Reduction of PAPR in Alamouti MIMO- OFDM Systems using an Efficient Phase Offset SLM Technique without Side Information

Mrs. J. Thameema Begum[1], S. T. Gnana Dhivya[1]
1 Department of Electronics and Communication, Madha Engineering College

***Abstract*—In this paper, an efficient scheme to reduce the peak-to-average power ratio (PAPR) called phase offset selected mapping (SLM) is proposed in Alamouti coded multi-input multi-output orthogonal frequency division multiplexing (MIMO-OFDM) systems, and the idea is that different phase rotation sequences and its corresponding phase offsets are multiplied to the ofdm symbol at the transmitter. A minimum Euclidian distance (MED) decoder at the receiver is also used to recover the phase rotation sequences. Therefore, this SLM scheme removes the need to reserve bits as side information to transmit to the receiver. Data rate is also increased. Theoretical analysis and simulation results show that the proposed SLM scheme could offer good performances of both the bit error rate and PAPR reduction.**

Index Terms - MIMO-OFDM, PAPR, side information, SLM.

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a promising modulation scheme for high performance broadband wireless communications. However, one major drawback of OFDM is the high peak-to-average power ratio (PAPR) of the output signals. However, wireless devices are range and data rate limited. The research community has spent a great deal of efforts on finding ways to overcome these limitations. One method is to use Multiple-Input Multiple Output (MIMO) links.

The multiple antennas allow MIMO systems to perform precoding (multi-layer beam forming), diversity coding (space time coding), and spatial multiplexing. Beam forming consists of transmitting the same signal with different gain and phase. Diversity consists of transmitting a signal space-time coded stream through all antennas. Spatial multiplexing increases network capacity. In spatial multiplexing, the receiver can successfully decode each stream given that the received signal have sufficient spatial signatures and that the receiver has enough antennas to separate the stream. The results of using MIMO technique is high data rate or longer transmit range without requiring additional bandwidth or transmit power. The primary advantage of OFDM over single-carrier systems is its ability cope with severe channel conditions such as attenuation of high frequencies in a long copper wire, narrowband interference and frequency selective fading due to multipath without complex equalisation filters.

There is another scheme called Blind SLM (B-SLM) for Alamouti MIMO-OFDM system which does not need the SI transmission. However the phase factors can only be chosen as 1 or -1, which is limited and not suitable for many scenarios.

In this paper, an efficient SLM scheme is used to reduce PAPR in Alamouti MIMO-OFDM systems. The phase rotation sequences are multiplied to the OFDM signal followed by the phase offset which corresponds to the phase rotation sequence. In conventional SLM technique, only phase rotation sequences are multiplied to the OFDM signal which necessitates the information about phase rotation sequence as side information to be transmitted to the receiver.

II ALAMOUTI MIMO-OFDM SYSTEM

Alamouti introduced a very simple scheme allowing to transmit at two antennas with the same data rate as on a single antenna but increasing the diversity at the receiver from one to two in a flat fading channel. It sends the sequence$\{S_1 S_2^*\}$ on the first antenna$\{S_2 - S_1^*\}$ on the other. Assuming a flat fading channel with coefficients h_1 and h_2 the received vector r is formed by stacking two consecutive data samples the$[r_1, r_2]^T$.

Here the symbol block S and channel vector h are introduced as

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

$$h=\begin{bmatrix} h_1 \\ h_2 \end{bmatrix}$$

Then it can be reformatted as

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix}=\begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}\begin{bmatrix} s_1 \\ s_2 \end{bmatrix}+\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \qquad (1)$$

Alamouti space-frequency block coding (SFBC) is employed for Alamouti MIMO-OFDM systems with two transmit antennas. Therefore, the input data block X={X(k), k=0,1,..N-1} is encoded into two vectors X_1, X_2

$$X_1=[X(0),-X^*(1),\ldots\ldots X(N-2),-X^*(N-1)],$$
$$X_2= [X(1), -X^*(0),\ldots\ldots X(N-1),-X^*(N-2)] \qquad (2)$$

