rotated PTSs. This is achieved in a cascaded manner. The reduction of PAPR is achieved for every PTS in a step-by-step manner, thus several candidate signals need not be generated. The new technique thus achieves good PAPR reduction with a much lower complexity.

The paper is organized as follows: Following this introduction Section II describes the standard PTS techniques. Section III describes the new algorithm and analyzes the implementation of the same. Section IV deals with the analysis of the computational complexity of the modified technique and compares with the original technique. The limitations of the proposed technique are discussed in Section V while Section VI presents simulation results and conclusion.

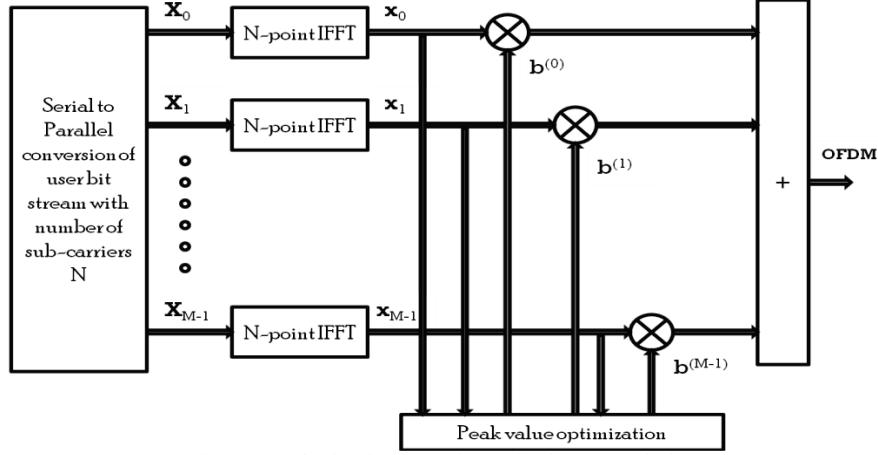


Figure 1: Block Diagram of Standard PTS Technique

II. PTS FOR PAPR REDUCTION: OVERVIEW

Figure 1 shows the implementation of the standard PTS. The incoming serial data stream will be converted into parallel blocks of data. The number of elements in a parallel data block is to be equal to the number of sub-carriers N [2,3]. Each parallel data block will be divided into M sub-blocks. Each sub-block will have N elements, where some subcarriers will have non-zero magnitude and rest will be zero. If the data vector be \mathbf{X} then the sub-blocks are \mathbf{X}_m and they satisfy (1) [3]

$$\mathbf{X} = \sum_{m=0}^{M-1} \mathbf{X}_m \quad (1)$$

N -point IFFT will be performed for all the sub-blocks simultaneously to obtain M PTSs, given by (2).

$$\mathbf{x}_m = \text{IFFT}(\mathbf{X}_m), \quad m = 0, 1, \dots, M-1 \quad (2)$$

Each of the PTS \mathbf{x}_m will be multiplied by a complex rotation factor $b^{(m)}$, $m=0, 1, \dots, M-1$. Typically the phase factor will be selected from the set of allowed phase factors, say W [3] given by (3)

$$\Phi = [e^{j\theta_i} | i = 0, 1, \dots, W-1] \quad (3)$$

All the phase rotated PTSs will be added together to form a complete OFDM symbol, given by (4).

$$\tilde{\mathbf{x}} = \sum_{m=0}^{M-1} b^{(m)} \mathbf{x}_m \quad (4)$$

Each of these OFDM symbols is termed as candidate signal. Such W^{M-1} candidate signals will be generated with all possible combinations of the phase factor

multiplication and the PAPR of all these candidate signals will be compared. The candidate signal with the minimum PAPR will be finally transmitted as the OFDM symbol.

III. THE SINGLE IFFT BLOCK BASED REDUCED COMPLEXITY PTS TECHNIQUE

A. The Algorithm

Figure 2 shows the implementation of the proposed method. The incoming serial data will be converted to parallel N element data block and then they will be divided into M sub-blocks, as given by (1). The sub-blocks will be held in temporary storage. A logic block to control loop execution is introduced, named as *Loop Logic*. It is followed by a single N -point IFFT block. The sub-blocks will be passed through the IFFT block one after another. In the first iteration, the first sub-block \mathbf{X}_0 will be passed through the IFFT block. The first PTS is obtained, as given by (5).

