Modified PTS Technique Of Its Transceiver For PAPR Reduction In OFDM System

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Abstract

This work aims at developing a simulation model of Partial Transmit Sequence (PTS) Technique based on gray code of Orthogonal Frequency Division Multiplexing (OFDM) systems. As Traditional PTS technique need side information for transmitting, so it increases its complexity. This PTS technique based on gray code reduces its complexity to great extent as there is no need for side information and also worked well as a Peak to Average Power Ratio (PAPR) suppression module compare to traditional PTS technique.
Keywords: *PTS, PAPR, Gray code*

1. Introduction

OFDM is a one of the popular multicarrier technique, came into existence from several decades. It has high data rate and high spectral efficiency. But it faces one major problem is high peak-to-average power ratio(PAPR) of transmitted signals, resulting in OFDM signals distortion in the nonlinear region of high power amplifier and high bit error rate [1]. To alleviate PAPR problem in an OFDM system, various techniques have been proposed such as selective mapping (SLM), partial transmit sequence (PTS) and active constellation extension (ACE).

2. PAPR Definition

Let N denote the number of subcarriers used for parallel information transmission and $X_k(0 \le k \le N-1)$ represent the k^{th} complex modulated symbol in a block of N information symbols. The outputs x_n of the N-point inverse discrete Fourier transform (IDFT) of X_k are given by $x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k \exp(\frac{j2\pi kn}{N})$ where $j^2 = -1$.

PAPR defined as maximum peak signal to the average peak signal.

$$PAPR = 10\log_{10}\frac{P_{peak}}{P_{av}}[dB]$$

where $P_{av} = \frac{1}{T}\int_0^T [x(t)]^2 dt$ is the average power of the transmitted signal and $P_{peak} = \max|x(t)|^2$ is the peak power.

3. Proposed Partial Transmit Sequence Technique

3.1 Conventional Partial Transmit Sequence Technique

The PTS approach is well known method as a distortion less technique based on combining signal sub-blocks or clusters, which are multiplied by weighting factors. The PTS technique partitions the input block X of length N into V disjoint sub-blocks Xi of length N, i=1,2,⋯,V, which can be represented as *v* {*X v* =1, 2,…,V}.

Hence, $X = \sum_{v=1}^{V} X^v$,

where $X^v = [X_0{}^v, X_1{}^v, ...X^v{}_{N-1}]$ with $X_k{}^v = X_k$ or 0 $(1 \le v \le V)$. Let b=$\{b_v = e^{j\theta v}, v = 1,2,...V\}$ be the set of phase factors which are applied to the subblocks X^v. The substitute frequency domain signals are

$$X^{'} = \sum_{v=1}^{V} b_v X^v, (b_v = e^{j\theta_v}, v = 1,2,...,V). \quad ....(1)$$

Note that these partial sequences are independently rotated by phase factors . Taking the IFFT of the above equation and using the linearity property of the IFFT, the time domain partial transmit sequences can be expressed

as $x^{'} = IFFT(X^{'}) = \sum_{v=1}^{V} b_v IFFT(X^{v}) = \sum_{v=1}^{V} b_v x^{v}$ …
……………………………………………………….(2)

The objective is to optimally combine the V subblocks to obtain the time domain OFDM signals with the lowest PAPR. Without any loss of performance, one can set $b_1 = 1$ and observe that there are (V-1) subblocks to be optimized. Consequently, to achieve the optimal phase factor for each input data sequence (assume that there are W phase factors in the phase set), W^{v-1} combinations should be checked in order to obtain the minimum PAPR. Therefore, the search complexity for an optimum set of the phase factors increases exponentially with the number of subblocks [3].

