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A REVIEW OF PARTIAL TRANSMIT SEQUENCE SCHEME FOR PAPR REDUCTION IN OFDM SYSTEMS

Meenu Bala[1], Sandeep Kumar[2]
[1](M.Tech Scholar), Electronics & Communication Engineering, PCET, Lalru Mandi,
[2](A.P) Electronics & Communication Engineering, PCET, Lalru Mandi,

Abstract-*The high Peak to Average Power Ratio (PAPR) of the transmitted signals the main drawback of OFDM system. OFDM Suffers as the no of Subcarriers operating in the large dynamic range operates in the non-linear region of amplifier due to OFDM suffer the PAPR problem Application of high power amplifiers results in increased component cost. To reduce Peak-to-average power ratio (PAPR) in orthogonal frequency division multiplexing (OFDM) Partial transmit sequence scheme is a promising algorithm. Partial Transmit Sequence (PTS) consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS. There are various methods and scheme has been proposed to reduce the complexity of the algorithm with no increment or reduction in the PAPR also. This article presents a review of various complexity reduction techniques for PTS.*

Keywords: *PAPR–Peak to Power ratio, OFDM, PTS.*

I. INTRODUCTION

In broadband wireless communications high bit rate transmission is required for high quality communications. OFDM is a very attractive technique for high speed data transmission over multipath fading channels. OFDM technique has been applied extensively to digital transmission, such as in wireless local area networks and digital video/audio broadcasting systems. Moreover, it has been regarded as a promising transmission technique for fourth-generation wireless mobile communications. However, due to its multicarrier nature, the major drawback of the OFDM system is the high peak-to-average power ratio (PAPR), which may cause high out-of-band radiation when the OFDM signal is passed through a radio frequency power amplifier. Consequently, the high PAPR is one of the most important implementation challenges that face designers of OFDM [1].

The PAPR problem is one of the most important issues for developing multicarrier transmission systems. Various methods for PAPR reduction have been proposed in the literature [2]–[6], to avoid the occurrence of high PAPR of OFDM signals. Among these methods, the partial transmit sequence (PTS) technique [6] is the most attractive scheme because of good PAPR reduction performance and no restrictions to the number of the subcarriers. In the PTS scheme, the input data is divided into smaller disjoint sub blocks. Each sub block is multiplied by rotating phase factors. The sub blocks are then added to form the OFDM symbol for transmission. The objective of the PTS scheme is to design an optimal phase factor for a sub block set that minimizes the PAPR.

The PTS technique significantly reduces the PAPR, but unfortunately, finding the optimal phase factors is a highly complex problem. To reduce the complexity of PTS several methods have been proposed. In this paper we have discussed those methods in regards to basic PTS technique.

II. OFDM SYSTEM FOR WIRELESS COMMUNICATION

In an OFDM system, the total signal frequency band is divided into N non-overlapping frequency sub channels. Each sub channel is modulated with a separate symbol, and then the N sub channels are frequency multiplexed. It seems good to avoid spectral overlap of channels to eliminate inter-channel interference. However, this leads to inefficient use of the available spectrum. To cope with the inefficiency, the ideas proposed in the mid-1960s were to use parallel data and FDM with overlapping sub channels, in which each, carrying a signaling rate b, is spaced b apart in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion, as well as to use the available bandwidth fully. By using the overlapping multicarrier modulation technique, almost 50% of bandwidth can be saved. Basic Principal of OFDM system [3] is to divide high data rate transmission into lower data rate and that are transmitted simultaneously over number of subcarriers. Each of these signal are individually modulated and transmitted over the channel. And at the Receiver and signal will be demodulated and recombine to recover the Original Signal. As shown in figure given below each subcarrier arranged orthogonally in spectrum. Periodic signal are orthogonal when integral of their product is zero. Fig. 1 shows the block diagram of the OFDM system.