$$\mathbf{x}_0 = \text{IFFT}(\mathbf{X}_0) \quad (5)$$

This PTS will then be passed through the second *Logic* block. The *Logic* block decides that if this is the first PTS, then it is not multiplied by any phase factor and is stored as it is as partially formed OFDM symbol. In the second iteration, the second sub-block will be passed through the IFFT block to get the second PTS \mathbf{x}_1 . \mathbf{x}_1 will then be multiplied by a phase factor b_w^1 . Typically the phase factor will be selected from the allowed set of phase factors [3] given by (3). The phase factor is denoted as $b_w^{(m)}$ and the value of $b_w^{(m)}$ can be between $(0, 2\pi)$ [2,3]. The index w varies from 0 to $W-1$ and m varies from 0 to $M-1$. The rotated PTS ($\mathbf{x}_1 b_w^1$) will be added to the existing partial OFDM symbol \mathbf{x}_0 , the PAPR will be calculated and stored for further comparison. The second PTS will be rotated by all the allowed W number of phase factors and every time the PAPR will be computed and compared with the previous

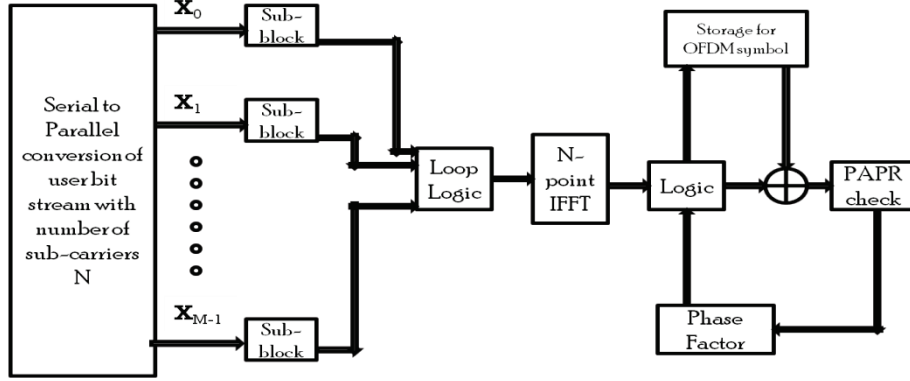


Figure 2: Proposed Implementation Block Diagram of Single IFFT Block based PTS Technique

value. The phase factor value corresponding to the minimum of all these PAPR values would be treated as the optimum value and the corresponding phase rotated PTS will be added to the partial OFDM symbol \mathbf{x}_0 to obtain the new OFDM symbol given by (6)

$$\hat{\mathbf{x}}_m = \min_{0 \leq w \leq W-1} \left(\frac{\max_{0 \leq k \leq N} |x_k b_w^{(m)} + \hat{\mathbf{x}}_{m-1}|}{E[|x_k b_w^{(m)} + \hat{\mathbf{x}}_{m-1}|]} \right) \quad (6)$$

This new OFDM symbol would replace the previous one in the storage. The next sub-blocks will be converted to PTS through the IFFT block and the same procedure of phase factor combination, addition of PTS to the partial OFDM symbol and PAPR comparison need to be done. At the end, all the PTSs would have been rotated by an optimum phase factor and added to form an OFDM symbol with minimum PAPR that can be transmitted.

IV. ANALYSIS OF COMPUTATIONAL COMPLEXITY

The main factors contributing to the complexity of the standard PTS technique are M zero padded N-point IFFT blocks, multiplication of PTSs by phase factors, vector addition of phase rotated PTSs and PAPR computation and comparison among $C = W^{M-1}$ candidate signals [5]. Table 1 shows the comparison of the complexity of the PTS and the single IFFT block based PTS where every operation is a vector operation over N-point matrix.

Let the number of subcarriers N be 64, number of sub-blocks M be 4 and the number of allowed phase factors W be 4. The complexity of the proposed method is approximately only 6% of that of the standard PTS, as shown in Table 2.

V. LIMITATIONS OF THE PROPOSED SINGLE IFFT BLOCK BASED PTS TECHNIQUE

The proposed technique adopts serial processing of the data rather than parallel processing. It has been

analyzed that the throughput time of the proposed method is better than that of standard PTS but may not be better than some of the modified low complexity PTS [4,5,6]. However, serial processing can be made faster by pipelining the process.

TABLE 1: COMPARISON OF COMPLEXITY OF STANDARD PTS AND SINGLE IFFT BLOCK BASED PTS

Process	PTS	Single IFFT block based PTS
IFFT	MW^{M-1}	M
N-point Vector Addition	MW^{M-1}	$W(M-1)$
Phase factor multiplication	$M(W^{M-1}-1)$	$W(M-1)$
PAPR calculation	W^{M-1}	$W(M-1)$
Comparison	$W^{M-1}-1$	$W(M-1)$

TABLE 2: COMPARISON OF COMPLEXITY OF STANDARD PTS AND SINGLE IFFT BLOCK BASED PTS: EXAMPLE

Process	PTS	Single IFFT block based PTS
IFFT	256	4
N-point Vector Addition	256	12
Phase factor multiplication	252	12
PAPR calculation	64	12
Comparison	63	12

Moreover, the proposed method requires some extra storage. However this can be addressed through a combined effect of pipelining and VLSI implementation of the method.

