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Peak to Average Power Ratio Reduction in MIMO OFDM using QPSK based on Partial Transmit Sequence method

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Abstract—
Orthogonal Frequency Division Multiplexing is a digital modulation method where at different frequencies; a signal is split into number of narrowband channels. Since low rate modulations are less sensitive to multipath, here several low rate streams are send in parallel instead of sending a high rate waveform. Noises like amplitude arise in OFDM signal and thus power amplifiers with high PAPR is required. High PAPR makes Analog to Digital to and Digital to Analog converters complex and power amplifier efficiency is reduced. The proposed work is to reduce the PAPR in MIMO OFDM. Multi Input Multi Output (MIMO) uses multiple antennas at transmitter and receiver by which communication performance can be improved. In the proposed work, a PAPR reduction technique called Partial Transmit Sequence (PTS) method is used to reduce high PAPR in OFDM signal. PTS sub- blocks reduction technique is used and analyzed, which effectively reduces the PAPR and the computational complexity. Finally, the performance of OFDM by computing PAPR versus Complimentary Cumulative Distribution Function is analyzed.

Index Terms—Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Multi Input Multi Output (MIMO), Partial Transmit Sequence (PTS).

I.   INTRODUCTION

In OFDM, data is carried by a large number of closely spaced orthogonal subcarriers. One for each subcarrier, data is divided into several parallel data streams. In wireless communication, for achieving high data rate and combating multipath fading, OFDM is a promising technique. It has been used for the high speed digital communications namely Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB). To improve the wireless system capacity multi-input multi-output (MIMO) technology is used. The combination of MIMO and OFDM uses multiple antennas at both transmitter and receiver.

High power amplifiers are used by OFDM systems in the transmitter to achieve transmit power and also to achieve maximum output power efficiency. This produces a non-linear distortion into communication channels. The non-linear characteristic is sensitive to signal amplitude. It is formed with large PAPR. Also high PAPR makes Analog to Digital and Digital to Analog converters complex and power amplifier efficiency is reduced. Thus high PAPR is a major drawback.
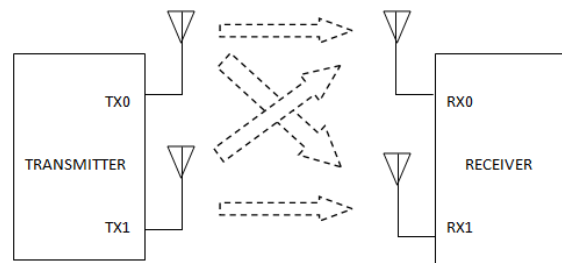

Figure1: Multi Input Multi Output

In the literature, many PAPR reduction schemes have been proposed namely, Alternative Multi Sequence (AMS) [1], Selective Mapping (SLM) [2], Coding techniques [3], [4], [5], non-linear companding transform [6]. In AMS method, data sequence at antennas are partitioned and multiplied by different factors to generate different pair of sub blocks. They are combined to form alternative multi sequences. In SLM, by different phase sequences, different representations of OFDM symbols are generated by original OFDM frame rotation. Coding techniques includes using Fountain codes, Precoding, Complement Block Coding etc. Non – linear companding transform scheme reduce PAPR by

compressing the peak signal and expanding the small signal.

In this paper, Partial Transmit Sequence (PTS) is the technique used for reducing the high Peak to Average Power Ratio (PAPR) in OFDM systems and to minimize the limitations of other techniques. The main objective of PTS technique is to partition the symbol sequence into number of subsequences and the result is multiplied with a set of distinct rotating vectors and are summed at last. From each resulting sequence, PAPR is measured and signal with lowest PAPR is transmitted.

