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PTS based Reduction in PAPR for Improving the Performance of MIMO-OFDM System

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ABSTRACT
Recent developments in wireless communications have shown that with the use of multiple antenna elements at both transmitter and the receiver, it is possible to substantially increase the capacity of a wireless communication system without increase in the transmit power and bandwidth. The current work is proposed to design an efficient fast fading channel estimation scheme for orthogonal frequency division multiplexing (OFDM) using 8x8 multiple input multiple output (MIMO) antennas. The current scenario describes about reduction in PAPR using Spatial Multiplexing (SM). The MIMO-OFDM system data rates are supported by 4G wireless networks. The use of PTS technique with QPSK modulation comprising of 1024 subcarriers resulting in reduction of PAPR up to 2.6dB is reported. The current work using similar parameters depicts the reduction in PAPR of 3.6 dB against 2.6 dB.

General Terms
OFDM Wireless communication, Scrambling Techniques, Number of subcarriers, Sub-block size.

Keywords
Bit error rate (BER), Peak to average power ratio (PAPR), Orthogonal frequency division multiplexing (OFDM), Multiple input multiple output (MIMO), Partial transmit sequence (PTS), Spatial Multiplexing (SM).

1. INTRODUCTION
The need for high speed data communication with minimum interference and least distortion is the utmost requirement of the new-age (4G) wireless communication system. In consideration with multipath fading, inter-symbol interference, and the various fading and distortion factors are required to overcome for improving the channel capacity and overall performance of the system. 4G wireless communications also provide high speed links that offers good Quality of Service (QoS). The hardware implementation of OFDM transceiver can carry high speed data transmission ranging from 2Mbps to around 100Mbps in 4G[1].The proposed system has better performance than other systems in terms of SNR improvement of 3-5 dB spectral efficiency and PAPR reduction up to 5dB. The two major drawbacks which degrades the performance and efficiency of OFDM systems are bit error rate (BER) in fading environments and high Peak to average power ratio (PAPR).There are various techniques used to minimize PAPR. OFDM system provides high data rate wireless communications links with transmission rates approach 1Gbps.The section 2. Gives details about block diagram of OFDM transmitter and receiver along with its mathematical expression. Section 3. Describes about MIMO using Spatial Multiplexing (SM) followed by Section 4. Where, PAPR and its various reduction techniques are discussed in brief. In Section 5. PTS reduction techniques has been elaborated to reduce PAPR which provides better result compared to other techniques. Thereby, concluding with simulation results.

2. Orthogonal Frequency Division Multiplexing (OFDM)
OFDM has shown significant interest over past decade for its robustness against multipath fading channels, effective high-speed data transmission scheme without using adaptive equalizers. OFDM has been used in wireless applications due to its orthogonal property which leads to improvement in bit error rates and SNR of the received signals.OFDM spectrum shown in figure 1. Is a graph of amplitude versus frequency. The various applications of OFDM are Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) [2]. The cyclic prefix (CP) is added after IFFT for solving the orthogonality problem. Instead of using an empty guard space it is required to fill guard space with cyclic extension of OFDM symbols. This effectively simulates a channel performing cyclic convolution, which implies orthogonality over dispersive channels when CP is longer than impulse response of the channel. This introduces energy loss proportional to the length of CP, but zero ICI generally motivates the loss. OFDM is considered for IEEE 802.20, IEEE 802.16 and 3GPP-LTE.Due to high PAPR, in OFDM system the use of nonlinear high-power amplifier (HPA), the OFDM signals will be distorted, as a consequence leads to severe degradation of bit error rate (BER) performance [3].

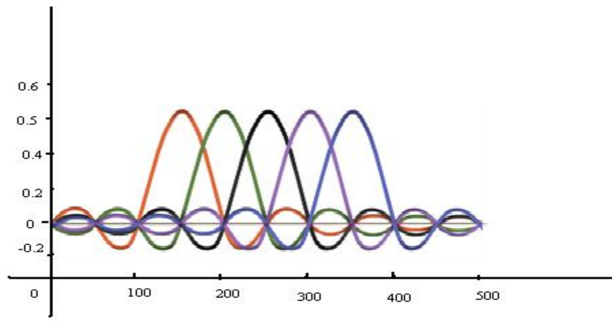

Figure.1 OFDM Spectrum

2.1 Mathematical description of OFDM

If N sub-carriers are used in OFDM, then each sub-carrier is modulated using M alternative symbols and OFDM symbol consists of M^Ncombined symbols.

