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A Matrix Based SLM Scheme For PAPR Reduction In Alamouti MIMO-OFDM Systems Without Side Information

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Abstract:
In this paper, a matrix based novel phase offset SLM scheme is combined with STFBC for PAPR reduction in Alamouti MIMO-OFDM systems without side information. The Selected Mapping (SLM) technique is one of the important PAPR reduction techniques for OFDM. This technique however increases the computational and phase search complexity and PAPR reduction is performance largely dependent on the selection of random phase sequences. It is also required to transmit the selected phase sequence to recover the original data at the receiver end. The other complexity is that the phase sequences are generated randomly in SLM. So, in this paper we propose the use of Circulant, Hadamard, and Riemann and Hilbert matrices to obtain phase sequences for the SLM technique. We can also combine this matrix approach with the DCT transform for better performance. This approach also avoids randomness in phase sequence selection, which makes it simpler to decode at the receiver. As an added benefit, the matrix can be generated at the receiver end to obtain the data signal and hence it is not required to transmit Side information (SI).

***Key words**: MIMO-OFDM, PAPR, SLM, side information*

1.Introduction

In the communication systems, the transmitted signals may not reach the receiver directly due to the diffraction, reflection and scattering which is caused by buildings, mountains and resulting in blocking of LOS (line of sight). In case of blocking the LOS, the received signals will come from different directions and this effect is termed as multipath propagation (Frequency Selective Channel).So in order to mitigate the effect of the frequency selective channel the technique called OFDM comes into existence. The basic principle of OFDM is that it splits the high data rate stream into number of lower rate streams and is transmitted simultaneously. OFDM deals with the multipath propagation by the use of guard interval in the transmitted signals i.e., to send a short symbol and then wait for the multipath echoes to fade away before sending the next symbol. The greater the guard interval better is the signal quality with less intersymbol interference but the spectral usage is more as the spectrum is not used during the guard time interval. So OFDM subcarriers can overlap to make the full use of spectrum efficiently but at the peak of each subcarrier, the power in all the other subcarriers is zero.

MIMO is much more fruitful in chances of signal scattering. MIMO uses multiple antennas at the transmitter and the receiver to enable multiple signal paths to carry the data, choosing separate paths for each antenna. So the signal received at the receiver is the mixture of both signals transmitted by each receiver and the received signal depends upon the transmission channel in between the transmitter and the receiver.

The spacing of subcarriers plays a vital role in MIMO-OFDM. Sub carrier spacing are selected such that they are mathematically orthogonal to each other. Each sub-carrier is then modulated with a conventional modulation scheme, such as quadrature amplitude modulation, phase shift keying or QPSK. In a conventional OFDM system, the orthogonality between the subcarriers is achieved by means of the Fast Fourier transform (FFT). However, MIMO-OFDM system suffer from high peak-to-average power ratio (PAPR). This PAPR plays an important role in OFDM. When N subcarriers are added with the same phase, peaks shoots up suddenly this may cause the amplifier to work in the nonlinear region and finally results in reduced efficiency [1]. If a non linear amplifier is used to boost up the signal then in-band and out of band distortion is created resulting in poor performance. [2] Shows the effect of PAPR with various modulation techniques.

A number of techniques were proposed to limit the PAPR, such as clipping [3], partial transmit sequence (PTS) [4], selected mapping (SLM) [6] and various other methods are proposed to reduce PAPR [5]. Among these methods, the SLM is an attractive and efficient technique, since it can achieve better PAPR reduction without signal distortion. The name of this technique indicates that one sequence has to be selected out of a number of sequences. According to the concept of discrete time OFDM transmission we should make a data block considering an N number of symbols from the constellation plot. Where N is the number of subcarriers to be used. Then using that data block U number of independent candidate vectors are to be generated with the multiplication of independent phase vectors. This technique however increases the computational and phrase search complexity and PAPR reduction performance largely depends on the selection of random phase sequences. Information about the selected phase sequence should be transmitted to the receiver as Side Information (SI). At the receiver, the inverse operation is performed to recover the original data. The conventional SLM technique requires B number of IDFT blocks and$[\log_2 B]$ number of SI bits. This approach is applicable for all types of modulation and any number of subcarriers. PAPR reduction performance is based on the number of phase sequences and the design of the phase sequences. [7] Explains the proposed SLM technique.

