Reduction of PAPR Performance in Alamouti Coded MIMO-OFDM System using Selected Mapping Techniques with BPSK Modulation

Tincy Mary Mathew  
ME Scholar, Electronics and Telecommunication Department  
Shri Shankaracharya Technical Campus  
Bhilai, Chhattisgarh, India.

Ekant Sharma  
Assistant Professor, Electronics and Telecommunication Department  
Shri Shankaracharya Technical Campus  
Bhilai, Chhattisgarh, India.

Abstract—Orthogonal frequency division Multiplexing (OFDM) is one of the most popular multicarrier or multiplexing modulation techniques in high speed wireless communication. The main principle of OFDM system is to transmit multiple numbers of signals simultaneously over a single transmission path. OFDM convert high data rate stream in to smaller data rate stream. Due to this high data rate and ability to combat frequency selective fading, OFDM has a strong candidate for 4G wireless networks. OFDM combined with multiple-input multiple-output (MIMO) to increase system capacity over the time variant frequency-selective channels and the diversity gain. The main idea of MIMO system is to use multiple antennas at both the transmitter and receiver end in order to improve communication performance. MIMO-OFDM system has a major drawback that might exhibit high peak-to-average power ratio (PAPR). In this paper, we present Selected Mapping scheme (SLM) based on Alamouti coded MIMO OFDM system with reduced PAPR using BPSK modulation schemes for N=128, 256 and 512. Simulation results show that MIMO OFDM system using SLM in Alamouti code has low PAPR when compared to conventional MIMO OFDM system. MATLAB simulations show that our proposed SLM modification significantly improves the PAPR reduction.

Index Terms— Alamoutic code, MIMO, OFDM, PAPR, SLM.

I. INTRODUCTION

Orthogonal Frequency Division multiplexing is also known as Multicarrier modulation (MCM) techniques or Multiplexing technique because of its increasing demand of high speed data rates, robustness to channel fading, flexibility and easy equalization. MCM will transmit signals through multiple carriers where these carriers (subcarriers) will have different frequencies and they are orthogonal to each other. As an effective technique OFDM have been widely adopted by many wireless communication systems, such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) and Wireless Metropolitan Area Networks (WMAN) for IEEE 802.16a standard and Wireless Local Area Networks (WLAN), for IEEE 802.11a standard.

In high-speed wireless communication, an arrangement of using multiple antennas at transmitter and receiver of OFDM system is called as (MIMO-OFDM) multiple input multiple output OFDM. OFDM combined with MIMO technology using Alamouti code of space time block coding (STBC) for mobile communication systems due to its ability to achieve high data rate robust transmission. Therefore, MIMO-OFDM systems achieve coding gain and diversity gain by space-time coding (STBC). MIMO-OFDM System takes advantages of multipath interference effect to increase user and data capacity. Like single-input-single-output OFDM (SISO OFDM), one of the major drawbacks of MIMO-OFDM is the high peak to average power ratio (PAPR) of the signal transmitted to different antenna. In order to reduced the high PAPR in Alamouti MIMO-OFDM system we would have to apply the PAPR reduction scheme [2-6].

However, there is one major problem associated with OFDM signals that is its inherent drawback of high peak-to-average power ratio (PAPR). High PAPR causes signal distortions such as the in-band distortion and out-of-band radiation and induces the degradation of bit error rate performance due to the nonlinearity effects [1]. There are several reduction technique that have been proposed to reduce the PAPR problem such as Clipping And Filtering[2], Partial Transmit Sequences (PTS)[3], Selected Mapping Technique[4], tone reservation (TR) and tone injection (TI)[5], Zadoff-Chu matrix Transform (ZCT)[6].
In this paper, we proposed to use the property of space-time block coded (STBC) coding technique ( Alamouti) in MIMO-OFDM system, with reduction techniques by which better PAPR performance is achieved by the most widely used methods are selective mapping (SLM) and the modulation techniques used is BPSK for different number of subcarriers. And we proved that by using the Alamouti scheme, the conjugate symbols transmitted on two antennas has same PAPR property. Section II explains MIMO system. Section III explains Alamouti MIMO OFDM system and their PAPR. The proposed system model for PAPR reduction of SLM Alamouti MIMO OFDM system is explained in section IV. Section V presents the simulation result and section VI describes the conclusion.

