International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-2 Issue-4, March 2013

Review of various PTS (Partial Transmit Sequence) techniques of PAPR (Peak to Average Power Ratio) reduction in MIMO-OFDM

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***Abstract*— MIMO-OFDM is the most important candidate for wireless communication. The main drawback of this MIMO-OFDM is high PAPR which results in signal distortion and power inefficiency in RF section of transmitter. In this paper we will discuss and compare all the Partial Transmit Sequence (PTS) techniques and conclude that why cooperative PTS is much better than PTS technique.**

***Index Terms*— PTS (Partial Transmit Sequence), Cooperative PTS, MIMO-OFDM, PAPR, Interleaved partitioning.**

I. INTRODUCTION

Orthogonal frequency division multiplexing with multiple inputs multiple output system is one of the best solutions for high speed, efficient and high-quality service for next generation wireless communication. MIMO-OFDM [1, 2, 3] offers spatial diversity and increase the system capacity on time variant and frequency selective channels to improve the reliability via diversity gain. A major drawback of MIMO-OFDM is high peak-to-average-power ratio (PAPR) of the transmitted signals at transmitter side. When N signals are added with the same phase, they produce a peak power that is N times the average power. Due to this high PAPR there is severe degradation of bit error rate (BER) performance and in-band and out-of-band distortion occurs in the non-linear amplifier and leads to power inefficiency in the RF section of the transmitter. There are different techniques for PAPR [1,2,3] reduction like selective mapping (SLM), constellation, coding techniques, clipping and filtering and partial transmit sequence (PTS). From these techniques partial transmit sequence is one of the best technique to reduce the PAPR in MIMO-OFDM but there are two problems of this technique like:

- A relatively high computational complexity for searching the optimum sequence of rotation factors.
- The need to transmit side information (SI) about the selected sequence to the receiver to undo the rotation of OFDM subs carriers.

Manuscript published on 30 March 2013.
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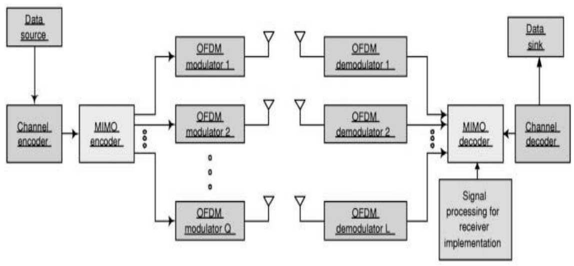
II. BACKGROUND

Assume that there is N_t transmitting antennas, over which the independent data streams are transmitted. It converts a high-rate data stream into a number of low data rate streams that are transmitted over serial to parallel converter, now the vector becomes .

$X= [X_0, X_1, \ldots\ldots X_{N-1}]^T$. After IFFT transform the signal $X_a(t)$ can be written as.

$X_a(t)$ =IFFT [X(K)]

$$X_a(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X(K) e^{j2n\Pi\Delta ft}, 0 \le t \le N-1$$



System Model of MIMO-OFDM Transceiver

Here $X_a(t)$ is the input symbol modulated by QPSK and these are transmitted signals. PAPR [16, 17, 2, 1] of an OFDM signal is defined as the power of sine wave with amplitude equal to the maximum envelope value. It is the ratio of maximum to the average power of the signal as follows:

$$PAPR = \frac{\max[x(t)x^*(t)]}{E[x(t)x^*(t)]}$$

$$PAPR = \frac{|x|^2_{peak}}{x^2_{rms}} = C^2$$

Where C is the Crest factor. The crest factor or peak-to-average ratio (PAPR) is a measurement of a waveform, calculated from the peak amplitude of the waveform divided by the RMS value of the waveform.

$$C = \frac{|x|_{peak}}{x_{rms}}$$

Where C is the Crest Factor which is defined as the maximum signal value divided by the RMS signal value. Large PAPR forces the transmit power amplifier to have large back off in order to ensure linear amplification of the signal. PAPR increases linearly with the number of sub carriers.

