

# Computational Complexity Reduction of OFDM Signals by PTS with Various PAPR Conventional Methods

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**Abstract:** - In this paper we analyze Partial transmit sequences (PTS), it is one of the most attractive schemes to reduce the Peak-to-Average Power Ratio (PAPR) reduction in Multi-Input Multi-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) system with Space Frequency Block Coding (SFBC) is proposed. However, the Optimal PTS (OPTS) scheme requires an exhaustive searching over all combinations of allowed phase factors. Consequently, the computational complexity increases exponentially with the number of the subblocks. Recursive phase weighting (RPW) technique is a novel method whose aim is to reduce computational complexity and achieve the same performance in PAPR reduction as compared to O-PTS. Theoretical analysis and simulation results show that, compared with O-PTS and PTS employing RPW, PTS with AO-RPW method reduces the computational complexity but at the cost of loss of performance for PAPR reduction.

**Keywords:** Orthogonal Frequency Division Multiplexing (OFDM) System, Multi-Input Multi-Output Orthogonal Frequency Division Multiplexing (OFDM), Space Frequency Block Code (SFBC), Partial Transmit Sequence (PTS), Peak-to-Average Power Ratio (PAPR)

## 1. INTRODUCTION

Orthogonal frequency division multiplexing [1], [2] is a promising technique that provides high spectral efficiency for next-generation broadband wireless systems. It has gained popularity in a number of applications including digital audio broadcasting (DAB), terrestrial digital video broadcasting (DVB-T), the IEEE 802.11a standard for wireless local area networks (WLAN) and the IEEE 802.16d standard for wireless metropolitan area networks (WMAN), owing to its high bandwidth efficiency and robustness to multipath fading. However, there remain some drawbacks in OFDM systems such as high peak-to-average power ratio. It may result in significant

distortion when the transmitted signals are passed through a nonlinear device such as the power amplifier [3]. In order to reduce PAPR many PAPR reduction schemes have been proposed in the literature such as clipping and filtering [5]-[8], partial transmit sequence [9], selected mapping [10], coding schemes, nonlinear companding transforms, tone reservation (TR) and tone injection (TI). Among all existing schemes, partial transmit sequences (PTS) is an important technique because of its good PAPR reduction performance without any signal distortion. In this paper, we propose a phase weighting method for PTS, named as alternate optimized recursive phase weighting method. Its aim is to reduce the computational complexity compared to O-PTS and PTS with RPW. However the proposed

scheme has some loss in PAPR reduction performance using MIMO-OFDM signals. It results in the increasing of the intricacy and redundancy with the increasing number of antennas [3]. Henceforth, the several new schemes namely, Poly-Phase Interleaving and Inversion (PII) have been proposed specially for MIMO-OFDM systems. The best advantage of both the PTS/SLM and PII schemes is providing a good PAPR reduction without signal distortion. However, the computational complexity of the PTS/SLM and PII schemes is very high, as they need to implement additional Inverse Discrete Fourier Transform (IDFT) operations and iterations of phase optimization. Apparently, the computational complexity of the scheme proposed is reduced, at the cost of PAPR reduction. Moreover, its optimal phase rotation vectors also need to be transmitted as side information to the receiver, resulting in loss of the data rate. In this paper, Partial Transmit Sequences (PTS) scheme is proposed to reduce the PAPR of MIMO-OFDM signals. For accessibility and simplicity, the Space Frequency Block Coding (SFBC) is employed in MIMO-OFDM systems.

## 2. PAPR AMONG INTEGRATED OFDM SYSTEM

PAPR System is a block of  $N$  symbols  $X = \{X_k, k = 0, 1, \dots, N-1\}$   $T$  is formed with each symbol modulating one of a set of subcarriers,  $\{f_k, k = 0, 1, 2, \dots, N-1\}$  where  $N$  is the number of subcarriers. The  $N$  subcarriers are chosen to be orthogonal, i.e.  $f_k = k\Delta f$  where  $\Delta f = 1/(NT)$  and  $T$  is the original symbol period. Now, the complex envelope of the transmitted OFDM signals can be written as,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi f_k t}, 0 \leq t \leq NT \quad (1)$$

Where  $j = \sqrt{-1}$

In general, the PAPR of OFDM signals is defined as the ratio of the maximum instantaneous power and its average power

$$\text{PAPR}[x(t)] = \frac{\max_{0 \leq t \leq NT} |x(t)|^2}{P_{av}} \quad (2)$$

