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Performance Improvements in Selective Transmission MIMO-OFDM Systems

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***Abstract*— Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) systems are widely used in broadband wireless communication, because it can provide high data rate over multipath channels. MIMO is a communication technology and OFDM is a multicarrier modulation. OFDM consists of number of closely spaced modulated carriers. It suffers high Peak to Average Power Ratio (PAPR). Due to high PAPR, hardware complexity and power consumption increases. PAPR can be reduced by applying many techniques such as clipping, Partial Transmit Sequence (PTS), Selective Mapping (SLM) etc. Clipping is a simple method but it causes data loss. In the case of SLM, it requires a phase sequence for PAPR reduction. The proposed work uses Riemann matrix as phase sequence in the selective mapping technique. The phase sequences, which are random, have to be sent to the receiver before the actual communication. But it is not necessary to send this information to the receiver while using Riemann matrix based technique. This is because the Riemann matrix has a particular structure so the receiver can generate the Riemann matrix itself. In PTS which uses distinct rotating vectors for PAPR reduction. Among the two methods PTS is complicated as compared with SLM, but both of them effectively reduce PAPR**.

***Index Terms*— MIMO-OFDM System, Peak to average power ratio, , Partial transmit sequence, Riemann matrix, Selective mapping**

I. Introduction

Wireless communication is an interesting area in the communication field today. It includes encoding, processing and decoding of messages. Multiple Input Multiple Output (MIMO) is a transmission reception technology, it uses multiple transmitting and receiving antennas for communication and also it helps to increase the information carrying capacity. OFDM is a good modulation scheme which is suitable for MIMO system. OFDM system uses multiple sub carriers for modulation and these subcarriers are orthogonal to each other. This orthogonality help to reduce inter symbol interference. Hence the available bandwidth is used very efficiently. Due to these advantages of OFDM it is used most commonly. But the major problem that affects while implementing this system is the high peak to average power ratio (PAPR). When PAPR is high it increases the complexity of ADC and DAC also reduces the efficiency of the power amplifier [1]. PAPR is the ratio of peak power to average ratio of the OFDM signal. In the case of hardware production the power amplifier become complicated due to this PAPR. There are different techniques are used for reducing peak to average power ratio they are clipping, partial transmit sequence, selective mapping etc. In the cause of clipping [8] it is the simplest approach for reducing the PAPR of OFDM signals. But it is a distortion based category method. Idea behind this method is clipped of the data envelop at predefined threshold. Since the clipping is done on the original information itself, so there is a possibility to lose the data. So this technique has some drawbacks which introduce in band signal distortion, and also resulting in Bit Error Rate performance degradation. It also causes out-of-band radiation in wireless communication. Next one is the Partial Transmit Sequence [5] here symbol subsequence are produced by partitioning the data. IFFT is then applied to each symbol subsequence and the resulting signal subsequences are summed after multiplied by a group of distinct rotating vectors. Next step is to compute PAPR of each subsequence and the sequence with lowest PAPR is used for transmission. In selective mapping the basic idea is to produce a number of transmit sequences from the same data source and then to select the transmit signal with the lowest PAPR and here uses phase sequence matrix for PAPR reduction. Here the proposed method uses Riemann matrix as phase sequence matrix [7]. The Riemann matrix has a particular form so the receiver can generate the Riemann matrix without any need of side information. In the case of PTS the key idea is to use the linearity of the operator such as IFFT. The input frequency domain data block is first partitioned into disjoint sub-blocks. Then each of the sub-blocks are then added with zeros appropriately and weighted by complex phase factors. They are finally combined in such a way that the IFFT of the sum of each of the sub-blocks yields a composite time domain signal whose PAPR is lower than the PAPR of the original input signal.

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II. METHODOLOGY

In broadband wireless communication systems uses Orthogonal Frequency Division Multiplexing (OFDM) with Multiple Input Multiple Output (MIMO) technique to achieve diversity gain. The idea of subcarrier grouping in OFDM is employed to combat the performance degradation and provide multi-user compatibility. A major obstacle is that the OFDM signal exhibits a very Peak to Average Power

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Ratio (PAPR) and it results in poor performance of power amplifier. PAPR can be reduced by using different techniques such as clipping, Partial Transmit Sequence and also by selective mapping etc. Among them clipping is the simplest method, but it results in data loss to a large extend. The basic system considered here is MIMO-OFDM. This uses two transmitter and two receiver antennas for communication. Channel used here is Rayleigh, it is because in practical line of sight communication not possible it is done with Rayleigh channel, At the transmitter data is encoded, modulated then perform PAPR reduction. IFFT is taken for generating OFDM, The use of Fast Fourier Transform algorithms eliminates arrays of sinusoidal generators and coherent demodulation required in parallel data systems and makes the implementation of the technology cost effective. Therefore, both transmitter and receiver are implemented using efficient FFT/IFFT techniques that reduce the number of operations. Finally the data is transmitted through the channel. At the receiver the reverse operation such as FFT, demodulation and decoding is done to reconstruct the data. The below given figure1 and 2 shows the transmitter and receiver section of the system.