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Our main motive is to reduce this PAPR now here we will discuss all the partial transmit sequence (PTS) and explain why cooperative PTS is very beneficial.

$$PAPR = \max_{0\le t\le T} |x_a(t)|^2$$

$$PAPR = \max_{0\le t\le T} \left| \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X(K) e^{2n\Pi\Delta ft} \right|^2$$

$$\le \frac{1}{N} \left| \sum_{K=0}^{N-1} X(K) e^{jn2\Pi\Delta ft} \right|^2$$

$$\le N$$

Now from here it is clearly shows that when number of sub carriers increases PAPR will also get maximum.

Complementary cumulative distributed function (CCDF) denotes the probability that PAPR of the data symbols exceeds a given threshold level which is commonly used to evaluate the performance of PAPR reduction technique.

$$\Pr(PAPR > PAPR_0) = 1-(1-e^{-PAPR_0})^N$$

III. DIFFERENT PTS TECHNIQUES

Partial transmit sequence is a signal scrambling technique which applies scrambling rotations to group of sub carriers. In PTS non overlapping subsets of OFDM subcarriers are formed which are rotated independently and combined again now these rotations exhibit different PAPRs. Selecting the representation with the minimum PAPR leads to PAPR reduction. This approach uses a similar number of N-point IFFT's if the transforms can take advantage of the fact that a large fraction of the input values are zero. In this technique phase rotation are prepared and we select optimum candidate with min PAPR. Due to this technique some problems arises like: A relatively high computational complexity for searching the optimum sequence of rotation factors and the need to transmit side information (SI) about the selected sequence to the receiver to undo the rotation of OFDM subcarriers.

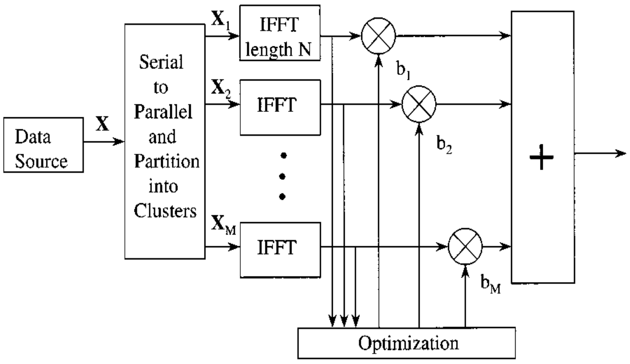
a. Ordinary PTS

In ordinary PTS [4, 6] technique we divided input data block of N symbols into V disjoint sub blocks:

$X=[X^0, X^1, X^2 \ldots\ldots X^{V-1}]^T$

These sub blocks are of equal size and successively located. In PTS technique each partitioned sub block is multiplied by a corresponding complex phase factor $b^v = e^{j\varphi v}$ $v = 1,2,3,\ldots\ldots V$ via taking IFFT.

$$x = IFFT\left\{\sum_{v=1}^{v} b^v X^v\right\} = \sum_{v=1}^{v} b^v.IFFT\left\{X^v\right\} = \sum_{v=1}^{v} b^v x^v$$



Partial transmit sequence approach.

Where b^v are weighting factors which are multiplied with different sub blocks and $b^v = e^{j\varphi v}$ is the pure rotations applied in the system. Drawback of this method is optimization of phase factor and complexity.

b. Adaptive PTS (Iterative Flipping Algorithm)

The main drawback of ordinary PTS technique is removed via this technique like optimization problem. In this technique terminating threshold [13,14] is set so that PAPR can be easily reduced. After setting this threshold level the search is terminated as soon as PAPR drops below threshold rather than searching all the 2^{M-1} combination. This shows that:

When threshold is to set small= search all the combinations
When threshold is to set large= search only fractions of 2^{M-1} combination.

This process will continue until the PAPR is less than L or all or part of 2^{M-1} combinations are reached.

Let $b= [b_1,b_2,\ldots\ldots\ldots b_m]$ set $b= [1,1,\ldots\ldots\ldots 1]$
Set intercount =1

While PAP(x) > L or intercount < K
Change b by one bit
Intercount^{++}

Max. no. of iterations =K, Minimum = 1

Complexity of Adaptive PTS can be greatly reduced by limiting the number of iterations by selecting a suitable threshold value. Lower threshold yield better performance but result in higher complexity.