Where  $P_{av}$  is the average power of  $x(t)$  and is given by:

$$P_{av} = \frac{1}{NT} \int_0^{NT} |x(t)|^2 dt \quad (3)$$

The complementary cumulative distribution function (CCDF) of the PAPR is the most frequently used performance measure for PAPR reduction techniques. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold  $\gamma$ . When the number of the subcarriers  $N$  is relatively small, the CCDF expression of the PAPR of OFDM signals can be expressed as

$$\text{Prob}\{\text{PAPR} > \gamma\} = 1 - (1 - e^{-\gamma}) \quad (4)$$

### 2.1. MIMO-OFDM SYSTEM

MIMO uses multiple transceivers at both the transmitter and receiver to operate. Because MIMO allows more bits/sec/hertz to be transmitted in a given bandwidth, it improves spectral efficiency and allows operators to simultaneously support more users with high data-rate requirements. Increased spectral efficiency, higher data rates and the ability to increase data throughput without additional bandwidth or transmit power, makes MIMO especially attractive for use in wireless communication systems. In MIMO terminology, the "Input" and "Output" are referenced to the wireless channel, which includes the antennas. Performance gains are achieved as multiple transmitters simultaneously input their signal into the wireless channel and then combinations of these signals simultaneously output from the wireless channel into multiple receivers. For downlink communication, a single Base Station (BS) would contain multiple transmitters connected to multiple antennas and a single Mobile Station (MS) would contain multiple antennas connected to multiple receivers [5]. Each subcarrier carries one bit of information out of total  $N$  bits by its existence or nonexistence in the output frequency band. The known frequency at the receiver of each subcarrier is selected to produce an orthogonal signal set. At a periodic

interval T, the output is timely upgraded with the symbol period as well as the time boundary for orthogonality. Figure 4 shows the resultant frequency spectrum. In the frequency domain, the resulting sin function side lobes produce overlapping spectra. The individual peaks of subbands all line up with the zero crossings of the other subbands [10]. The overlapping of spectral energy does not interfere with the system's ability in recovering the original signal. The receiver multiplies (i.e., correlates) the incoming signal by the known set of sinusoids to produce the original set of bits sent. The digital implementation of an OFDM system will enhance these simple principles and permit more complex modulation.

### 3. PAPR REDUCTION TECHNIQUES

The high Peak-to-Average Power Ratio (PAPR) or Peak-to-Average Ratio (PAR) or Crest Factor of the Orthogonal Frequency Division Multiplexing (OFDM) systems can be reduced by using various PAPR reduction [4] techniques namely:-Multiple Signal Representation Techniques 1. Partial Transmit Sequence (PTS) 2. Selective Mapping (SLM)

#### 3.1. Partial Transmit Sequence (PTS) Techniques:

Partial Transmit Sequence (PTS) algorithm is a technique for improving the statistics of a multicarrier signal [7]. The basic ideas of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen (fig 1)

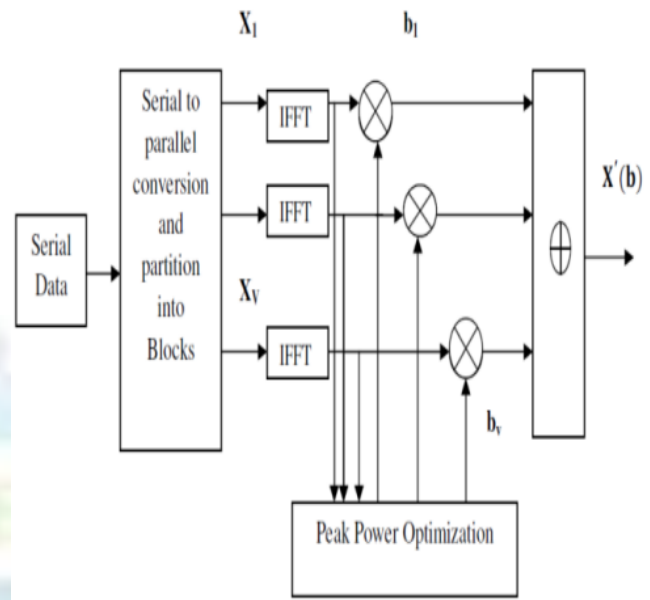


Fig 1. Block Diagram of Partial Transmit Sequence Technique

From the left side of diagram, the data information in frequency domain X is separated into V no overlapping sub-blocks of size N [11], that each N/V nonzero elements and set the rest part to zero. These sub-blocks are assumed to have the same size and no gap between each other