In this paper, the sequences for the SLM technique is generated via circulant, Hadamard and Riemann matrices. These matrices in turn can be combined with the DCT transform for better performance. [8]The data stream is first transformed by the DCT matrix and then each data block is multiplied by the phase sequences. The row of the matrix that is generated is considered as the phase sequences for multiplication. This technique is applied to the Alamouti MIMO-OFDM system.

2.PAPR In Alamouti MIMO-OFDM Systems

2.1.Alamouti Scheme In MIMO-OFDM Systems

Space-time block codes face problems in fast fading whereas space-frequency block codes suffer from frequency selectivity. Therefore, we propose to distribute the elements of the orthogonal design both in time and frequency in order to relax the requirements for constant channel coefficients in both dimensions. In this paper, the Alamouti space-time frequency block coding (STFBC) 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 andX_2,

x_1=[X (0),-X*(1), X*(2), 0… X (N-3), X*(N-2), - X*(N-1), 0],
X_2 =[X(1),X*(0),0,X*(2)],…,X(N-2),X*(N-3),0,X(N-1)], (1)

where X (k) is modulated by a given signal constellation Q, N is the number of subcarriers, and (.)* denotes the complex conjugate. After Inverse Fast Fourier Transform (IFFT) operation the time domain signal $x_i= [x_i(0), x_i(1), \dots\dots, x_i(JN-1)]$ is,

$$x_i(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_i(k)\, e^{\frac{j2\pi kn}{JN}}, \qquad (2)$$

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

$$PAPR_i = \frac{\max_{0 \le n \le JN-1} |x_i(n)|^2}{E|x_i(n)|^2} \qquad (3)$$

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

$$\mathrm{PAPR} = \max_{i=1,2}\{PAPR_i\} \qquad (4)$$

2.2.The C-SLM Scheme

For the C-SLM scheme, the U phase rotation sequences are generated as

$$P^u = \{P^u(k, k = 0,1 \dots N-1)\},$$
$$u=0,1,\dots U-1, \qquad (5)$$

where, $P^u(k) = e^{-j\psi^{u(k)}}$,j=$\sqrt{(-1)}$ and $\psi^{u(k)}$ Є[0,2π) .

Therefore, the input data X is multiplied by P^u to generate alternate signal X^u as

$$X^u = P^u(k)X(k) \qquad (6)$$

After being operated by the Alamouti SFBC, the alternative signal X^u is encoded into two vectors X_1^u and X_2^u as

$$X_1^u = [P^u(0)X(0), -P^{u*}(1)X^*(1), \dots\dots, P^u(N-2)\,X(N-2), -P^{u*}(N-1)X^*(N-1)],$$
$$X_2^u = [P^u(1)X(1), -P^{u*}(0)X^*(0), \dots\dots, P^u(N-1)\,X(N-1), -P^{u*}(N-2)X^*(N-2)], \quad (7)$$

Then the alternative frequency domain signals X_i^u are transformed into time domain signals x_i^u via the IFFT operation and the optimal set with the minimum PAPR of the two signals is chosen as

$$\hat{u} = \arg\min_{0\le u\le U-1}\left(\max_{i=1,2}\max_{0\le n\le JN-1}|x_i^u(n)|\right) \quad (8)$$

Generally, the U phase rotation sequences P^u should be transmitted to the receiver as the SI with $\log_2 U$ bits.

2.3.The P-SLM Scheme

For the P-SLM scheme, U different phase offsets $\{e^{\frac{j2\pi u}{U}}, u = 0,1,\dots,U-1\}$ are generated for the U phase rotation sequences P^u.

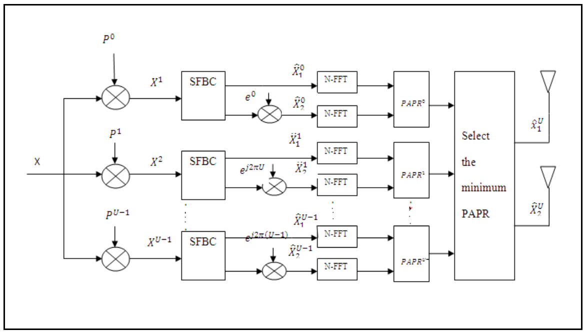

Figure 1: Block Diagram Of The P-SLM Scheme

As depicted in the Figure.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 $e^{\frac{j2\pi u}{U}}$.