The low-pass equivalent OFDM signal is expressed as:

$$V\,(t) = \sum_{k=0}^{N-1} X_k\, e^{j2\pi kt/T} \quad , 0 \le t \le T \qquad (1)$$

Where, $\{X_k\}$ are the data symbols, N is the number of sub-carriers, and T is the OFDM symbol time. The sub-carrier spacing of $\frac{1}{T}$makes them orthogonal over each symbol period; this property is expressed as:

$$= \frac{1}{T}\int_0^T (e^{j2\pi k1t/T}) * (e^{j2\pi k2t/T})\mathrm{dt} \qquad (2)$$

$$= \frac{1}{T}\int_0^T e^{\frac{j2\pi(k2-k1)t}{T}}\mathrm{dt} = \delta_{k1k2} \qquad (3)$$

Where $(.)^*$denotes the complex conjugate operator and δ is the Kronecker delta.To avoid inters-symbol interference in multipath fading channels, a guard interval of length Tg is inserted prior to the OFDM block. During this interval, a cyclic prefix is transmitted such that the signal in the interval -Tg$\le t < 0$ equals the signal in the interval (T-Tg)$\le t < T$. The OFDM signal with cyclic prefix is thus: [4]

$$V\,(t) = \sum_{k=0}^{N-1} X_k\, e^{j2\pi kt/T} \quad , -Tg \le t \le T \qquad (4)$$

The low-pass signal above can be either real or complex-valued. The real-valued low-pass equivalent signals are typically transmitted at baseband wire line applications such as DSL use this approach. For wireless applications, the low-pass signal is typically complex-valued where; the transmitted signal is up-converted to a carrier frequencyf_c. In general, the transmitted signal is represented as:

$$S\,(t) = R\,\{v\,(t)\, e^{j2\pi fct}\} \qquad (5)$$

$$= \sum_{k=0}^{N-1} |X_k| \cos\,(2\pi[f_c + k/T]\, t + \arg\,[X]$$

2.2 OFDM Transceiver Systems

A simplified OFDM system block diagram is shown above in Figure. 2. In OFDM, The high data input cannot be transmitted serially so a block of serial input data is converted into a parallel form and then this data is mapped into Quadrature Phase shift keying (QPSK) modulation technique. The encoding requires initial phase reference that has to be added at start. The data on each symbol is then mapped to a phase angle based on the modulation method. The QPSK produces a constant amplitude signal and this technique has been selected due to its simple design and also reduces the problems with amplitude fluctuations due to fading. By transmitting the symbols in parallel, the interval between the signals becomes much larger and this effectively eliminates inter symbol interference in time dispersive channels. Inverse fast Fourier transformation (IFFT) is used to transfer the signal from time domain to frequency domain. It takes in N symbols at one time where N is the number of subcarriers in the system. Each of these N input symbols has a period of T seconds. The value of the symbol determines both the amplitude and phase of the sinusoid for that subcarrier. Thereby, the IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. The basic structure of OFDM transmitter and receiver is shown in Figure.2.Then this signal is transmitted through the channel. When the frequency signals reach the receiver, the receiver has to perform Synchronization (both timing and frequency), Channel Estimation, Demodulation and Decoding.

The data processing at receiver end reverses that at the transmitter side, that is, at the receiver, an FFT block is then used to transfer the received time-domain signal into frequency-domain. Ideally, the output of the FFT block should be identical to the transmitted symbols before the IFFT block. However if there are more than one transmission path between the transmitter and the Receiver. The received signal is the addition of the transmitted input signal with varying delay, attenuation, and Inter symbol interference from the multi-path fading occurs, among which ISI effect is the most important. To reduce this effect, two methods are generally used in the OFDM scheme: parallel data transmission and cyclic prefix. Cyclic prefix is to be added has a guard band to eliminate intersymbol interference from the wireless channel. Again further at receiver side this added CP has to be removed .The duration of the guard period ***Tg*** has to be longer than the delay spread of the multi-path environment [5].

