Novel PTS Technique to PAPR Reduction for STBC MIMO-OFDM using Four Transmitting Antennas

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ABSTRACT
Today's system requirement is higher bandwidth for wireless communications. To meet the requirements new systems are being implemented. These systems are specified by multi carrier frequencies, high data transmission rate and mobility and are implemented with MIMO OFDM (Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing). Integration of STBC to MIMO OFDM over frequency selective channel is adopted to improve further performance which convert frequency selective channel to several flat fading channels thereby eliminating ISI. But the multicarrier technique STBC MIMO-OFDM has high Peak-to-Average Power Ratio (PAPR). To achieve better performance this PAPR has to be reduced. In this paper, the effect on PAPR by variation of different parameters like number of subcarriers, OFDM symbols has been presented. Simulation Results show that PAPR performance is improved with increase in number of transmitting antennas. But there is only small difference in PAPR reduction for different subcarriers and when OFDM symbols are varied, there is recognizable reduction in PAPR. Thus, different subcarriers have minimum influence on PAPR performance compared to OFDM symbol variation.

Keywords
OFDM, MIMO, STBC, modified PTS, ISI, QPSK.

1. INTRODUCTION
Wireless digital communications are rapidly expanding, resulting in a large demand for wireless systems which are reliable and have a high spectral efficiency. With the constant demand of high spectral efficiency and high transmission speed for audio, video and internet applications, Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing i.e. MIMO-OFDM has become the most promising technology combination for present and future wireless communications. MIMO offers spatial diversity and therefore increase the capacity while OFDM allow systems to work in time varying or frequency selective environment [1].

MIMO take advantage of the spatial diversity obtained by placing separate antennas in a dense multipath scattering environment. MIMO is implemented in a number of different ways to obtain either a diversity gain or to enhance the channel capacity[3]-[4]-[5]. Space Time Block Coding (STBC) is an effective and practical way to implement with MIMO to improve the reliability of the transmission, as redundant copies of the original data are sent over independent fading channels. To achieve full transmit diversity for given number of antennas the codes are orthogonal. However, the main limitation of using MIMO-OFDM suffers with the problem of high PAPR and carrier frequency offset sensitivity. Hence, it is important to reduce the PAPR; otherwise, high power amplifiers (HPA) in the transmitter need to have a linear region that is much larger than the average power, which makes them expensive and inefficient. This is because if an HPA with a linear region slightly greater than the average power is used, the saturation caused by the large peaks will result in inter modulation distortion. The inter modulation of signal results in increase of the bit error rate (BER) and spectral widening, which generates adjacent channel interference (ACI). The design of a system with lower PAPR depends on requirement of system and different parameters are taken in to account for the same. The various parameter are transmit power, data rate, BER, computational complexity (receiver end). A number of techniques were proposed to control the PAPR as partial transmit sequences (PTS)[9]-[11], selective mapping (SLM)[6]-[7], clipping, clipping and filtering[12], coding, tone reservation (TR) and tone injection (TI)[15].Among these, PTS and SLM techniques are popular phase optimization techniques as they can obtain better PAPR performance without distortion by generating and selecting the optimum candidate.

2. PAPR IN MIMO-OFDM
An OFDM data block with N subcarriers with X_k=(X_0 ,X_1,......,X_{N-1}), is formed with each symbol modulating the corresponding subcarrier from a set of subcarriers. For MIMO-OFDM system, N=subcarriers chosen to be orthogonal, over the period $0 \le t \le T$ where, T = original data symbol period, and f_0=1/T is the frequency spacing between adjacent subcarriers.

The complex baseband OFDM signal for N subcarriers is defined as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi k f_0 t} , \quad 0 \le t \le T \qquad (1)$$

Replacing t=nT_b , where T_b=T/N, gives the discrete time version is written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi kn/LN} , \text{ n=0,1,…, NL-1} \qquad (2)$$

where L = oversampling factor.

The sampling can be implemented by an inverse fast Fourier transform (IFFT)[8].