II. MIMO SYSTEM

MIMO stands for Multiple Input Multiple Output system that means MIMO system has two antennas at both the transmitter and receiver side. Multiple transmitting and receiving antennas will achieve antenna diversity without reducing the spectral efficiency. MIMO system has disadvantages like complexity, power consumption and size of the mobile device.

A. System Model

MIMO system consists of basically three components transmitter (TX), channel (H) and the receiver (RX). Let us consider $n_t$ be the no. of transmitter antenna, $n_r$ be the no. of receiving antennas and $h_{i,j}$ represent the complex value of the channel for transmitter antenna $i$ and receiver antenna $j$ respectively. Let $x_i = \{x_1, x_2, \ldots, x_{n_t}\}$ be the complex signals transmitted via $n_t$ antennas. Then the receiving antenna can be expressed as:

$$y_j = \sum_{i=1}^{n_t} h_{i,j} x_i + n_i \quad (1)$$

$n_i =$ noise term

The received signal of Eq (1) can be written as:

$$y = Hx + n \quad (2)$$

Where $H = \begin{pmatrix} h_{1,1} & \cdots & h_{1,n_r} \\ \vdots & \ddots & \vdots \\ h_{n_t,1} & \cdots & h_{n_t,n_r} \end{pmatrix} \quad (3)$

$y$ is the received vector of size $N_r \times 1$, $x$ is the transmitted vector of size $N_t \times 1$, $H$ is channel matrix of size $N_r \times N_t$ and $n$ is the noise vector.

B. Alamouti Space-Time Block Code (STBC)

The first space time block code (STBC) is the Alamouti code that provides full diversity to data rate for the two transmit antennas. Fig.2 represents the block diagram of Alamouti code.

Firstly the input data source $X$ is passed through the modulator using a digital modulation schemes in this case BPSK modulation is used. After the process of modulation it is passed through the STBC encoder which generate two modulated symbols $x_1$ and $x_2$ in each precoding operation.

$$X = \begin{pmatrix} x_1 \\ x_2 \\ x_1^* \end{pmatrix}$$

The first row represents the first transmission period and the second row represents the second transmission period. During the first time slot, the symbols $x_1$ and $x_2$ are transmitted simultaneously from $1^{st}$ and $2^{nd}$ antenna respectively. In the second time slot, the symbol $-x_2^*$ and $x_1^*$ are transmitted from $1^{st}$ and $2^{nd}$ antenna respectively.

III. ALAMOUTI MIMO OFDM SYSTEM AND THEIR PAPR

Fig.3 shows the general block diagram of a STBC Alamouti MIMO-OFDM system. Let us consider the MIMO-OFDM systems with $M$ transmit antennas that use $N$ subcarriers. The complex vector of size $N$ can be expressed as $X = [X_1, X_2, \ldots, X_M]$. These modulated baseband signal are passed through serial to parallel converter such that each modulated signal has different subcarrier and form a set of $\{f_n, n = 0, 1, ..., N - 1\}$. The $N$ subcarriers are orthogonal to each other i.e. $f_n = nT$ where $T = \frac{1}{f_s}$ and $T$ is the symbol period. The complex vector, $X$ is the passed through space time encoder which generate two sequences.
From the 1st antenna $X_1$ is generated

$X_1 = [x_1, -x_2^*, x_3, -x_4^*, ..., x_{N-1}, -x_N^*]$ \hspace{1cm} (5)

And for 2nd antenna $X_2$ is generated

$X_2 = [x_2, x_1^*, x_4, x_3^*, ..., x_N, x_{N-1}^*]$ \hspace{1cm} (6)