Where X (k) is modulated by a given signal constellation Q, N is the number of sub-carriers, and denotes the complex conjugate operation. After inverse fast Fourier transform (IFFT) operation, the time domain signalis given by,

$$X_i = X_i(0), X_i(1) \ldots \ldots X_i(JN-1)$$

$$X_i(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_i(k)\, e^{j2\pi kn/JN} \qquad (3)$$

where i=1,2 and n= 0,1….JN-1 . The oversampling factor J is an integer. In general, the PAPR of the MIMO-OFDM signals at each antenna is defined as

$$PAPR_i = \frac{MAX_{0 \le k \le \le NL-1} |x'_i(n)|^2}{E[|x'_i(n)|^2]} \qquad (4)$$

Where E [.] represents the expectation. Therefore, the PAPR of the Alamouti MIMO-OFDM signals is defined as

$$\text{PAPR} = MAX_{i=1,2} PAPR_i \qquad (5)$$

III. C-SLM SCHEME

In SLM technique from a single OFDM sequence D having a length of N, number of sequences are generated that represent the same information using some rotation factors and the sequence with lowest PAPR is transmitted. If the number of generated new sequences is U, called the SLM length, then all these sequences are the result of multiplying the incoming original OFDM sequence X by U different rotation factors. These factors are given in vector form

$$P^{(i)} = [p_0^{(i)}, p_1^{(i)}, \ldots \ldots \ldots \ldots . p_{N-1}^{(i)}] \qquad (6)$$

where $i = 1$ to U and represents the indices of these factors and P represents the rotation factor in vector form.

The multiplication factors are phase rotations selected appropriately such that multiplying a complex number by these factors results in rotation of that complex number to another complex number representing a different point in the constellation. Hence $p_n^i = e^{-j\theta_n^{(i)}}$

Where $\theta_n^{(i)} \varepsilon [0, 2\pi]$

where θ is the angle of rotation. The rotation vectors are used as side information which is transmitted for signal recovery. The efficiency of SLM approach depends on the amount of scrambling done by these rotation factors e and the length of SLM U The number of bits that must be transmitted as SI is log_2U bits.

IV. P-SLM SCHEME

For the P-SLM scheme U different phase offset $e^{j2\pi u/U}$, u= 0, 1,...U-1 are generated for the U phase rotation sequences P^u. As depicted in fig 1.1, the data at the first antenna X_1^u keeps unchanged, while the data at the second antenna X_2^u is multiplied by the phase offset $e^{j2\pi u/U}$.

X_e^u=[$X^u(0)$,$X^u(2)$,..$X^u(N-4)$,X^u(N-2)]X_o^u=[$X^u(1)$,$X^u(3)$,..$X^u(N-3)$, X^u(N-2)] (7)

These are the even and odd parts respectively. Therefore, the odd and even parts of the data blocks at two transmit antennas can be expressed as follows

$$X_{1,e}^u = -X_e^{u*}$$

$$X_{2,e}^u = X_e^{u*} e^{j2\pi u/U} \qquad (8)$$

Then the space frequency matrix C can be expressed as

$$C = \begin{pmatrix} X^u(2l) & -X^{u*}(2l+1) \\ e^{\frac{j2\pi u}{U}} X^u(2l+1) & e^{\frac{j2\pi u}{U}} X^{u*}(2l) \end{pmatrix} \qquad (9)$$

Where l=0,1,…..N/2-1.

It is obvious that matrix C is orthogonal, since that

$$CC^H = (|X^u(2l)|^2 + |X^u(2l+1)|^2) I_{2\times 2} \qquad (10)$$

Therefore, the P-SLM scheme maintains the structure of the Alamouti, thus, full diversity can be achieved at the receiver.