The PAPR of the transmitted OFDM signal, x(t), is defined as the ratio between the maximum instantaneous power and the average power[17], defined by

$$PAPR = \frac{max_{0 \le t \le T} |x(t)|^2}{E[|x(t)|^2]} \qquad (3)$$

where E[・] is the expectation operator .

The theoretical maximum of the PAPR for N number of subcarriers is as follows,

$$PAPR_{max}=10\log(N)\ dB \quad (4)$$

PAPR is a random variable, because it is a function of the input data and the data are random variable. Therefore PAPR can be calculated by using level crossing rate that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution signals probability of instantaneous amplitude above threshold can be easily calculated and it is applicable for power also. This is performed by calculating complementary cumulative distribution function for different PAPR values as:

$$CCDF=P_r(PAPR>PAPR_0) \quad (5)$$

where P_r=probability value
PAPR=instantaneous value
$PAPR_0$=threshold value

2.1. Influencing Factors of PAPR

PAPR is closely related to modulation schemes, number of sub-carriers and oversampling rate.

2.1.1. Modulation schemes:-

Different modulation schemes produce different PAPR performance. A set of CCDF curves which are processed by several commonly used modulation schemes like BPSK, QPSK, 16QAM and 64QAM with the number of sub-carriers.

2.1.2. Number of sub-carriers:-

Different number of sub-carrier results in different PAPR performances due to the varying information carried. When the number of sub-carriers increases, the PAPR also increase. Therefore, the number of sub-carrier is a very important influence factor on the PAPR.

2.1.3 Oversampling rate:-

In real implementation, continuous-time OFDM signal cannot be described precisely due to the insufficient N points sampling. Some of the signal peaks may be missed and PAPR reduction performance is unduly accurate. To avoid this problem, oversampling is usually employed, which can be realized by taking L·N point IFFT/FFT of original data with

(L-1)· N zero-padding operation. Over-sampling plays an important role for reflecting the variation features of OFDM symbols in time domain.

2.1.4. No. of symbols

In this paper PAPR variation by varying no. of subcarriers and symbols are discussed.

2.2. Multiple Input Multiple Output (MIMO)

In a multipath wireless communication, Multiple Input Multiple Output (MIMO) system leads to the gain of high data rate transmission without increasing the total transmission power or bandwidth. The communication transmission models are single input single output (SISO), single input multiple output (SIMO), multiple input single output (MISO), Multiple input multiple output (MIMO). Multiple-Input Multiple-Output antenna systems are a form of spatial diversity. An effective and practical way to approaching the capacity of MIMO wireless channels is to use space-time block coding in which data is coded through space and time to improve the reliability of the transmission, as redundant copies of the original data are sent over independent fading channels.

2.3. Space-Time Codes

Previously, multipath fading in multiple antenna wireless systems was mostly dealt with by other diversity techniques, such as temporal diversity, frequency diversity and receive antenna diversity, with receive antenna diversity being the most widely applied technique. However, it is hard to effectively use receive antenna diversity at the remote units because of the need for them to remain relatively simple, inexpensive and small. Therefore for commercial reasons, multiple antennas are preferred at the base stations, and transmit diversity schemes are growing increasingly popular

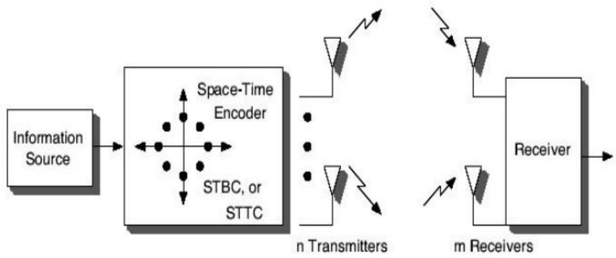

Fig. 1: System Block Diagram for STC

as these can be implemented for high data rate transmission over wireless fading channels in both the uplink and downlink path with diversity implementation at the base station. There are two main types of STCs, namely space-time block codes (STBC) and space-time trellis codes (STTC). Space-time block codes operate on a block of input symbols, producing a matrix output whose columns represent time and rows represent antennas et al [20].