Eq (5) and (6) means that in the 1st time slot signal $x_1$ and $x_2$ are transmitted from the 1st and 2nd antennas respectively, in 2nd time slot signal $-x_2^*$ and $x_1^*$ are transmitted from the two antennas, in the 3rd time slot signal $x_3$ and $x_4$ are transmitted from the two antennas and in the 4th time slot signal $-x_4^*$ and $x_3^*$ are transmitted respectively from the two antennas and so on. Both of these sequences are then passed through each IFFT block for antenna 1 and antenna 2 respectively. After the process of IFFT it is then passed through cyclic prefix where the last part of an MIMO OFDM symbol is inserted into the front of an MIMO OFDM symbol. The resulting baseband STBC MIMO-OFDM signal for antenna $i$ with $N$ subcarriers can be written as:

$$x_i(k) = \frac{1}{\sqrt{N}} \sum_{n=1}^{N} X_i(k) e^{j2\pi nk/N}$$ \hspace{1cm} (7)

Where $k = 1, 2, ..., N$, $i = 1, 2$ and $j = \sqrt{-1}$. PAPR of the STBC MIMO-OFDM signal for antenna $i$ can be written as:

$$PAPR = \frac{\max_{1 \leq n \leq N} |x_i(k)|^2}{E[|x_i(k)|^2]}$$ \hspace{1cm} (8)

E[.] denotes expectation value. Complementary cumulative distribution function (CCDF), define the probability that the PAPR of an OFDM symbol exceeds the given threshold $PAPR_0$ can be written as:

$$CCDF = P_r(PAPR > PAPR_0)$$ \hspace{1cm} (9)

For MIMO OFDM, the CCDF of PAPR can be written as:

$$CCDF = 1 - (1 - e^{-PAPR_0})^{MN}$$ \hspace{1cm} (10)

IV. SLM ALAMOUTI MIMO OFDM SYSTEM

Selected Mapping (SLM) technique is one of the most promising reduction techniques to reduce Peak to Average Power Ratio (PAPR) in Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO OFDM). The main principle of SLM technique is to generate a number of MIMO OFDM symbols as candidates and then select the one with the lowest PAPR for actual transmission that have the same information the main idea of SLM technique is based on the phase rotation. Fig. 4 shows the block diagram of SLM STBC Alamouti MIMO-OFDM system.

The input sequence $X$ are mapped with BPSK modulation and passed through serial to parallel converter which generate complex vector of size $N$ is $X = [X_1, X_2, ..., X_N]$. The modulated data are then passed through the space time encoder (2x2) which generates two sequences $X_1 = [X_1, -X_2^*, ..., X_{N-1}, -X_N^*]$ for antenna 1 and $X_2 = [X_2, X_1^*, ..., X_N, X_{N-1}^*]$ for antenna 2. Both of these sequence is then multiplied by the U different phase sequence vector $P_m^u = [P_1^u, P_2^u, ..., P_N^u]$ where $m=1,2$ and $u=1,2,....,U$. The output of phase sequence vector is written as:

$$X_m^u = X_m^u P_m^u$$ \hspace{1cm} (11)

Fig.3 Block diagram of STBC Alamouti MIMO-OFDM system

Fig.4 Block diagram of SLM STBC Alamouti MIMO-OFDM system.
For antenna 1 and 2, $X_1^u$ and $X_2^u$ can be written as:

$$X_1^u = [X_1P_1^u, -X_2P_2^u, \ldots, X_{N-1}P_{N-1}^u, -X_NP_N^u]$$  \(12\)

$$X_2^u = [X_2P_2^u, X_1P_1^u, \ldots, X_NP_N^u, X_{N-1}P_{N-1}^u]$$  \(13\)

These frequency domain signals $X_m^u$ are transformed into time domain signals $x_m^u$ via the IFFT operation.

$$x_m^u = \text{IFFT}(X_m^u)$$  \(14\)

$$x_m^u = \frac{1}{N} \sum_{k=1}^{N} X_m^u(k)e^{\frac{j2\pi mk}{N}}$$  \(15\)

The PAPR of an SLM MIMO OFDM signal of Eq(15) can be written as:

$$PAPR = \max \frac{|x_m^u|^2}{E[|x_m^u|^2]}$$  \(16\)

The optimal set with the minimum PAPR of the two signals is chosen as.

$$\hat{u} = \arg \min_{1 \leq u \leq U} (\max_{m=1,2} \max_{1 \leq n \leq N} |x_m^u|)$$  \(17\)

The $U$ phase rotation sequences $P_m^u$ should be transmitted to the receiver as the SI with log$_2 U$ bits.