#### 3.2. OPTIMAL PTS (O-PTS) and RPW for PTS

##### (a). Mathematical Model for the O-PTS Technique

In O-PTS, the input data sequence of an OFDM system with N subcarriers is firstly partitioned into M disjoint subblocks  $X_i$ ,  $i = 1, 2, \dots, M$ , where all the subcarriers which are occupied by the other subblocks are set to zero. The frequency domain input sequence is given as

$$X = \sum_{i=1}^M X_i \quad (5)$$

By applying a phase weighting factor  $b_i = \exp(j\Phi_i)$ ,  $\Phi_i \in [0, 2\pi)$  to the  $i$ th subblock  $X_i = [X_{i,1}, X_{i,2}, \dots, X_{i,N}]^T$ ,  $i = 1, 2, \dots, M$ , alternative frequency signal sequence is given as

$$X' = \sum_{i=1}^M b_i \quad (6)$$

After being transformed to time domain by IFFT, the time domain signal sequence becomes

$$x' = \text{IFFT} \left\{ \sum_{i=1}^M b_i X_i \right\} = \sum_{i=1}^M b_i \cdot \text{IFFT} \{X_i\} = \sum_{i=1}^M b_i x_i \quad (7)$$

In the above equation, denotes the candidate sequence. For generating different phase weighting sequences, a set of phase weighting factors is normally chosen. Assuming that there be  $W$  allowed phase weighting factors in this set, without any loss of performance, we can set phase weighting factor for the first subblock to one and we see that there are  $(M-1)$  subblocks to be optimized. It is obvious that  $WM-1$  combinations must be checked to find the optimum candidate sequence with the minimum PAPR. For optimal PTS (OPTS), the optimum PAPR performance can be got after searching  $WM-1$  possible alternative combinations where  $M$  is the number of subblocks and  $W$  is the number of allowed phase weighting factors. In the process of phase weighting combination, large number of complex multiplications is needed and hence the computational complexity is very large.

**(b). Recursive Phase Weighting for PTS** As above mentioned, there are  $WM-1$  phase weighting sequences generated for obtaining candidate sequences. Considering all the phase weighting sequences, we can find the relationship (which will be mentioned in the observation later) between phase weighting sequences if the following conditions are satisfied: i) The number of phase weighting factors  $W$  is even; ii) The set of allowed phase weighting factors is  $\{e^{j(2k/W)}, k = 0, 1, \dots, W-1\}$ . Under the aforementioned conditions, we can have an important observation as follows. Observation: For any one from all the phase weighting sequences, there exists the other one such that in the corresponding positions of these two sequences, some phase weighting factors are opposite and the rest ones are same. The relationships among phase weighting sequences can be recursively continued to reduce

computational complexity. Thus, PTS with RPW has low computational complexity as compared to O-PTS.

### (C) SFBC Using Partial Transmit Sequence

The most well-known transmit diversity technique was introduced by SFBC where the proposed orthogonal code ensures full diversity. As shown in, the Block code pre-coding can be implemented either as a SFBC or as a Space-Frequency Block Code (SFBC). In order to simplify the descriptions of our proposed method, we consider a SFBC System with two transmits and one receives antennas [8]. For other systems with more transmit antennas, our proposed method can be easily extended fig (2)

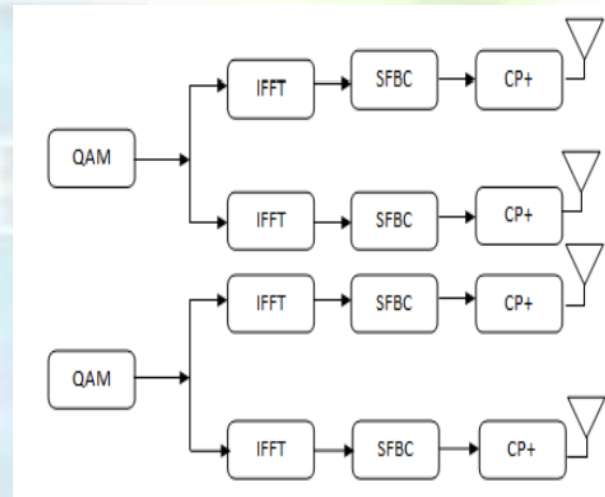


Fig 2. Basic SFBC MIMO-OFDM Systems

### 3.2. SELECTIVE MAPPING METHOD

The CCDF of the original signal sequence PAPR above threshold  $PAPR_0$  is written as  $\Pr \{PAPR > PAPR_0\}$ . Thus for  $K$  statistical independent signal waveforms, CCDF can be written as  $\Pr \{PAPR > PAPR_0\}$ , so the probability of PAPR exceed the same threshold [6]. The probability of PAPR larger than a threshold  $Z$  can be written as in equation (1)