II.METHODOLOGY

The input signal to be transmitted is a serial stream of binary digits. By inverse multiplexing, the serial stream of binary digits is converted into N parallel streams. The N parallel streams are converted into the state space components by using QPSK modulation technique An Inverse Fast Fourier Transform (IFFT) is computed on each set of symbols, which gives a set of complex time-domain samples. The time-domain samples are then quadrature mixed to pass band in the normal way. The real and imaginary components are first changed to the analog domain by using Digital-to-Analog Converters (DACs). High power amplifier is used to amplify the signals. This gives rise to high peak signals which is higher than the target level. Thus average power has to be taken which should be done by ignoring the peak amplitude which increases the Peak to Average Power Ratio. This reduces the power amplifier efficiency and makes it complex.
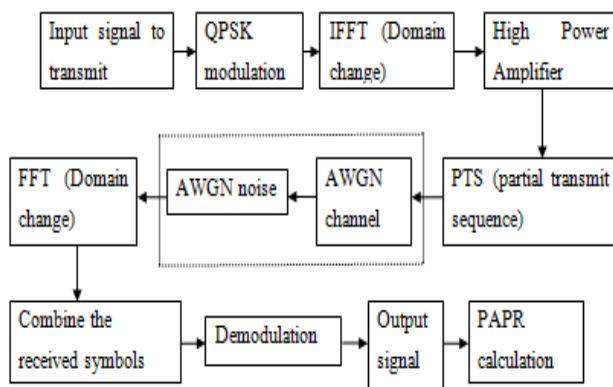

Figure2: Block Diagram of Proposed system

In the proposed system, the technique used to reduce the PAPR is Partial Transmit Sequence (PTS). PTS technique partition the symbol sequence into number of subsequences and the result is multiplied with a set of distinct rotating vectors and are summed at last. From each resulting sequence, PAPR is measured and signal with lowest PAPR is transmitted.

The signal is transmitted via the AWGN channel by adding the AWGN noise.

At the receiver, baseband signals are sampled and digitized by using Analog-to-Digital Converters (ADCs). A Fast Fourier Transform (FFT) is used to convert back into the frequency domain. Demodulation is done. The frequency domain signals are then converted to N parallel streams, which is converted to a binary stream using an appropriate symbol detector. The binary streams are recombined into a sequential stream, which is an estimate of the original binary stream at the transmitter.

III. PAPR IN OFDM

The Peak-to-Average Power Ratio (PAPR]]]) is a measurement of a waveform, designed from the maximum amplitude of the waveform divided by the Root Mean Square (RMS) value of the waveform. The PAPR is given by,

$$C=|X|_{peak}/X_{rms} \qquad (1)$$

Where, C – Peak-to-Average Power Ratio
$|X|_{peak}$ -Peak Amplitude of the Waveform
X_{rms}- RMS Value of the Waveform

The Peak-to-Average Power Ratio (PAPR) is also named as the Peak-to-Average Power (PAR) or the Crest Factor. The PAPR of the actual OFDM signals is approximately equal to 12 dB.

The PAPR of the original OFDM signals can be calculated by using the equation,

$$PAPR(x)\cong \max_{0\leq n\leq N-1} |X_n|^2/E[|X_n|^2] \qquad (2)$$

Where, PAPR – Peak-to-Average Power Ratio
X_n - Oversampled OFDM signal
$\max_{0\leq n\leq N-1}|X_n|^2$ - Peak Power
$E[|X_n|^2]$ – Average Power

The oversampled OFDM signal, given as x_n, is the IDFT of the complex data symbols. The oversampled OFDM signal is obtained with the help of the modulation techniques like QAM or PSK at the kth subcarrier. The oversampled OFDM signal is given by the equation,

$$X_n= 1/\sqrt{N} \sum_{k=0}^{N-1} X_k \, e^{j2\pi kn/N} \text{ , n=0, 1, . N-1} \qquad (3)$$

Where, x_n – Oversampled OFDM Signal
N – Number of Subcarriers
X_k – Complex Data Symbols using PSK or QAM at the kth Subcarrier

The PAPR of the OFDM system in dB is given as,

$$PAPR \text{ in } dB = 10\log_{10}(PAPR) \qquad (4)$$

Where, PAPR – Peak-to-Average Power Ratio

The PAPR of any OFDM signal is to be calculated in terms of the Complimentary Cumulative Distribution Function (CCDF) as the CCDF is one of the most frequently used performance measures for the PAPR reduction techniques.