Space-time block codes are designed to achieve the maximum diversity order for the given number of transmit and receive antennas and because of this reason space-time block codes a very popular and most widely used scheme.

Alamouti scheme is the base of the Space Time Coding technique. Using two transmitting antennas at the transmitter side, a block of two symbols is taken from the source data and transmitted to the modulator. After that, Alamouti space-time encoder takes the two modulated symbols, in this case called s1and s2 creates encoding matrix S where the symbols s1 and s2are mapped to two transmit antennas in two transmit time slots. The encoding matrix using two transmitting antenna is represented as below[2].

$$S=\begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix}$$

2.4. Encoding of STBC for four transmitting antennas

Using four transmitting antennas at the transmitter, for the given symbol period four signals are transmitted simultaneously from four transmit antennas. The signal transmitted from antenna one Tx1 is denoted as s_1, the signal from antenna two (Tx2) by s_2, the signal from antenna three (Tx3) by s_3, and the signal from antenna four (Tx4) by s_4 [5].

Table 1: Encoding of STBC for four transmit antennas

Tx Ant. / Time Slot	Tx1	Tx2	Tx3	Tx4
T	s_1	s_2	s_3	s_4
t+T	$-s_2$	s_1	$-s_4$	s_3
t+2T	$-s_3$	s_4	s_1	$-s_2$
t+3T	$-s_4$	$-s_3$	s_2	s_1
t+4T	s_1^*	s_2^*	s_3^*	s_4^*
t+5T	$-s_2^*$	s_1^*	$-s_4^*$	$-s_3^*$
t+6T	$-s_3^*$	s_4^*	s_1^*	$-s_2^*$
t+7T	$-s_4^*$	$-s_3^*$	s_2^*	s_1^*

3. PAPR REDUCTION TECHNIQUES

The PAPR reduction methods are divided into three major categories as Signal distortion techniques, Signal scrambling techniques and Coding techniques. Some powerful schemes are the signal scrambling techniques, contains Selective Level Mapping (SLM) & Partial transmit sequence (PTS) among which PTS is used for the work. In this paper PTS technique is used for reducing PAPR [14].The complexity and computation time is minimum compared to others. In a typical OFDM system with PTS approach several full IFFT operations are avoided in PTS, which is its advantage over SLM .

3.1. Partial Transmit Sequence

The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences, and for each sub-sequence, multiplied by different weights until an optimum value is chosen.

3.2. Selected Mapping Algorithm

Selected mapping (SLM) is scrambling technique. It uses to select the data from phase rotated input data block. It selects the most favorable signal (having low PAPR) from a set of phase rotated candidate data blocks generated by transmitter, which are all represent the same information as the original data block.

In SLM the transmission of side information is required so that the receiver can use the it to determine which candidate block is selected in the transmission and then recover the information. SLM technique leads additional complexity, and loss in efficiency. However, the PTS PAPR reduction scheme's performance improvement is achieved at the expense of high complexity and difficult parameter setting problems. Therefore, modified PTS indeed use the potential of MIMO transmission for PAPR reduction.

3.3 System Architecture*:*

A block diagram of STBC MIMO-OFDM system with Tx=4 transmit antennas is given below in Figure2.

1. For system having four transmit antennas, the data symbol vector S=[X_0, X_1 ,…..X_{N-1}] is encoded with space-time encoder into four vectors as follows :

$S_1=[X_0, -X_1^*, \dots\dots X_{N-2}, -X_{N-1}^*]$

$S_2=[X_1, X_0^*, \dots\dots X_{N-1}, -X_{N-2}^*]$

$S_3=[X_2, X_{1,}^*X_0, \dots\dots X_{N-1}, X_{N-2}, X_{N-3}^*]$

$S_4=[X_3, X_{2,}^*X_1, X_0, \dots\dots X_{N-1}, X_{N-2}, X_{N-3,}X_{N-4}^*,]$

Symbol S1 and S2 represent the two neighboring OFDM signals in time domain.