V. SIMULATION RESULT

In this section, we present some simulation results showing the PAPR performance of the proposed SLM Alamouti MIMO OFDM system. To show the effect of our proposed SLM Alamouti MIMO OFDM system we use two transmitting antenna $M=2$ using BPSK modulations. We also compared our results with Alamouti MIMO OFDM system with and without adding cyclic prefix for $N = 128, 256$ and 512.

Fig.5 shows the CCDF comparisons of PAPR of Alamouti MIMO OFDM systems with $N = 128$ using BPSK modulation. At clip rate of $10^{-3}$, the PAPR is to 10 dB for Original MIMO OFDM systems and 10 dB for MIMO OFDM CP.

Fig.6 shows the CCDF comparisons of PAPR of Alamouti MIMO OFDM systems with $N = 256$ using BPSK modulation. At clip rate of $10^{-3}$, the PAPR is to 10.6 dB for Original MIMO OFDM systems and 10.6 dB for MIMO OFDM CP.

Fig.7 shows the CCDF comparisons of PAPR of Alamouti MIMO OFDM systems with $N = 512$ using BPSK modulation. At clip rate of $10^{-3}$, the PAPR is to 11 dB for Original MIMO OFDM systems and 11 dB for MIMO OFDM CP.
Fig. 8 shows the CCDF comparisons of PAPR of SLM Alamouti MIMO OFDM systems with \( N = 128 \) using BPSK modulation. At clip rate of \( 10^{-3} \), the PAPR is 9.7 dB for Alamouti MIMO OFDM systems, 9.7 dB for Alamouti MIMO OFDM CP and 8.5 dB for SLM Alamouti MIMO OFDM.

Fig. 9 shows the CCDF comparisons of PAPR of SLM Alamouti MIMO OFDM systems with \( N = 256 \) using BPSK modulation. At clip rate of \( 10^{-3} \), the PAPR is 9.9 dB for Alamouti MIMO OFDM systems, 9.9 dB for Alamouti MIMO OFDM CP and 8.8 dB for SLM Alamouti MIMO OFDM.

Table I PAPR ANALYSIS

<table>
<thead>
<tr>
<th>Systems</th>
<th>( N = 128 )</th>
<th>( N = 256 )</th>
<th>( N = 512 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original MIMO OFDM</td>
<td>10</td>
<td>10.6</td>
<td>11</td>
</tr>
<tr>
<td>MIMO OFDM CP</td>
<td>10</td>
<td>10.6</td>
<td>11</td>
</tr>
<tr>
<td>Alamouti MIMO OFDM</td>
<td>9.7</td>
<td>9.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Alamouti MIMO OFDM CP</td>
<td>9.7</td>
<td>9.9</td>
<td>10.6</td>
</tr>
<tr>
<td>SLM Alamouti MIMO OFDM</td>
<td>8.5</td>
<td>8.8</td>
<td>9</td>
</tr>
</tbody>
</table>
VI. CONCLUSIONS

In this paper, we present an analysis of the PAPR for the SLM Alamouti MIMO OFDM system especially space time block encoder alamouti schemes has been used. In the proposed method we multiply the space time encoder value with the phase rotation vector. Therefore it reduce the PAPR more than the conventional SLM OFDM and have higher data rate And compare this SLM Alamouti MIMO OFDM system with the original Alamouti MIMO OFDM system. Simulation results have shown that the SLM Alamouti MIMO OFDM system has much lower PAPR than original MIMO OFDM system. Thus the proposed system does not require any complex optimization, side information and power increase.

REFERENCES