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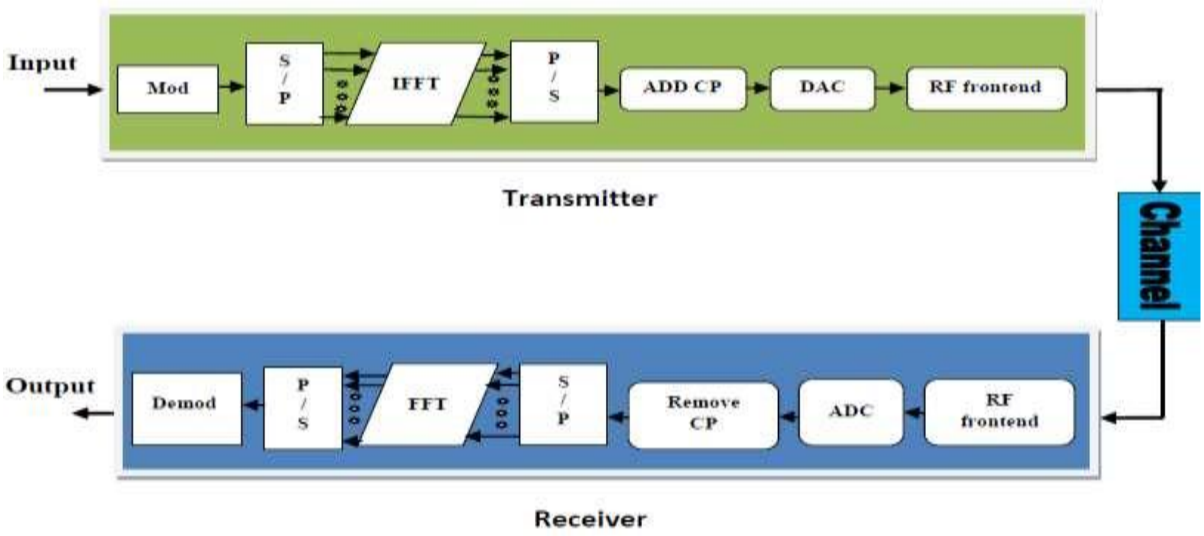


III.OFDM SYSTEM MODEL AND PROBLEM DEFINITION

A. Model and PAPR Definition

In an OFDM system with *N* subcarriers, the discrete-time transmitted OFDM signal is given by:

$$x_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi nk/PN}, \quad k = 1, 2, \ldots, PN-1 \qquad (1)$$

where √ . are input symbols modulated by PSK or QAM, and *P* is an integer that larger or equal 1 called over-sampling factor. When, the samples are achieved by use of the Nyquist rate sampling. We shall write the input data block as a vector, [ ]. The PAPR of the transmitted signal in (1), defined as the ratio of the maximum to the average power, can be expressed by

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

,where [ ] denotes the expected value operation.

PAPR is a random variable because it is a function of the input data, and the input data are random variable. Therefore PAPR can be calculated by using level crossing rate theorem that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution of the OFDM output signals, it is easy to compute the probability that the instantaneous amplitude will be above a given threshold and the same goes for power. This is performed by calculating the complementary cumulative distribution function (CCDF) for different PAPR values as follows:

$$\textbf{CCDF} = \textbf{Pr (PAPR} > \textbf{PAPR}_0\textbf{)} \qquad \textbf{(3)}$$

B. OFDM System with PTS to Reduce the PAPR

As shown in Fig. 1, in a typical OFDM system with a PTS scheme to reduce PAPR, the input data X is partitioned into smaller disjoint sub blocks M, which are represented by the vector Xm, where m= 1,2….M,

such that-

$$\mathbf{X} = \sum_{m=1}^{M} \mathbf{X}_m. \qquad (4)$$

Here, it is assumed that each sub block consists of a set of sub carriers of equal size. Next, the partitioned sub blocks are converted from the frequency domain to the time domain using the N-point inverse fast Fourier transform (IFFT). Since the IFFT is a linear transformation, the representation of the block in time domain is given by:

$$\mathbf{x} = IFFT\left\{\sum_{m=1}^{M} \mathbf{X}_m\right\} = \sum_{m=1}^{M} IFFT\{\mathbf{X}_m\} \triangleq \sum_{m=1}^{M} \mathbf{x}_m.$$

Then, the time domain sequences are combined with complex phase factors [ ] to minimize the PAPR. That is, the PAPR is reduced by the weighted combination of sub blocks. The resulting time domain signal after combination is given by

$$\mathbf{x}'(\mathbf{b}) = \sum_{m=1}^{M} b_m \cdot \mathbf{x}_m. \quad (6)$$

The allowable phase factors are $b_m = e^{j\phi_m}$ (7)