Serial input data first passes through the serial to parallel converter. Then the parallel signal is mapped with QPSK modulation to generate the data block S. It is further partitioned into V disjoint sub-blocks S1, S2, ... ,Sv . A sub-block Sm (m=l, 2, ... , V) is mapped into a set of symbol sequences, which are fed to the IFFT blocks and sent simultaneously from antennas Tx1, Tx2, Tx3 and Tx4 respectively.

2. All subcarriers positions which are occupied in another sub-block are set to zero. Each of the blocks, has an IFFT performed on it.

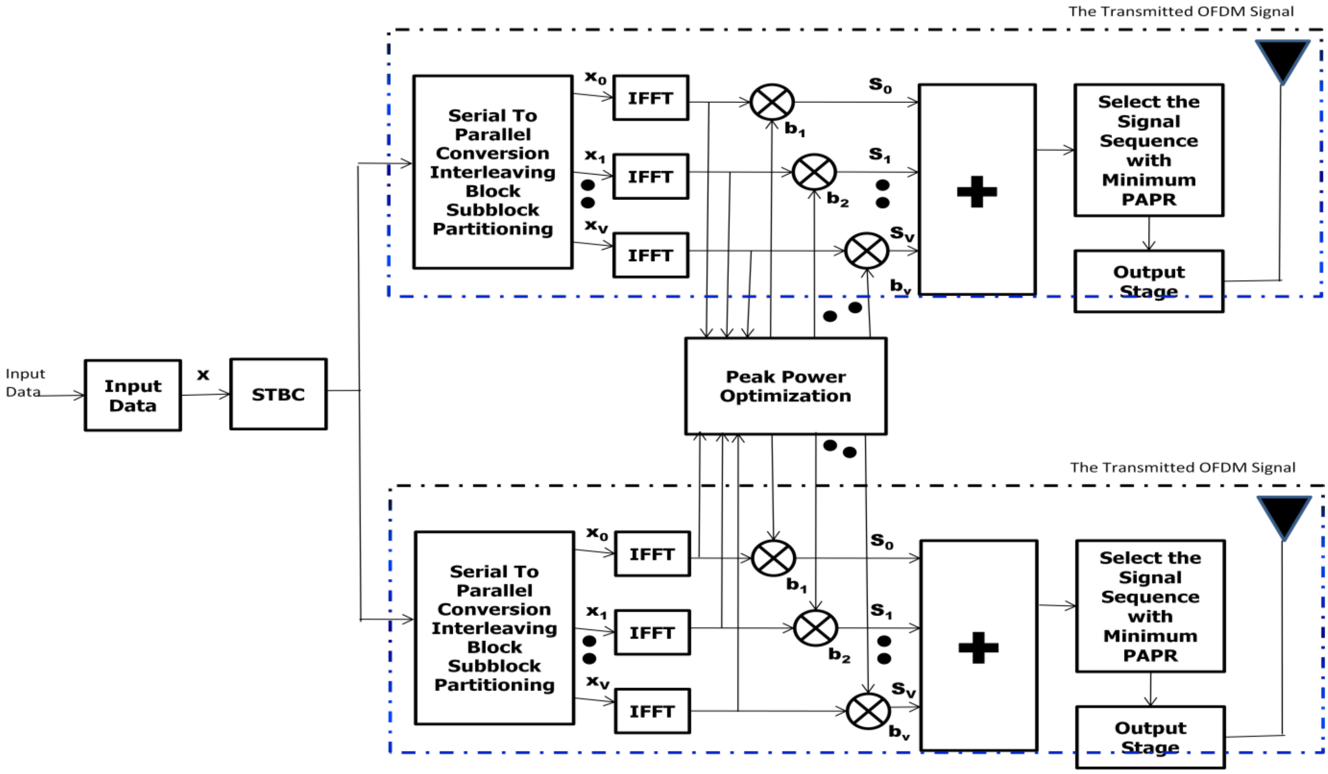

Fig.2 Block diagram of STBC MIMO-OFDM system with Tx=4 transmit antennas

3. The output of each block except for first block which is kept constant, is phase rotated by the rotation factor as given by