VI. RESULTS AND DISCUSSIONS

The proposed single IFFT block based PTS technique was simulated and the CCDF of PAPR was plotted. It has been compared with the CCDFs of the standard PTS technique and an OFDM transmission system without any PAPR reduction technique. The simulation was performed using QPSK modulation for different number of sub-carriers, sub-blocks and allowed set of phase factors. Figures 3-6 show that for all the cases, the proposed method achieves 2-3 dB reduction in PAPR over the standard PTS and a 6-7 dB reduction over OFDM transmission without any PAPR reduction technique, at a CCDF of 0.01. So the proposed method achieves a better performance with a significant reduction in the computational complexity.

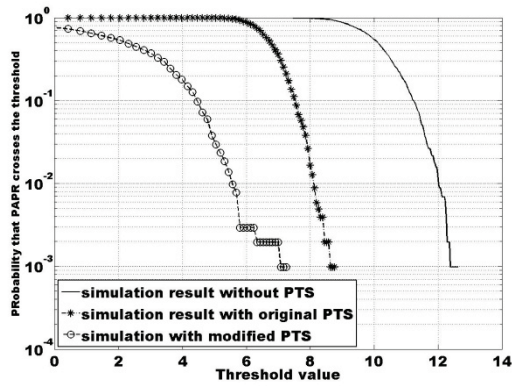


Figure 3: CCDF of PAPR with $N=32$, $W=2$ and $M=4$ for OFDM without PTS, OFDM with PTS technique and OFDM with single IFFT block based PTS technique

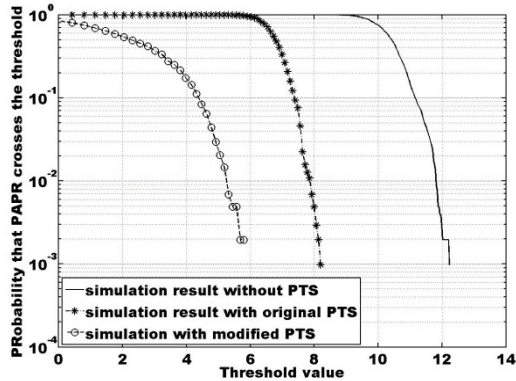


Figure 4: CCDF of PAPR with $N=64$, $W=2$ and $M=4$ for OFDM without PTS, OFDM with PTS technique and OFDM with single IFFT block based PTS technique

VII. CONCLUSION

A new reduced complexity implementation of standard PTS using a single IFFT block has been proposed in this paper. The parallel processing has been replaced by serial processing. Complexity has been reduced manifolds in comparison to standard PTS due to reduction in number of IFFT blocks and serial processing of data. The method

also achieves a better PAPR reduction. However, method has to be pipelined for better throughput time. VLSI implementation of the method will address the issues of extra storage and logic blocks added.

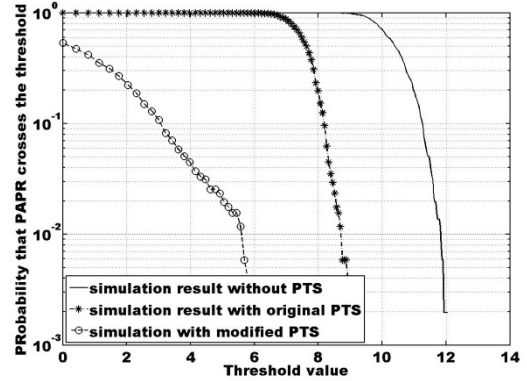


Figure 5: CCDF of PAPR with $N=64$, $W=2$ and $M=8$ for OFDM without PTS, OFDM with PTS technique and OFDM with single IFFT block based PTS technique

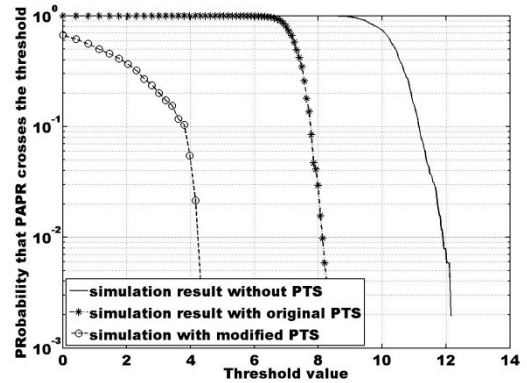


Figure 6: CCDF of PAPR with $N=64$, $W=4$ and $M=4$ for OFDM without PTS, OFDM with PTS technique and OFDM with single IFFT block based PTS technique

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