A Tree Structure PTS Technique for PAPR Reduction in OFDM Systems

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Abstract

High peak-to-average power ratio (PAPR) of the transmitted signals is the major problem in orthogonal frequency division multiplexing (OFDM) system. The partial transmit sequence (PTS) technique can reduce PAPR in OFDM system. However, the severe computational complexity in conventional PTS (C-PTS) is the major drawback. In this paper, we propose the tree PTS (T-PTS) to find codewords of a linear code as weighing factors by executing the PTS method in the tree structure of this code. The combination of PTS and tree structure not only reduce the computational complexity but also provide error correction capability for the weighing factors. Simulation results show that the T-PTS achieves good PAPR reduction with lower complexity, compared to conventional PTS.

Keywords: OFDM, PTS, PAPR, tree structure, linear block codes.

1. Introduction

Orthogonal frequency-division multiplexing (OFDM) is a multi-carrier modulation (MCM) technology for high data-rate transmission in wireless channels and is adopted in a number of communication systems, such as DAB [1], ADSL [2], and WiMAX [3]. One of the major problems in OFDM system is the high Peak-to-Average Power Ratio (PAPR) of transmitted signals, which means that a complicated power amplifier is needed at the transmitter. Therefore, the subject of finding a computationally efficient algorithm to decrease the PAPR in OFDM systems is an active research. There are many proposed methods to reduce PAPR of OFDM signals, such as clipping and filtering [4], coding techniques [5] and partial transmit sequence (PTS) [6].

The C-PTS technique partitions the input data into

disjoint subblocks, forms the partial transmit sequences by taking the Fourier transform of these subblocks, and generates a number of OFDM candidates by linear combination of these PTS with different weighting factors. However, the computation complexity of exhaustive search in C-PTS increases exponentially with the number of subblocks and C-PTS is thus not easily implemented for a large number of subblocks. In [7] the authors proposed an iterative algorithm to reduce PAPR with low complexity, however its PAPR performance is relatively unsatisfied. Thus, the issue of low complexity PTS techniques with good PAPR performance is an active area of research and has widely attracted the attention of researchers, such as [8, 9, 10].

In this paper, we present a novel low complexity PTS algorithm by combining the C-PTS and tree diagrams, called T-PTS. More precisely, a linear code with good error correction and low complexity tree diagram, consisting of all weighting vectors, is used to generate all possible transmitted OFDM candidates. The advantage of T-PTS method not only reduces the search complexity but also provides error control capability for side information. This paper is organized as follows. Section II introduces PAPR of OFDM systems and the PTS method. Section III describes our proposed low complexity T-PTS algorithm. Section IV shows the simulation results and Section V gives a conclusion.

2. PAPR Definition and PTS Technique

In an OFDM system of N subcarriers, we denote $\mathbf{X}=(X_0, X_1, \dots, X_{N-1})$ as the input data block of length N where each symbol is modulated with one of orthogonal subcarriers f_k , $k=\{0, 1, \dots, N-1\}$. In the continuous time domain, an OFDM baseband signal $x(t)$ of N subcarriers can be expressed as

Fig. 1. The block diagram of conventional PTS.

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

the PAPR of a transmitted signal is defined as

$$10 \log_{10} \frac{\max |x(t)|^2}{E[|x(t)|^2]}. \quad (2)$$

Shown the Fig. 1, conventional PTS (C-PTS) technique, the input data block X is partitioned into M disjoint subblocks. they has three methods of partition are adjacent partition, interleaved partition and random partition, our proposed method uses random partition to subblocks. So we expressed as

$$X = \sum_{m=0}^{M-1} X^{(m)}, \quad (3)$$

these frequency sequences $X^{(m)}$, are then passed into M IFFTs and transformed into the time domain signals called partial transmit sequences as

$$x^{(m)}(t) = IFFT[X^{(m)}], \quad (4)$$

after that, these PTS signal are independently rotated by the phase weighting factor b_m and combined together to generate many different OFDM candidates:

$$\tilde{x}(t) = \sum_{m=0}^{M-1} b_m x^{(m)}(t), \quad (5)$$

were $b_m = e^{j(2\pi w/W)}$, $w=0,1,2,\dots,W-1$ and W is the number of the varying phases.

3. Proposed Method and Computational Complexity

In the C-PTS method, we know decided to calculate the Complexity of weighting factor by dividing into

sub-blocks M and W is an interference amount related to the exponential, then reducing computational complexity of C-PTS is an important topic. So in [10] proposed a method to reducing the computational complexity of C-PTS. In this proposed then the interference amounts $W=2$, must be have full weighting factor for equivalent to using a coding for $G[M-1, M-1, 1]$ matrix. Example: $M=8$, $W=2$ is the optional weighting factor of $2^{8-1}=128$, and the choose matrix of $G[7,7,1]$ is a same. Therefore if we make a matrix $G[n, k, d]$, $n=M-1$, we can ensure that this codewords has the 2^k weighting factor and error correction capability. In the computational complexity has from the $2^{(M-1)}(M-1)$ reduced to $2^k(M-1)$. So, then one of G matrix having the error correction capability in accordance with the codeword a certain regular arrangement, we can get his needed computational complexity from the $2^k(M-1)$ reduction to $2^k d$ and in the changing symbols have need an added. But this is a computational complexity is very high.