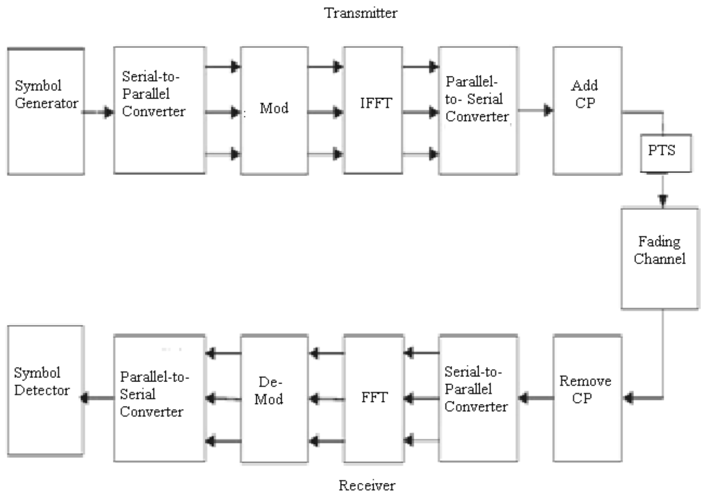

Figure. 2 Block diagram of OFDM System

3. Multiple Input Multiple Output

MIMO channels are usually associated with multiple antenna systems. MIMO employs multiple antennas on both the receiver and transmitter to utilize the multi-path effects that always exist to transmit additional data, thus providing increased transmission data rates without additional power. The basic MIMO structure is shown in Figure.3 where ***Tn*** indicates for the nth transmitter antenna and ***Rn*** resemble the nth receiver antenna. Multiple-Input Multiple-Output (MIMO) systems offer high reliability and data rate [6]. High reliability and data rates can be obtained using spatial multiplexing (SM) in MIMO systems. The purpose of these systems is to improve the performance in terms of throughput and link covering, but with constant bandwidth and the transmit power, using the concept of diversity [7].

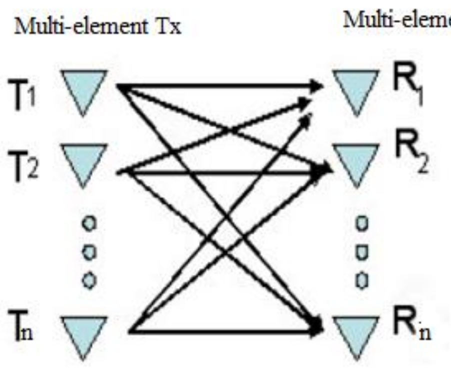

Figure.3 Structure of MIMO

3.1 Spatial multiplexing

Spatial multiplexing (SM) is a signaling scheme where independent data are transmitted simultaneously in parallel channels from each element in a streams array of antennas [8]. The basic principle of SM is illustrated by examining a system with two elements at the transmitter and two elements at the receiver below. Firstly, the bit stream of data to be transmitted is demultiplexed into two sub streams, then modulated and transmitted simultaneously from each transmit antenna as shown in below Figure.4.

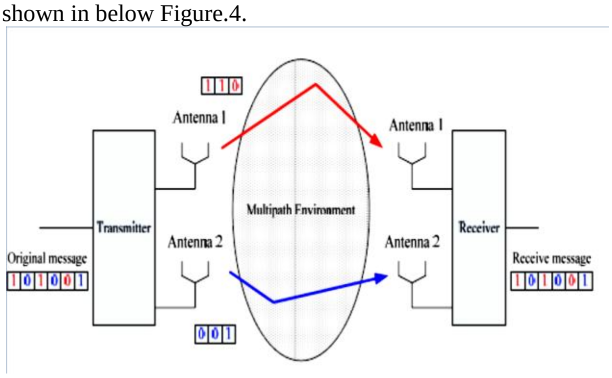

Figure.4 A 2x 2 MIMO systems with a spatial multiplexing scheme

Spatial multiplexing increases the channel capacity with the number of transmit-receiver antenna pairs. This concept can be extended to more general MIMO channel [9].

4. Peak-to-Average Power Ratio (PAPR)

In orthogonal frequency division multiplexing (OFDM) the peak power might be much larger than the average power; this is due to adding up subcarriers coherently which result in large peak-to average power ratio (PAPR).High PAPR arises due to IFFT operation. PAPR is an important parameter in the communication system because it has big effects on the transmitted signal. Low PAPR makes the transmit power amplifier works efficiently whereas, the high PAPR allows the signal peaks move into the non-linear region of the RF power amplifier which in turn reduces the efficiency of the RF power amplifier [10].

PAPR is usually defined as:

$$P_{peak}/P_{average} = 10 \log_{10} \frac{\max[|xn^2|]}{E[|xn^2|]} \qquad (6)$$

Where, Ppeak =peak output power

$P_{average}$ = means average output power.

E = expected value

X_n= transmitted OFDM signals

There are many different algorithms that have been proposed to provide a solution to the problem of high PAPR of OFDM system [11].

4.1 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 into Selective Level Mapping (SLM) & Partial technique sequence (PTS) among which PTS is used for the work. In this paper PTS technique is used for reducing PAPR [12].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.