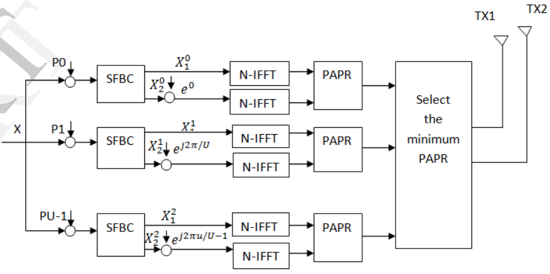

Fig 1.1P-SLM Transmitter

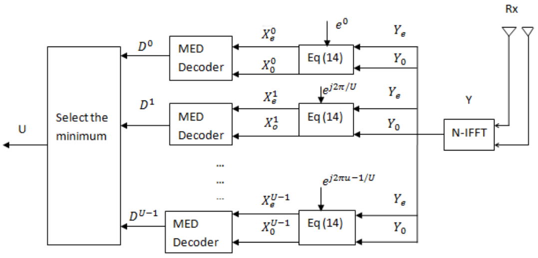

Fig1.2 P-SLM Receiver

When these alternative vectors are transformed into time domain Signals X_1^u, X_2^u via IFFT operation, the optimal signals and with the minimum PAPR are sent to the receiver. Therefore, the P-SLM scheme maintains the structure of the Alamouti SFBC, thus, full diversity can be achieved at the receiver. At the receiver, after removing the cyclic prefix and employing the FFT operation, the received vector could be expressed as

$$Y=[Y[0],Y[1],\ldots\ldots Y[N-1]] \qquad (11)$$

$$Y(k)=X_1^u(k)H_1(k)+H_2(k)X_2^u(k)+W(k) \qquad (12)$$

Where H_i(k) is the frequency response of the fading channel between the ith transmitter and the receiver antenna, and W (k) is the additive white Gaussian noise (AWGN) in frequency domain. Then substituting we have

$$Y_e(l) = H_{1,e}(l)X_e^u(l) + e^{j2\pi u/U}H_{2,e}(l)X_o^u(l) + W_e(l)$$

$$Y_o(l) = -H_{1,o}(l)X_o^{u*}(l) + e^{j2\pi u/U}H_{2,0}(l)X_e^{u*}(l) + W_o(l)$$

$$(13)$$

For the P-SLM scheme, the index of the optimal phase sequence needs to be firstly detected at the receiver. We have to try different phase offsets to obtain the appropriate, since is unknown at the receiver. Therefore, we propose a MED decoder for the P-SLM scheme as follows

$$X_e^u(l) = Y_e(l)H_{1,e}^*(l)+e^{j2\pi u/U}H_{2,o}(l)Y_o^*(l)$$

$$X_o^u(l) = Y_e(l)H_{2,e}^*(l)-H_{1,o}(l)Y_o^*(l) \qquad (14)$$

Moreover, as stated the channel coefficients are assumed to be the same for two adjacent subcarriers in Alamouti MIMO-OFDM system.

$$H_{1,e}(l)=H_{1,o}(l)$$

$$H_{2,e}(l)=H_{2,o}(l) \qquad (15)$$

The recovered signals can achieve the minimum Euclidian distances from the signal constellation. Supposing that the channel coefficients are random, when the minimum Euclidian distance is achieved, can be nearly perfectly detected .After obtaining the index of the phase offset, we could easily obtain the phase rotation sequence . Therefore, the P-SLM scheme does not need to transmit the SI.

V. SIMULATION RESULTS

In this section, simulation have been done for PAPR performance for c-slm and p-slm wherein 10^4 data blocks are used with N=1024 and the oversampling factor j=4.The 16-QAM modulation is done and the saturation point of the solid state power amplifier is C=4.

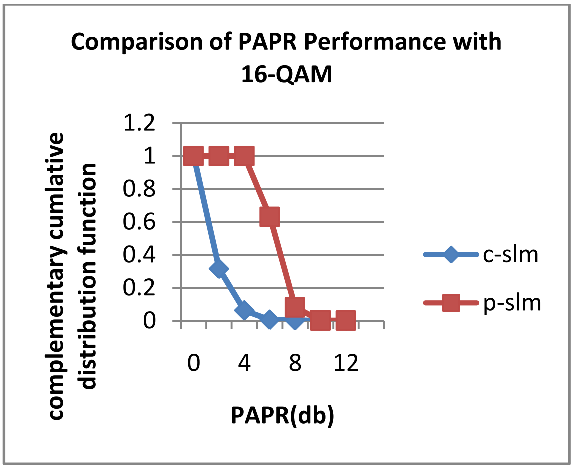

Fig: 2 Comparison of PAPR of 16-QAM

VI. CONCLUSION

Compared to C-SLM, in P-SLM, the need to transmit side information for the phase rotation sequence is not required which improves the data rate. Instead the phase offset corresponding to the sign of phase rotation sequence is multiplied.At the receiver,minimum Euclidean distance decoder is used to decode the phase offset.

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