3.1 Proposed Method

First, we know that they meet the linear block code characteristic can be draw the tree structure. So we can be find the information bits $[v_1, v_2, \dots, v_k]$ and parity check bits $[p_1, p_2, \dots, p_{n-k}]$ of G matrix, and will the same bits position

Fig. 2. The tree diagram of generator matrix form $G[7, 4, 3]$.

together. Example $G[7, 4, 3]$ expressed as

$$G = \begin{bmatrix} 1000110 \\ 0100011 \\ 0010111 \\ 0001101 \end{bmatrix}, \quad (6)$$

After finishing the matrix G is a generator matrix. From this generator matrix, we can draw into a tree structure. In the branch case of information bit is 0 or 1, parity check bits use not alteration. Example: From (6), if $P_1=[1011]$ and now information is $v_1=0, v_2=1, v_3=1$, and $v_4=0$ then we can find in this branch bit is 1. Shown the Fig. 2, we can from this tree structure to get 2^k codewords for used as weighting factors. But this still a high computational complexity. Therefore, we propose to a suboptimal for reducing the computational complexity methods.

Fig. 3. The tree diagram of G_{DLP} matrix form $G[7,4,3]$.

We use references [11], if information bits are concentrated on one side of generator matrix, and make soon expansion of the tree structure of the last branch, such a tree structure is relatively not good. So, if We can reset some of information bits moving backwards, then the relativity of the slow growth branch. View of this we adjusted the generator matrix in accordance with the references [11], maybe also make the reducing computational complexity. First, we know a generator matrix G and find the dual codes $G^\perp$ of matrix $[n, r, dc]$, then $r=n-k$. Find the dual codes, we started for performing matrix G a row computation to make over a certain amount of information bits after the dc , next the 1 of the last row had generator matrix the minimum hamming distance d , while the previous row is the 1 number of $\lceil d/2 \rceil$, and next previous row is a number of $\lceil d/4 \rceil$. Accordance with this method until the upper limit is 1, put the remaining information bits to fill. After the complete this procedure the matrix we define as G_{DLP} . For the Example we after finishing (6) a result as

$$G_{DLP} = \begin{bmatrix} 1001011 \\ 0101010 \\ 0011001 \\ 0000111 \end{bmatrix}, \quad (7)$$

Next, we also draw out the G_{DLP} of tree PTS (T-PTS). Shown the Fig. 3, we can see that a G_{DLP} matrix their information bits it will slowly increase the selection number.

3.2 Computational complexity

Like the C-PTS method of computational complexity, we propose a method of reducing the computation. In the tree structure representation of every stage it corresponds to every subblocks can be represented as a selectable weighting factor. In each strata, if there is a change we will as a computing element. So when we can get all codeword on this T-PTS. In the process of the moment weighting factor has changes will only the computational this subblocks and find the PAPR [9]. So we set a generator matrix $[n, k, d]$, and information bits is $[v_1, v_2, \dots, v_k]$, then a generator matrix of T-PTS the computational complexity result as

$$SC = \sum_{i=1}^{k+1} (v_i - v_{i-1}) 2^{i-1}, v_{k+1} = n+1. \quad (8)$$

Our proposed method wherein knows the generator matrix $G[n, k, d]$ and dual code $G^\perp$, Worth noting that when the $i=k+1$ then $(v_i - v_{i-1})=d; i=k, (v_k - v_{k-1})=\lceil d/2 \rceil$. Accordance with this method until the upper limit is 1, and then $i=dc$ the $(v_i - v_{i-1})=2$. For the Example: we set generator matrix $G[23,12,7]$ and dual code $G^\perp[23,11,8]$ form (8), find the generator matrix in the sequence of its complexity as $SC=2^0+2^1+2^2+2^3+2^4+2^5+2^6+2^7+2^8+2^9+2^{10}+2^{11}+2^{12} \cdot 12$. However, we proposed method of its complexity as $SC=2^0+2^1+2^2+2^3+2^4+2^5+2^6+2^7 \cdot 2+2^8+2^9+2^{10} \cdot 2+2^{11} \cdot 4+2^{12} \cdot 7$. From the process, we can draw a lot of computational complexity in the generator matrix, through the moving information bit is reducing the computational complexity.

4. Simulation

We examine the PAPR performance of a QPSK OFDM system with 256 subcarriers on proposed method, we are using a different subblock, and accordance number of different linear block code. Shows the Tab. 1, we can examine the computational complexity of linear code has

been reduced from $2^{(M-1)}(M-1)$ to $2^k(M-1)$. And using the proposed method of the $G[15,5,7]$ can reduce the computational complexity from 480 to 166, in $G[15,7,5]$ can reduce the complexity from 1920 to 468.

Table 1. Different linear code in the different methods of computation complexity.

linear code	C-PTS	[10]	Generator matrix	T-PTS
$G[15,5,7]$	480	224	192	166
$G[15,7,5]$	1920	640	640	468
$G[15,11,3]$	10720	6144	6144	4672
$G[23,12,7]$	94208	28672	26624	20032

Fig. 4, is the PAPR CCDF of the generator matrix and our proposed method for different codes with subblock number $M=24$ and $M=16$. In the $M=24$ using the $G[23,12,7]$, $G^\perp[23,11,8]$, and $M=16$ using the $G[15,7,5]$, $G^\perp[15,8,4]$ and $G[15,11,3]$, $G^\perp[15,4,8]$. The PAPR performances by generator matrix and T-PTS method is the same. However, the T-PTS method can reduce the computational complexity from 26624 to 20032 in $G[23,12,7]$, and $G[15,11,3]$ is reducing the computational complexity from 6144 to 4672. In the simulation results, our proposed method reduces the computational complexity and also provide error protection on the weighting factors.

Fig. 4. Different linear block codes for $N=256$.

5. Conclusions

In this paper, we present an algorithm, T-PTS, for PAPR reduction in OFDM systems by combining the C-PTS technique with the tree diagram of linear codes.

The optimal weighting vector for T-PTS are selected by executing the tree search of the code. The proposed method not only reduces the search complexity for optimal

weighting factor but also provide the error protection for side information. Simulation results show that our proposed algorithm achieves good PAPR performance with lower complexity, compared to the C-PTS method.

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