c. Reduced Complexity Pts Technique

This technique based on gradient descent search which is useful in solving optimization problems. This technique [9, 10, 14] starts with pre-determined vector of phase factors and next it finds an updated vector of phase factor in its neighborhood that result in largest reduction in PAPR. Neighborhood of radius r is defined as the set of vectors with hamming distance equal to or less than r from its origin. Updates of phase factor from b to b' is given by:

$$b' = \arg\left\{\max_{\|b'-b\|m\le r}(PAPRforb - PAPRforb')\right\}$$

Where $\|.\|_m$ denotes the hamming weight of its vector argument. This process is repeated using the updated vector of phase factors as a new starting point as long as PAPR reduction is achieved. We may limit the no, of maximum iterations to update the phase factors. The performance and the complexity of the technique are dependent on the value of r. If r=m the proposed technique searches for all combination of allowed phase factor.

d. New Pts Technique

MIMO-OFDM system applies NPTS technique [5, 15] for each transmit antenna individually. In the individual NPTS I/P data sequence $X= [X_0,X_1,\ldots\ldots\ldots X_{N-1}]^T$ with N subcarrier is partitioned into M disjoint Sub blocks.

$X^{(m)} = [X_0^{(m)}, X_1^{(m)},\ldots\ldots\ldots\ldots X_{N-1}^{(m)}]^T$, $m = 0,1,\ldots\ldots\ldots M$

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Where interleaved partition has been incorporated. Here it is assumed that each sub block consists of set of sub carriers of equal size. For interleaved partition the element is given as:

$X_k^{(m)} = X_{rM+m-1}$ K= rM+m-1
0 otherwise

Each partitioned sub blocks are converted into frequency domain to time domain using N point inverse fast Fourier transform (IFFT). After this phase rotations are prepared then we select the optimum candidate with minimum PAPR. In this case when they transmit symbols from transmitter antenna they take Hermitian transpose and divide symbols into conjugate symmetry component and anti symmetric component.

e. Pts With Sub Optimal Combination Algorithm

Main drawback of PTS technique is search complexity of finding the optimum set of phase vectors. For this problem sub optimal algorithm [11, 12] is proposed. The no of commutation algorithm is much lower than required by the original PTS technique. This algorithm is proposed to reduce the PAPR of the system. The performance of PAPR utilizing the PTS technique improves by the use of the proposed sub optimal combination algorithm. In this case they have taken Single carrier frequency division multiple access (SC-FDMA) with Interleaved-FDMA or Localized- FDMA rather than OFDMA because of their better performance in uplink direction where transmitter power efficiency is of great importance.

f. Cooperative Pts Technique

In cooperative PTS [7, 8] technique alternate and spatial sub block circular permutation are combined. Number of candidate sequences is increased by spatial sub block circular permutation across all transmitting antenna and the use of alternate optimization results in reducing computational complexity and the use of spatial which improves the performance of PAPR reduction. Suppose In this case when we transmit the signals from transmitting antennas then the new sets of sub blocks are generated using spatial sub block circular permutation. After this we transmit one of the odd sub blocks at each antenna so we can use the entire weighted even sub blocks once more to increase the number of candidate sequences. Then we obtain the signal with low PAPR at each transmitting antenna. This technique will reduce the number of complex additions due to the generation of new candidate sequences by using spatial sub block circular permutation.

Comparison table for all these techniques:

Techniques	Parameters			
	Computational Complexity	PAPR Performance	Optimization of phase factor	Methods Applied
Ordinary PTS	more	Not better	Yes	Phase factor multiplication
Adaptive PTS	more	Better than OPTS	No	Iterative Flipping Algorithm
Reduced Complexity PTS	less	Improves	No	Update phase factor with Hamming Weight updating
PTS with Sub-Optimal Algorithm	Less	Improve	No	Sub-Optimal Algorithm to reduce searching problem of phase vectors
Cooperative PTS	No	Better	No	Spatial sub block circular permutation and alternate Optimization

Conclusion and Future Scope

In this paper we have discussed all the Partial Transmit Sequence (PTS) techniques for PAPR reduction in MIMO-OFDM system and at the end we concluded that Cooperative PTS technique is the preeminent technique for PAPR reduction because it makes use of alternate optimization and sub block circular permutation which reduces the computational complexity and equivalently improves the performance for PAPR reduction. In future I want to do work with cooperative PTS for reducing the PAPR and improve the performance of the system.

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