3.2 Modified Partial Transmit Sequence Technique

In order to reduce the computational complexity of PTS, many papers have proposed effective solutions. "PAPR Reduction of OFDM Signals Using a Reduced Complexity PTS Technique"[2], "Peak-to-Average Power Ratio Reduction of OFDM Signals Using PTS Scheme With Low Computational Complexity" [3] used a low complexity phase weighting process is implemented, where the relationship between phase weighting sequences is considered and the computation for candidate signals is simplified by making use of this inherent feature. These methods reduce the computational complexity to some extent, but the implementation of hardware is still so difficult. As these methods reduce the computational complexity to some extent, but the implementation of hardware is still so difficult. Aiming at this problem, the improved PTS approach's main idea is to reduce the correlation operation of the calculation by Gray code encoding the phase factors [1].

Gray code is one of the popular code pattern for the structured light system. An n-bit Gray code is a kind of binary code whose adjacent code-strings differ only in one bit position. Take the number of sub-blocks V = 4 and the set of phase weighting factors W=2 is {1, -1} for example, all the phase weighting sequences are shown in Table 3.2.1.

Let b_1 and b_2 be phase weighting sequences for generating the candidate signals y_1 and y_2, and then according to the rules 1 and 2, we can obtain the following formulae [1].

Table 3.2.1: Phase weighting sequences

No.	Bit Labeling	Gray Code
b_1	1000	1100
b_2	1001	1101
b_3	1010	1111
b_4	1011	1110
b_5	1100	1000
b6	1101	1010
b_7	1110	1001
b_8	1111	1000

$$y_1 = \sum_{i=1}^{V} b_{1,i} x_i = x_1 - x_2 - x_3 - x_4 \quad \text{………} \quad (3)$$

$$y_2 = \sum_{i=1}^{V} b_{2,i} x_i = x_1 - x_2 - x_3 + x_4 \quad \text{……..........} \quad (4)$$

From above equations, it can be indicated that there is common term $x_1 - x_2 - x_3$. Let $S_1 = x_1 - x_2 - x_3$, then y_1 and y_2 can be written as

$$y_1 = \sum_{i=1}^{V} b_{1,i} x_i = S_1 - x_4 \quad (5)$$

$$y_2 = \sum_{i=1}^{V} b_{2,i} x_i = S_1 + x_4 \quad (6)$$

From the above expressions we can find that we should calculate y_1 first, and then the candidate signal y_2 can be easily obtained. On this basis, then y_{k-1} and y_k can be written as

$$y_{k-1} = \sum_{i=1}^{V} b_{k-1,i} x_i = \sum_{i=1, i \neq m_0}^{V} b_{k-1,i} x_i \pm b_{k-1,m0} x_{m0} = S_k \pm b_{k-1,m0} x_{m0} \quad \text{..(7)}$$

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$$y_k = \sum_{i=1}^{V} b_{k,j} x_i = \sum_{i=1, i \neq m_0}^{V} b_{k,j} x_i \pm b_{k,m0} x_{m0} = S_k \pm b_{k,m0} x_{m0} \quad ..(8)$$

3.3. Reduced Computational Complexity PTS

The improved PTS algorithm is mainly reflected in the calculation of reducing the amount of multiplication which reduces the hardware complexity. In the PTS algorithm, assuming that the number of sub-blocks is V, the number of phase factor is W, and the number of points in IFFT operation is N. Meanwhile, the computational complexity of traditional calculation PTS noted as O_PTS, the improved algorithm noted as R_PTS, we can obtain the following formulas [1].

$$O\_PTS = N*(V-1)*W^{v-1}$$

$$R\_PTS = N*(V-1) + N*(W^{V-1}-1) \quad (9)$$

Further simplify the ratio of the calculation:

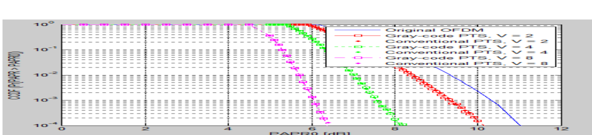
$$\frac{O\_PTS}{R\_PTS} = \frac{N*(V-1) + N(W^{v-1}-1)}{N(V-1)*W^{v-1}} \quad (10)$$

Eq.(10) shows that with the increase number of sub-blocks, the computational complexity reduces drastically. When employ sub-blocks defined value of V, the computation can be reduced to about 42%, comparing to the original PTS algorithm.