5. Partial Transmit Sequence for reducing PAPR

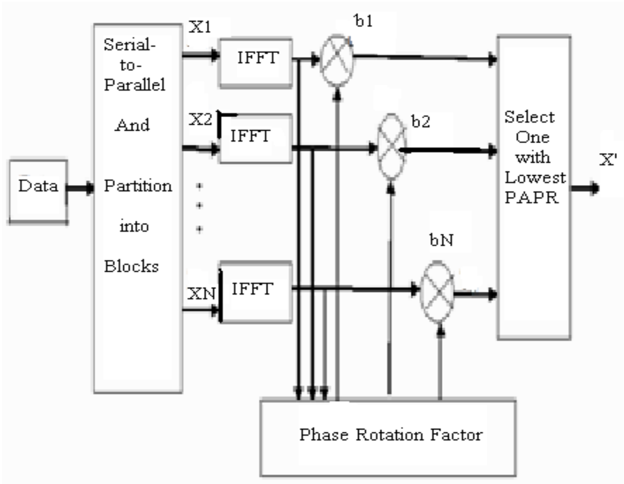

Figure.5 Block Diagram of Partial Transmit Sequence

The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences, each sub-sequence is later multiplied by different weights until an optimum value is chosen. The block diagram of PTS algorithm is depicted in Figure 5. The data information in frequency domain X is separated into V non-overlapping sub-blocks and each sub-block vectors has the same size N [13]-[14].

The PTS algorithm is described as:

- Firstly divide the OFDM sub-carriers into M disjoint Sub-blocks.
- Then generate the OFDM signal for each sub-block by Taking IFFT of each sub-block.
- Combine the M output OFDM signals with random Weighting factors bi.
- The weighting factors are generated with some Optimization algorithm. [15]-[16].

Assume that these sub-blocks have the same size and no gap between each other, the sub-block vector is given by

$$X = \sum_{v=1}^{V} b_v x_v \quad (7)$$

Where, $b_v = e^{j\phi_v}(\phi_v[0,2\pi])$ $\{v=1,2,\ldots..V\}$ is a weighting factor been used for phase rotation[17]-[18]. The signal in time domain is obtained by applying IFFT operation on X_v, that is

$$X = IFFT(X) = X = \sum_{v=1}^{V} b_v \, IFFT \, x_v = \sum_{v=1}^{V} b_v \, . \, x_v \quad (8)$$

Select one suitable factor combination $b = [b_1, b_2 \ldots\ldots b_v]$ which makes the result achieve optimum [19].
The combination can be given by

$$b = [b_1, b_2 \ldots\ldots b_v] = \arg\min_{[b1,b2\ldots\ldots bv]} (\max_{1<n<N}) \left| \sum_{v=1}^{V} b_v \, . \, x_v \right|^2 \quad (9)$$

Where, arg min (·) is the judgment condition that output the minimum value of function.

6. Simulation & Result Analysis of PAPR reduction

To implement active set approch for PAPR reduction signal. The simulation parameters considered for analysis are summarized as mentioned below [12]-[15].

Table 1 Simulation Parameters

Parameters	Types/Values
System Subcarriers	128,256, 512, 1024
MIMO-SCheme	8x8
Over Sampling factor	8
Modulation Scheme	QPSK
Phase Factor	1,-1,-j,j
No.of Sublocks used in PTS	1,4,8
Fading Channel	Rayleigh Channel
No. of iterations	10,000

PAPR reduction performance is affected by the use of number of subcarriers:
Simulation depicts the PAPR reduction performance for different N subcarriers without using PTS technique which is shown in Figure.6
The PAPR performance with and without PTS is as mentioned in Table 2.

Table 2 PAPR Performance with & without PTS

No. of subcarriers	PAPR without PTS in dB	PAPR with PTS in dB	Reduction in PAPR using PTS in dB
128	11.9	7.2	4.7
256	12.1	7.8	4.3
512	12.2	8.2	4
1024	12.3	8.7	3.6

Simulation evaluates the PAPR reduction performance using PTS algorithm for different N,subcarriers, QPSK modulation scheme and Rayleigh fading channel is applied for N = 128, 256, 512, 1024 subcarriers and V = 8 sub-block size
PTS algorithm undeniably improves the performance of OFDM system moreover**,** with the increasing value of N; the improvement of PAPR reduction performance becomes poor as in Figure.7