IV.PARTIAL TRANSMIT SEQUENCE

Partial Transmit Sequence (PTS) is the technique used for reducing the high Peak to Average Power Ratio (PAPR) in OFDM systems and to minimize the limitations of other techniques. The main objective of PTS technique is to partition the symbol sequence into number of subsequences and the result is multiplied with a set of distinct rotating vectors and are summed at last. From each resulting sequence, PAPR is measured and signal with lowest PAPR is transmitted. In the proposed work, the symbol sequence is partitioned into 8 blocks to form the number of subsequences.
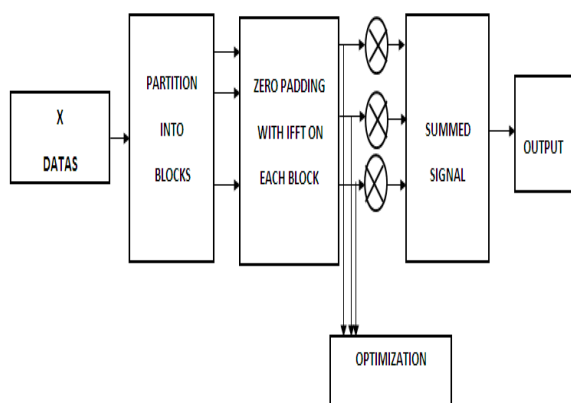

Figure3: PTS Block Diagram

In Partial Transmit Sequence, data X is partitioned into M pair wise disjoint sub blocks. It is given as, $X^{(m)} = [X_0^{(m)} \ldots X_{N-1}^{(m)}]$ with $X_k^{(m)} = X_k$ or $0, 0 \leq m \leq M-1$ such that,

$$X = \sum_{m=0}^{M-1} X^{(m)} \qquad (5)$$

The number of non zero components of $X^{(m)}$ is denote as n_m, which is different for different m. Three partition methods in PTS are,

   i.   Interleaved

  ii.   Adjacent

 iii.   Random

The sub blocks $X^{(m)}$ are transformed into M time domain Partial Transmit Sequences,

$$x^{(m)} = [\, x_0^{(m)} \ldots x_{LN-1}^{(m)}] \qquad (6)$$

$$x^{(m)} = IFFT_{LN \times N}(X^{(m)}) \qquad (7)$$

$b_m = e^{j\phi m}$ is the phase factor by which the sequences are independently rotated. It is then combined to produce the time domain OFDM signal,

$$x = \sum_{m=0}^{M-1} b\, x^{(m)} \qquad (8)$$

b_m attains W different values and $b_0=1$ is fixed without loss in PAPR reduction. There are W^{M-1} alternative representations for an OFDM symbol and the representations correspond to all possible vectors $b = [b_1 \ldots b_{m-1}]$.

V. RESULTS AND DISCUSSION

The original OFDM signal has a high PAPR which can be calculated using the above equations (1) and (2). For the original OFDM, the PAPR is equal to 11dB approximately with a CCDF of 10^{-2}. This high PAPR results in complexity and reduces the efficiency. Thus to reduce this high PAPR, technique called Partial Transmit Sequence (PTS) is used.