3.4. Performance Analysis and Simulation Results

Take computational complexity and PAPR performance into consideration, the simulation results is shown in figure 3.4.1. It can be seen through the MATLAB simulation, Gray code encoding PTS algorithm and the traditional PTS PAPR performance is almost in consistent, but the computation time of Gray code encoding PTS algorithm is greatly reduced. When We are using Conventional PTS approach to get a OFDM signal then it takes 12.004181 µs, while it only takes 10.516851µs Gray code encoding PTS approaches.

Fig.3.4.1 BER performance of the theoretical,



conventional modified PTS

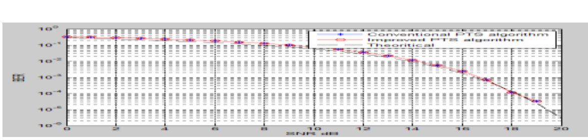


Fig.3.4.2 PAPR performance comparison between the modified and the conventional PTS algorithm

Fig.3.4.1 shows that the BER performance of conventional and modified PTS are almost same but little bit differ from the theoretical value.

As shown in the figure 3.4.2, when employ V=8, the PAPR performance increases 1.8dB compared with V=4, increases 2.7 dB when V=2. However, the computational complexity of V=8 is much larger than V=2 or V=4. Therefore, comparing the PAPR performance and the computational complexity, we divided entire data stream into 4, then the computational complexity of the final hardware implementation is lower and the PAPR performance can be achieved as well.

4. Design and Implementation

4.1 Modified PTS Simulink Model

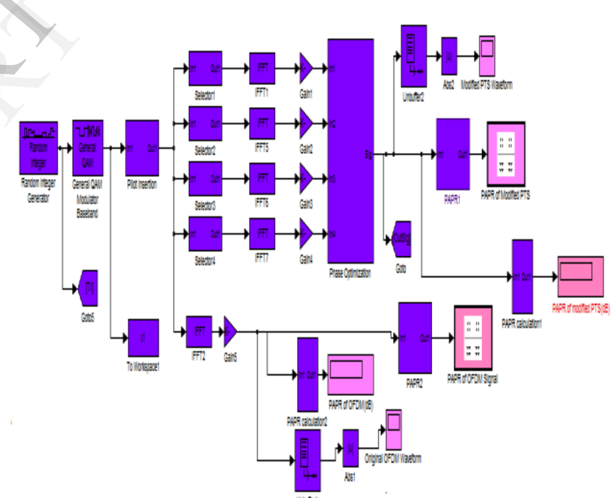


Fig. 4.1.1 A Simulink Transmitter Model

This simulink model can be used in real-time application. The data is coded with any of the matlab coding and interfaced with the simulink model. So, reduction of the PAPR will be obtained in modified PTS model compare to OFDM model. This model is developed in order to give a comparison analysis of the performance with the OFDM model and modified PTS model. This system consisted of the Transmitter part consist of OFDM transmitter, PTS transmitter, Phase optimization, PAPR Calculation System and Receiver part consist of AWGN channel and BER Calculation system.

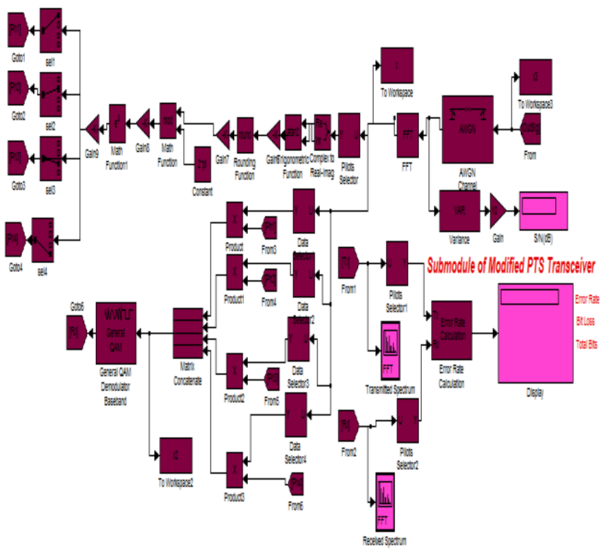


Fig.4.1.2 Basic Receiver Simulink Model

- **Design Parameters**

  Number of Symbols =15,000
  Number of subcarriers = N=64
  Modulation =M=16QAM
  Subblocks=V=4
  Number of phase factors=W=2=(1,-1)
  Symbol Length=T=1
  Symbol Energy=E=1