$$P(PAPR < z) = F(z) N = (1 - \exp(-z))N$$

Assuming that  $M$ -OFDM symbols transmit the same valid information, which is statistically independent of each other. Here, the probability of PAPR is greater than  $Z$  and is equal to the product of each independent

probability. This process can be written as in equation (2)

$$P(\text{PAPR}) = 1 - (\exp(-Z))^{M-2}$$

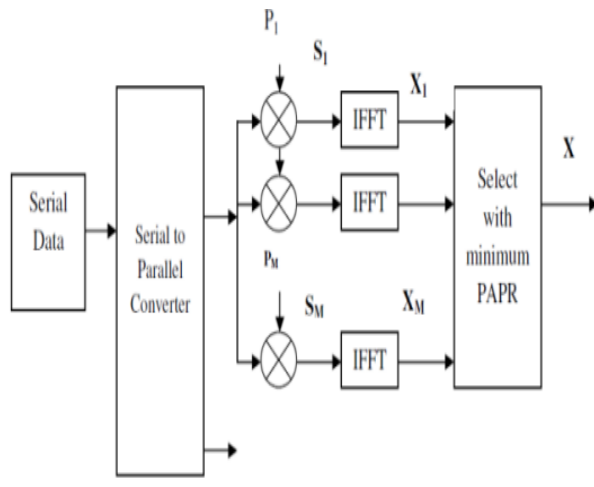


Fig 3. Block Diagram of Selected Mapping Technique

In selection mapping method (fig 3), Initially  $M$  statistically independent sequences are generated, to represent the same information and next, the remaining  $M$  statistically independent data blocks  $S_m = [S_{m,0}, S_{m,1}, S_{m,2}, \dots, S_{m,n-1}]$ , for  $m=1, 2, \dots, M$  are then forwarded into IFFT operation  $= [x_1, x_2, x_3, \dots, x_n]$ . In discrete time-domain are acquired and then the PAPR of these  $M$  vectors are assessed individually.

Eventually, the sequences  $x_d$  with the smallest PAPR is selected for final serial transmission.

## 4. RESULT ANALYSIS

To reduce the computational complexity of a PTS-based OFDM system, most authors focus on reducing the number of candidate signals. Performance Analysis The advantage in AO-RPW is that it has lesser computational complexity than RPW and O-PTS but the disadvantage is that it has lesser PAPR reduction capability than RPW and O-PTS.

**Simulation Results** In this section, we do extensive simulations to verify the performance of the proposed schemes. For PAPR reduction performance, the CCDF is used to evaluate and compare the performance of any PAPR reduction schemes. Figure 4, 5 and 6 show performance comparison between the original OFDM, AO-RPW method and RPW method. As is Obvious from the figures AO-RPW method has lesser PAPR reduction capability than that of the RPW method which is the disadvantage as stated in the theoretical analysis. Also it is evident from the figures that PAPR reduction capability decreases as we increase the number of subcarriers.

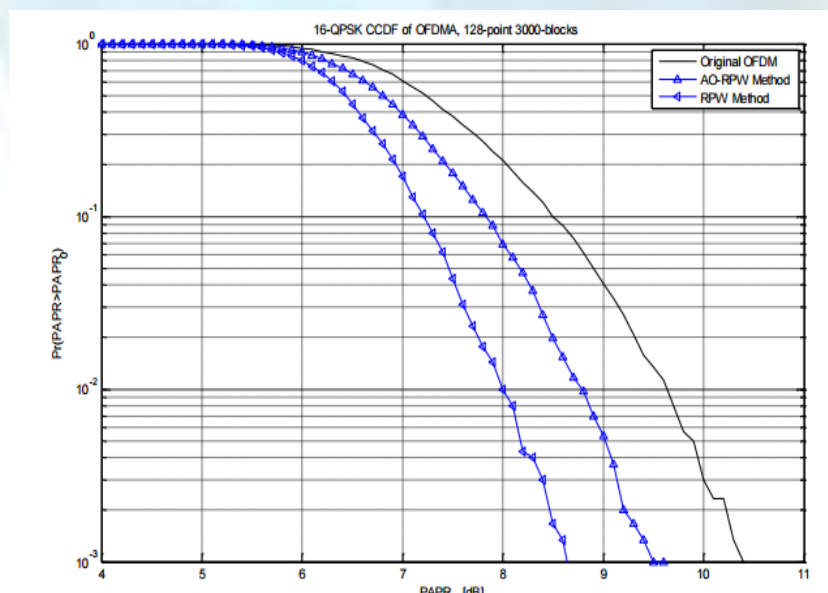


Figure 4: Comparison of CCDF of PAPR of PTS with AO-RPW, RPW and Original OFDM Signal (N=128)