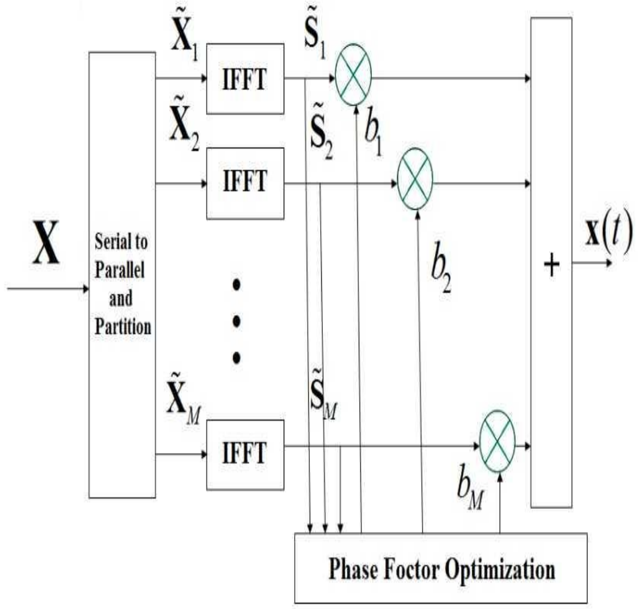
Where can be chosen freely within [0 2π]. For convenience, (5) can be expressed as

$$\mathbf{x}'(\Phi) = \sum_{m=1}^{M} e^{j\phi_m} \cdot \mathbf{x}_m, \quad (8)$$

Hence, the objective of the PTS scheme is to design an optimal phase factor for the sub block set that minimizes the PAPR. Thus, the minimum PAPR with the PTS technique is related to the problem.

$$\begin{aligned} &\text{minimize} \quad \max |\mathbf{x}'(\Phi)| \\ &\text{subjectto} \quad 0 \le \phi_m < 2\pi, \quad m = 1, 2, \ldots, M. \end{aligned}$$

It is obvious that finding a best phase factor set is a complex and difficult problem; therefore, in the next section, we propose a novel implementation of the PTS scheme based on the CE method.



IV. VARIOUS METHODS FOR COMPLEXITY REDUCTION OF PTS TECHNIQUE

There are various approaches have been followed for the reduction in the PAPR along with the complexity of the PTS technique.

For this purpose, either some changes has been made in the algorithm or some phase sequence has been altered.

Block A. Partition Based PTS Techniques

1) *Interleaved sub-block partition based PTS*

Let X= [X (0) X(1) …………………X(N0-1)] is OFDM input symbol sequence with length N0. And with length N are OFDM symbols after portioning and the *X'0………………………….X'M-1* with length N0 after zero padding, Where M is the no. of sub-blocks. Consider that the interleaving partition method is used in PTS OFDM scheme, *Xm'* would be expressed as *Xm =[X(m)X(M+m)…………X(NM-M+m)] 1*N* and Xm ' would be expressed as *Xm'T=[0…….0X(m)0……..0X(M+m)0……..0X(NM-M+m)0…….0]* 1*N0 where and N=N0/M. It is clear that the most elements of *Xm'* are zeros, therefore there are many unnecessary multiplications and additions to zeros while applying N0* N0 IFFT would be replaced by N*N IFFT [9].

2) *Adjacent sub-block partition based PTS*

In this scheme, the complexity of PTS scheme would be reduced by eliminating these multiplications and additions in figure 1. Consider that the adjacent partition method is used in PTS OFDM scheme,
*Xm=[X(mN)X(mN+1)…………X(Nm+N 1)] 1*N* and
Xm'T=[0……0X(m)0……0X(mN+1)0……0X(Nm+N-1)0……0] 1*N0 where and N=N0/M.
In fig 1, the complexity reduction of partial transmit sequence (PTS) PAPR reduction scheme in OFDM systems by reducing the complexity of the IFFT architecture are investigated in this scheme. In the IFFT architecture of PTS OFDM scheme, there are a lot of additions and multiplications with zero, which are obviously unnecessary. We can efficiently reduce the computational
complexity without changing the resulting signal or degrading the performance of PAPR reduction by eliminating the addition
and multiplications with zero from the architecture [9].
*Sub-optimal sub-*3) *block partition based PTS*
In the fig 1, there are steps to be taken in sub-optimal method, these are as follows:
(1) Set, $bm = 1$, m = 1, 2…M using (2) and (3), we can calculate PAPR of OFDM signals with the value of PAPR1, and set
index= 1;
(2) Set *b index* =1, PAPR at this time is calculated by the same method with the value of PAPR2.
(3) If PAPR1 > PAPR2, *b index*=1; otherwise PAPR1 = PAPR2, 1 index *b index*=-1;
(4) *index* = *index* + 1;
(5) Repeat from step 2-4 if *index* < M + 1.
The amount of computation can be effectively reduced by sub-optimal PTS algorithm. Compared to 2M-1 IFFT operations of optimum PTS, the computational cost of PTS is only M IFFT operations [10].