When these alternative vectors are transformed into time domain signals $\tilde{x}_1^u$ and $\tilde{x}_2^u$ via IFFT operation, the optimal signals $\tilde{x}_1^{\hat{u}}$ and $\tilde{x}_2^{\hat{u}}$ with the minimum PAPR are sent to the receiver.

3.Proposed Scheme

In the proposed scheme the phase sequences required for SLM scheme are generated via special matrices. In conventional SLM phase sequences are selected at random and may not always yield optimum result. The three different types of special matrices, namely, Circulant, Hadamard and Hilbert to generate the phase sequences for the multiplication of data blocks.

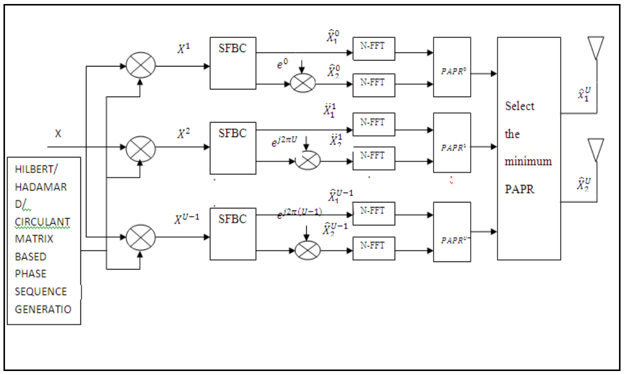

Figure 2: The Proposed Scheme For P-SLM

3.1.Phase Sequence Generation Using Circulant Matrix

A circulant matrix is a special kind of toeplitz matrix where each row vector is rotated one element to the right relative to the preceding row vector. A toeplitz matrix is an $n \times n$ matrix, defined as

$$T_n = \lfloor t_{k,j}; k,j = 0,1,\dots,n-1 \rfloor;\ t_{k,j} = t_{k-j}$$

Matrix T_n can then be expressed as

$$T_n=\begin{bmatrix} t_0 & t_{-1} & t_{-2} & & \\ t_1 & t_0 & t_{-1} & \cdots & t_{-(n-1)} \\ t_2 & t_1 & t_0 & & \\ & \vdots & & \ddots & \vdots \\ & t_{n-1} & & \cdots & t_0 \end{bmatrix}$$

Circulant matrices are significant because they are diagonalized by a Discrete Fourier Transform, and hence linear equations that contain them can be quickly solved using a Fast Fourier Transform. The first column of circulant matrix is obtained by choosing any row of the Riemann matrix.

3.2.Phase Sequence Generation Using Hadamard Matrix

Hadamard matrix is a square matrix whose entries are either +1 or -1 and whose rows are orthogonal [6]. Hadamard matrix is defined recursively as,

$$H_1=\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$H_n=H_1 \otimes H_{n-1}=\begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix}$$

Data block is multiplied with each row of the Hadamard Matrix.

3.3.Phase Sequence Generation Using Hadamard Matrix

Hilbert matrix is a special case of Cauchy matrix. Cauchy matrix of dimension m × n with elements a_{ij} is derived as,

$$a_{ij}=\frac{1}{x_j-y_j}; 1\le i\le m, 1\le j\le n;$$

where x_j and y_j are elements of field F and $x_j-y_j\neq 0$.

Hilbert matrix is calculated from the Cauchy matrix using,

x_j-y_j=i+j-1;

Data block is multiplied with each row of the Hilbert matrix.