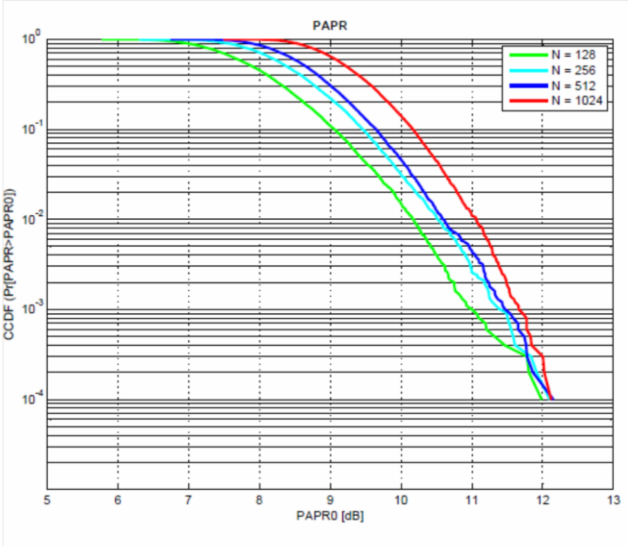

Figure.6 CCDF of PAPR reduction performances with different N values while M is fixed without PTS.

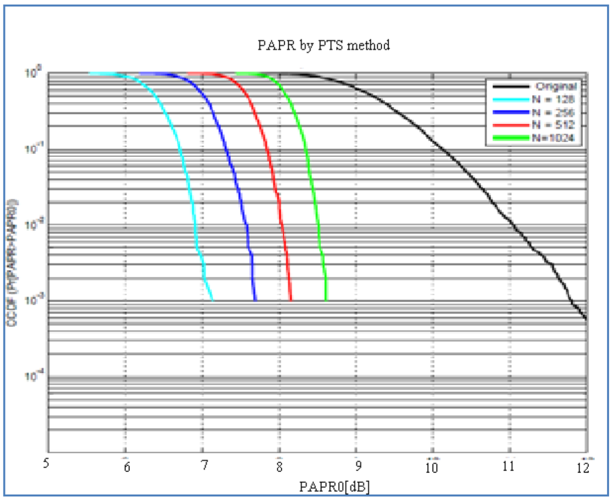

Figure.7 CCDF of PAPR reduction performances with different N values while M is fixed with PTS

The Complementary Cumulative Distribution Function (CCDF) depicts variation in PAPR values for 128 sub-carriers for which the PAPR is reduced on comparing with the original signal without PTS is up to 4.7dB, for 256 PAPR is 4.3 dB, for 512 its 4dB and for 1024 it is 3.6 dB. For 1024 subcarriers without PTS, PAPR is 12.3 dB which is very high as compared to with PTS. Here improvement of 3.6 dB has been achieved.
The CCDF performance of modified PTS for various sub blocks for random data block size 1000 with N = 128 is mentioned in Figure. 8
The below CCDF depicts that, while the sub-block size (V) increases from 1, 4, 8 the PAPR is reduced subsequently.
On comparing the reduction of PAPR with original signal for V= 1 is 3.7dB, at V= 4 is 4dB and V=8 is 4.9dB.Thereby, it is observed that with increase in the value of sub-block size it is possible to achieve reduction in PAPR up to 4.9 dB and beyond.

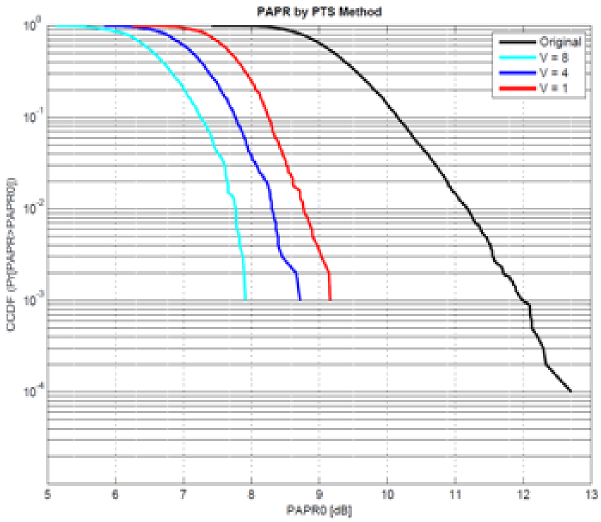

Figure.8 CCDF of PAPR reduction performances with different V values while *N* is fixed at 128

7. Conclusion

The MIMO-OFDM is an attractive system to achieve 4G broadband wireless transmission.OFDM offers high data rates due to its design that performs better robust against the multipath fading and intersymbol interference. 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. Based on simulation result justifies that PTS technique succeeds reduction in the PAPR of OFDM signal. Additionally, as the number of sub-block size is increased, high PAPR reduction performance is achieved. The result depicts that proposed scheme results in better PAPR reduction. Further, the research can be carried out to reduce effectively the computation complexity by using Cross Entropy (CE) method to reduce both the PAPR and computational load.

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