$$e^{j\theta\,(v)}\epsilon[0,2\pi]$$

4. The blocks are then added together to produce alternate transmit signals [9].

5. Each alternate transmit signal is stored in memory and the process is repeated again with a different phase rotation value. After a set number of phase rotation values.

6. The weighting rotation parameter set is chosen to minimize the PAPR. The computational complexity of PTS method depends on the number of phase rotation factors allowed.

7. After addition of all the sub-blocks, select the sequence with minimum PAPR.

8. To increase the potential capability of PAPR reduction performance for the PTS method, these phase factors combination correctly maintains the orthogonality between the different modulated carriers.

9. However, the PTS PAPR reduction scheme's performance improvement is achieved at the expense of high complexity and difficult parameter setting problems. Therefore, modified PTS indeed use the potential of MIMO transmission for PAPR reduction.

4. SIMULATION AND DISCUSSION

To evaluate the performance of modified PTS technique for different number of transmitting antennas, we simulate it using MATLAB 7.12. PAPR reduction performance depends on the number of subcarriers N and the number of OFDM symbols. In this paper we study the effects of subcarriers and OFDM symbols.

Table 2: Parameters used in simulation

Information	Parameters
Modulation	QPSK, 16-QAM
Number of subcarriers(N)	64,128,256,512
Number of OFDM symbols(U)	4,8,16
Number of sub-blocks(V)	4
Number of transmitting antenna(Tx)	2,4
Number of phase factor(W)	2

Fig. 3 display the PAPR reduction using modified PTS method with different subcarrier, in which modulation scheme, QPSK is applied, V=4 and W=2. From this figure it is observed that PAPR reduction for N=64, N=128, N=256, N=512, very small for four transmitting antennas.

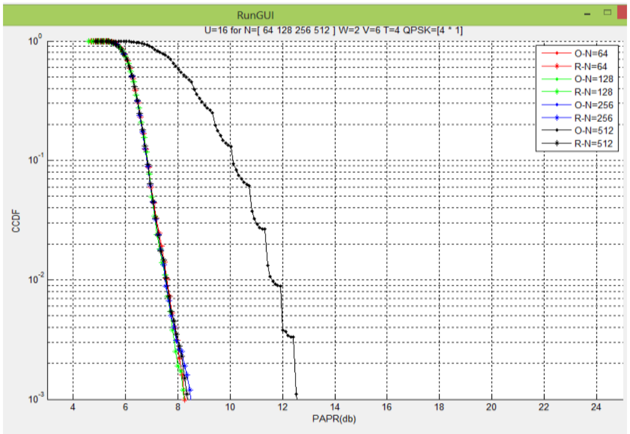

Fig.3 CCDF of PAPR for QPSK modulation using different subcarriers when V=4,W=2 with Tx=4 transmit antenna.

Fig. 4 displays PAPR reduction for QPSK modulation using different OFDM symbol using four transmitting antenna and V=4, W=2.Figure shows the reduction in PAPR according to the OFDM symbol candidate increases.

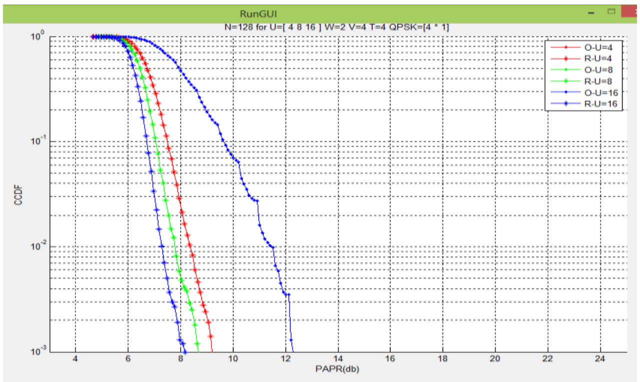

Fig.4 CCDF of PAPR for QPSK modulation use indifferent

OFDM symbols when V=4, W=2 withTx=4 transmit antenna.