B. The CE Algorithm Based PTS Technique

In the PTS approach, the objective is to find the phase factors with the aim of minimizing the PAPR. However, in order to employ the CE method to find the phase factors that minimize the PAPR in the PTS technique, we have to define the score function for the proposed CE algorithm. We define the inverse of the PAPR as the evaluation function such that its value increases as the PAPR decreases. Hence, in the proposed CE algorithm-based PTS approach, we are interested in maximizing the score function The CE method is an adaptive importance sampling method that transforms the deterministic optimization problem into a family of stochastic sampling problems. Hence, the first step in using the CE method is to randomize our original deterministic problem by including a set of sampling distribution over deterministic.

C. Altered Phase Sequence Based PTS Techniques

There are various different phase alteration techniques and Different Phase sequences have been proposed for the reduction in complexity and PAPR.
In order to decrease the complexity of conventional PTS, in [11] a new phase sequence has been generated. This new phase sequence is based on the generation of N random values of {1 -1}, If we consider the number of allowed phase factors is W = 2.
Hence the new phase subsequence has a formation as follows:

$$\hat{\mathbf{B}} = \begin{bmatrix} b_{1,1}, & b_{1,2} & ,\dots, & b_{1,N} \\ \vdots & \vdots & \vdots & \vdots \\ b_{M/2,1}, & b_{M/2,2} & ,\dots, & b_{M/2,N} \end{bmatrix}_{M/2\times N} \quad (9)$$

According to (9), N random phase sequences are generated and periodically M/2 times will be generated where M is the number of sub block partitioning.
In [11] author has use random phase sequence matrix is given in (10). For computing the actual PAPR, the oversampling needs to be considered. Hence the matrix can be expressed as:

$$\hat{\mathbf{B}} = \begin{bmatrix} b_{1,1} & ,\dots, & b_{1,NL} \\ \vdots & \vdots & \vdots \\ b_{M/2,1} & ,\dots, & b_{2,NL} \\ b_{M/2+1,1} & ,\dots, & b_{M/2+1,NL} \\ \vdots & \vdots & \vdots \\ b_{D,1} & ,\dots, & b_{D,NL} \end{bmatrix}_{[D\times NL]} \quad (10)$$

where L is the oversampling factor. It should be noted that in order to have exact PAPR calculation, at least 4 times oversampling is necessary.

Further explanation is given in [12]. The new phase sequence is based on the generation of N random values from the possible phase factors {1 -1}, if we consider the number of allowed phase factor W=2. Therefore the new phase sequence can be

$$\hat{b} = \begin{bmatrix} b_{1,1}, & b_{1,2}, \ldots, & b_{1,N} \\ \vdots & \vdots & \vdots \\ b_{V,1}, & b_{V,2}, \ldots, & b_{V,N} \end{bmatrix}_{V \times N}$$

V. CONCLUSION

In this paper we have seen the Basics of OFDM. We have seen the OFDM system model and problem in the OFDM system. We have also seen the definition and significance of PAPR in OFDM. Then we have discussed the PTS technique in detail. Further we have discussed the various techniques for the Complexity reduction of PTS technique. We have studied the Block partition based methods, the CE Algorithm Based PTS Technique, Altered Phase Sequence Based PTS Techniques and Low Complexity PTS with Clipping. In [13] a method is used in which the Altered Phase Sequence Based PTS Techniques and Low Complexity PTS with Clipping is used in a combined way. We may implement the same technique for the SLM and this would be the base of our future work.

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