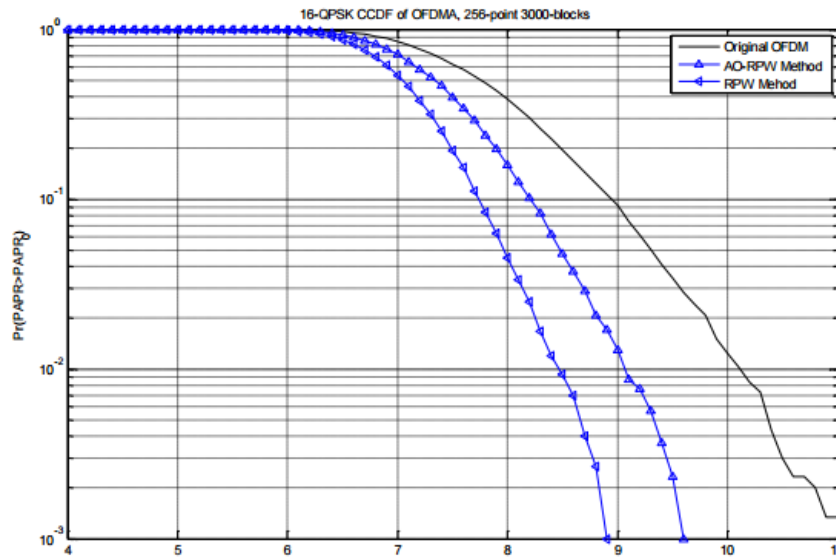


Figure 5: Comparison of CCDF of PAPR of PTS with AO-RPW, RPW and Original OFDM Signal (N=256)

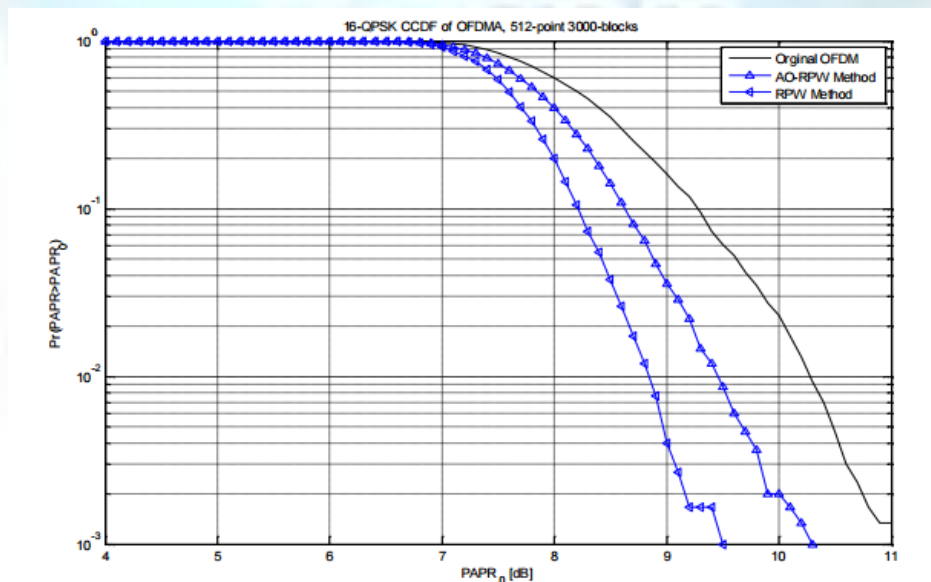


Figure 6: Comparison of CCDF of PAPR of PTS with AO-RPW, RPW and Original OFDM Signal (N=512)

## 5. CONCLUSIONS

In this paper, a phase weighting method with low computational complexity for PTS is proposed. This method (AO-RPW) has lesser computational complexity as compared to existing methods viz. RPW and O-PTS. However it has the drawback that its PAPR reduction capability is lesser as compared to GPW

method and the advantage that PAPR reduction capability is greater than that of O-PTS Method. Hence the computational complexity is reduced but at the cost of PAPR reduction performance.

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