Fig. 5 displays CCDF of PAPR comparison for QPSK verses 16-QAM with V=4, W=2, N=128,U=16 and Tx=4. Figure shows PAPR reduction performance improvement in higher order modulation that is 16-QAM.

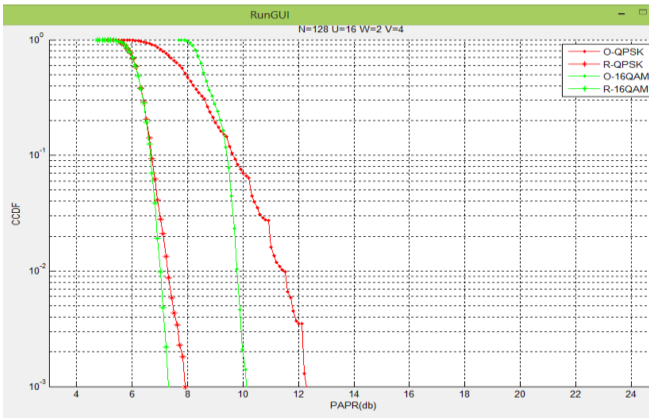

Fig.5 CCDF of PAPR for 16-QAM verses QPSK modulation using different subcarriers when V=4 with Tx=4 transmit antenna .

In Fig. 6 it is shown that CCDF of PAPR for Tx=2 and Tx=4 with V=4, W=2, N=128,U=16 and QPSK modulation are improved. Figure shows PAPR reduction performance improvement for more number of transmitting antennas.

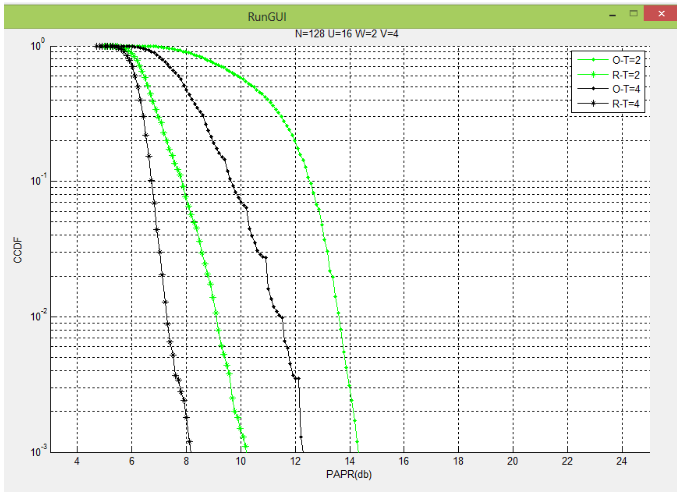

Fig.6 CCDF of PAPR for Tx=2 verses Tx=4 using QPSKmodulation when V=4 with N=128,W=2.

5. CONCLUSION

MIMO-OFDM offers high data rates due to its design that performs better robust against the multipath fading and inter-symbol interference (ISI). STBC is orthogonal schemes that can achieve full transmit diversity. This paper focuses on major drawback of OFDM signal which is high PAPR. The PTS provides a distortion less technique in eliminating the PAPR at the expense of additional complexity. In this paper, the analysis of PAPR reduction is based on varying the number of subcarriers and OFDM symbols for higher order modulations. The simulation results showed PAPR reduction for phase factor W=2. PAPR reduction is observed when transmitting antennas are increased from 2 to 4 and OFDM symbols increased from 4,8 to 16. Improvement in PAPR reduction can also be observed by increasing phase factor W.

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