In Partial Transmit Sequence (PTS), PAPR is calculated by the partitioning of the symbol sequence into 8 blocks to form number of subsequences. The symbol with lowest PAPR is selected and transmitted at last. The obtained PAPR using the PTS technique is about 4.3dB with a Complimentary Cumulative Distribution Function of 10^{-2} or 0.01.
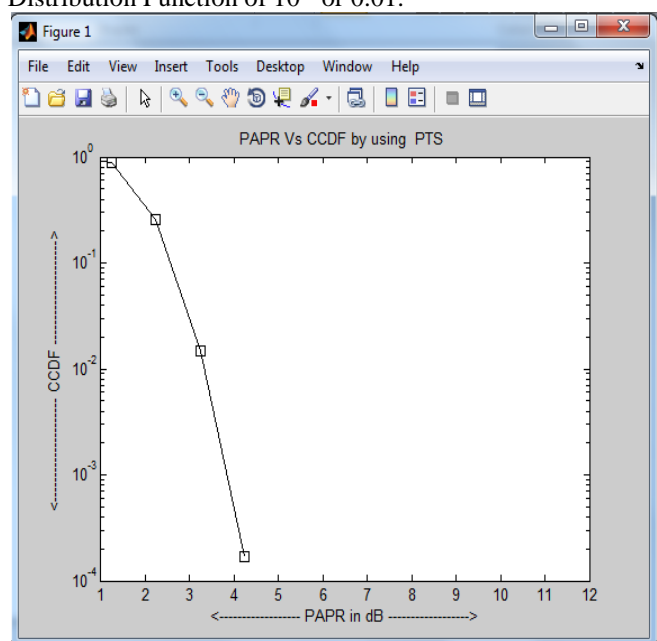

Figure4: PAPR Vs CCDF for PTS

For the original OFDM signal or the OFDM signal without using any other algorithm the obtained PAPR is about 11dB. In the proposed work, using PTS the symbol sequence is divided into 8 blocks whereas when it is divided into 4 blocks the obtained output is about 7.5dB which is much greater when compared to 8 block partitioning. The comparison graph is shown in figure 5.
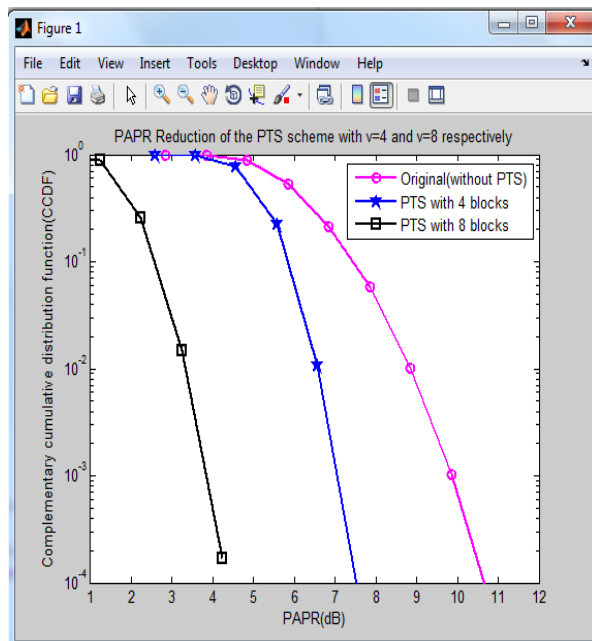

Figure5: Comparison graph for OFDM signal without using any algorithm, PTS with 4 blocks and PTS with 8 blocks

Table – Comparison of PAPR (in dB) and CCDF for different techniques

Different Techniques	PAPR (in dB)	CCDF
Original OFDM Signal	11	10^{-2} or 0.01
Alternative Multi-Sequence (AMS) Algorithm	8.3	10^{-2} or 0.01
PTS Technique with 4 blocks	7.5	10^{-2} or 0.01
PTS Technique with 8 blocks	4.3	10^{-2} or 0.01

When comparing with the original OFDM signal without using any algorithm, in the proposed work PTS with 8 blocks has obtained a PAPR reduction of about 6.7dB.

VI. CONCLUSION

In this paper, Partial Transmit Sequence (PTS) method is proposed to reduce the PAPR of MIMO-OFDM signals. It provides good PAPR reduction with low computational complexity. Simulation result shows that the proposed PTS method is efficient and has achieved a good PAPR reduction when comparing to the other techniques.

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