4.Simulation Results

4.1.The Effect Of PAPR When The Subcarrier Varies

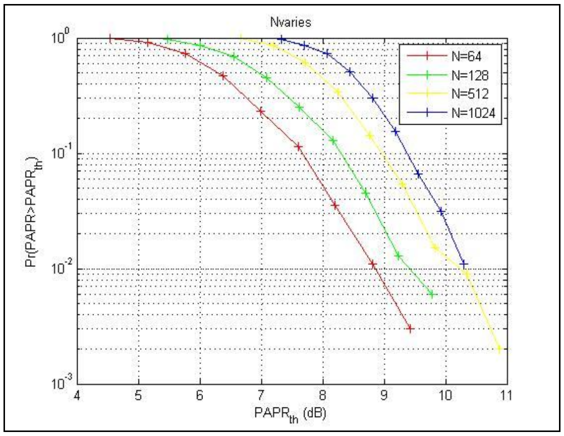

Figure 3: PAPR Varies As Subcarriers Increases

4.2.SLM Technique Applied In Order To Reduce The PAPR

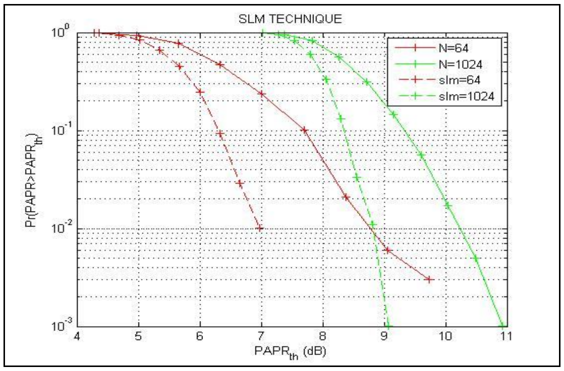

Figure 4: SLM Technique Applied To Reduce PAPR.

4.3.Reducing The PAPR By Generating Hilbert Matrix

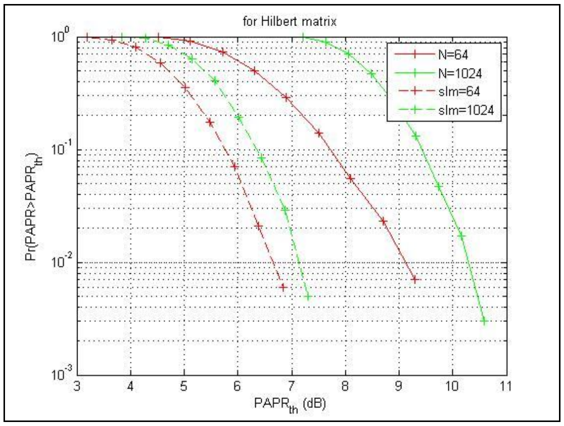

Figure 5: SLM Technique By Generating Hilbert Matrix

4.4.Reducing The PAPR By Generating Hadamard Matrix.

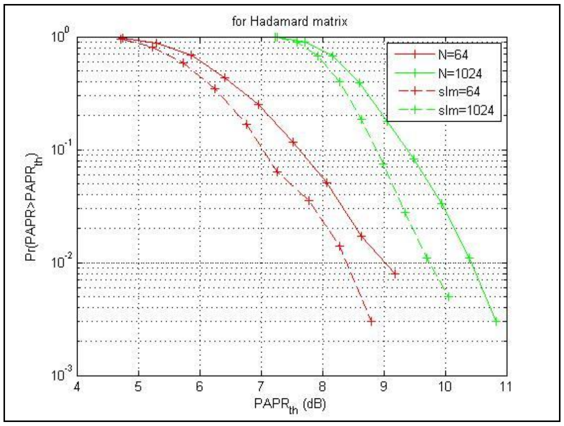

Figure 6: SLM Technique By Generating Hadamard Matrix

5.Results And Discussion

Figure.3 shows that when the subcarrier increases the PAPR also increases. In this paper, we consider N=1024 Subcarriers. Figure 3. Shows that PAPR for 1024 subcarriers is approximately 11db. So by applying SLM technique the PAPR should be reduced below 11db. Figure4.shows that by applying SLM technique the PAPR is reduced to approximately 9.1db.Usually the phase sequences are generated randomly using the SLM technique. So instead of generating the phase sequences randomly the phase sequences can also be generated using the Hadamard, Hilbert or the Circulant Matrix and the PAPR can be further reduced. Figure5. Shows that by the use of Hilbert Matrix the PAPR is further reduced to about 7.2db. Figure 6. Shows that by the use of Hadamard Matrix the PAPR is reduced to about 10db.

6.Expecting Results

In Future work, we should apply STBC and the Alamouti Scheme for further reduction of PAPR and to reduce the computational complexity in the SLM technique.

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