- **Phase Optimization**

  This is the subsystem of phase optimization block. In this sub-system all combination of phases based on the binary representation of the phase are generated and the PAPR of all these combinations are computed. Then the smallest one will be selected for transmission. The simulink is usually used for the front-end system and is not as flexible as the m-file. Therefore, in this simulink only 8 combinations of different phases are considered as for the generation of the candidate signal formula is W^{V-1}.

- **PAPR Calculation**
  It is used to calculate peak to average power ratio in dB.

4.2. Results and Discussions

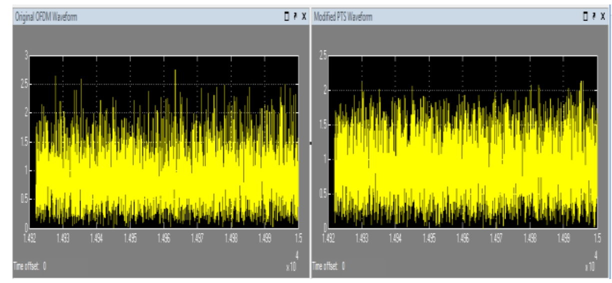


Fig.4.2.1 shows the waveform of original ofdm signal and modified PTS

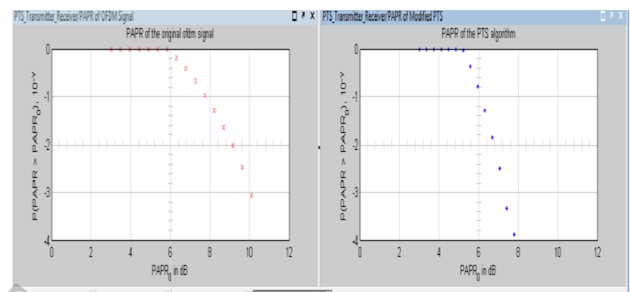


Fig.4.2.2 shows the comparision of PAPR of original ofdm signal and modified PTS signal

From the above figures, Fig.4.2.1 shows the waveform of original ofdm signal and modified PTS and .4.2.2 shows the comparision of PAPR of original ofdm signal and modified PTS signal, it can be concluded that PAPR of OFDM signal is greatly reduced.

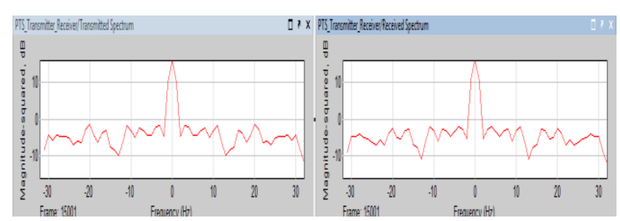


Fig.4.2.3 shows the square spectrum of input transmitted signal and output received signal

The PAPR of the original ofdm signal is 2.019dB and that of modified PTS signal is 1.688dB when simulation time is 15000.

The signal to noise ratio is 10.31dB and bit error rate is 0.0034 of Modified PTS signal when simulation time is 15000.

5. Conclusion

In Conventional PTS, the computation is high and need to transmit side information but when we use gray code than complexity is reduced and hardware can be implemented easily. Simulation results show that complexity is reduced to 42% of the original PTS when subblocks V=4.

Matlab Stimulation show that Gray code Encoding PTS takes less time for encoding than Conventional PTS. We have consider AWGN channel, the bit error rate is almost same in both of them.

By observing Waveforms, we conclude that high peak amplitude signals is greatly reduced in Modified PTS as compared to original OFDM waveforms. So there is no need of High Power RF Amplifier and also cost get reduced.

6. References:

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