A. Encoding and Decoding

Encoding is used at the transmitter section for protecting the data. For the purpose of encoding we use some specially designed redundant data. This data is added with the information bits and then transmitted. At the receiver when a sequence of data is received from the channel, it is required to estimate original data that has been sent.

B. Modulation

Modulation is an important part of wireless or wired communication. The basic idea behind it is to provide an envelope for the data signal with a carrier signal. It is process of varying any of the features of a carrier signal. Also it is the process of transmitting a digital data or an analog data inside an another signal. In the case of OFDM which uses IFFT/FFT operation for modulation. There are different modulation techniques are used here uses QAM modulation as a basic modulation for the data sequence.

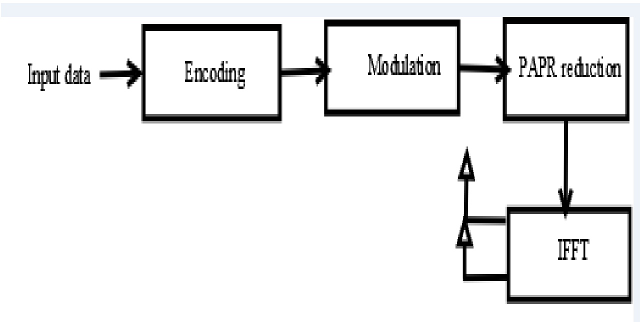

Fig. 1. MIMO-OFDM transmitter

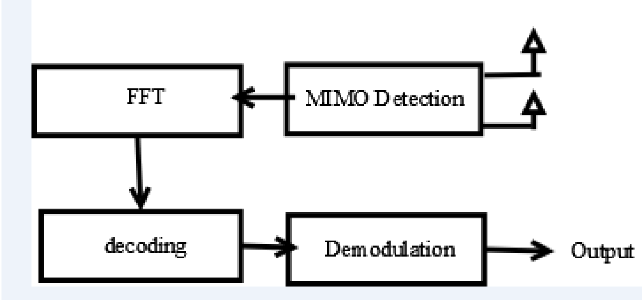

Fig. 2. MIMO-OFDM receiver

C. Multiple Input Multiple Output

Multiple Input Multiple Output (MIMO) is a transmission reception technology and is based on multiple transmitting and receiving antennas at both transmitter and receiver and provide special diversity, interference reduction and multiplexing gain. Here the transmitted signal takes multiple paths to reach the receiver with multiple copies of the signal. A two antenna transmitter receiver system is shown in figure 3

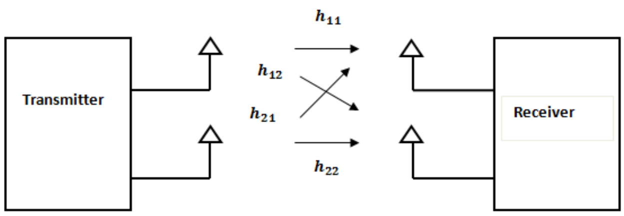

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Fig. 3. 2x2 MIMO Transmissions

D. PAPR Reduction

OFDM system suffers with high Peak to Average Power Ratio (PAPR). PAPR is the ratio of peak power to average power of the OFDM signal. IFFT/FFT operation is used to generate OFDM data and demodulate OFDM data. Input to the IFFT has a uniform spectrum and the output of IFFT has a spiky power spectrum.

$$PAPR= P_{peak}/P_{avg}$$

PAPR for discrete time signal x (n) is,

$$PAPR= \mathrm{Max}[x(n)^2]/E[x(n)^2]$$

Here the input is a random data and PAPR is a random variable because it is a function of input data. Level crossing rate theorem is used for calculating average number of times the envelop of the signal cross a predefined level. If knowing the amplitude of OFDM data it is easy to compute probability of crossing the predefined amplitude level. This is done by using a function called complementary cumulative distribution function (CCDF). CCDF is the probability that the PAPR exceeds a certain threshold $PAPR_0$

$$CCDF (PAPR(x(n))) = Pr(PAPR(x(n))) > PAPR0$$

E. PAPR reduction with SLM

In selective mapping (SLM) it is also called selective mapping with new phase sequence because it uses Riemann matrix, the signal having lowest PAPR is selected from a set of different signals which all represents the same information. Here input data is multiplied with different phase sequence matrix then the modified sequence with reduced PAPR is used for transmission. At the receiver, the reverse operation is performed to recover the original data block. Here phase sequence matrix used is Riemann matrix. In selective mapping techniques, the phase sequences they used are random and they must be sent to the receiver before the actual communication occurs. It is not necessary to send this information to the receiver using this technique. It is because the Riemann matrix has a general structure so the receiver can generate the Riemann matrix. In the cause of Partial transmit sequence method here the input symbol sequence is converted into a number of disjoint symbol subsequences. IFFT is then applied to each symbol subsequence and the resulting signal subsequences are summed after being multiplied by a set of distinct rotating vectors. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted.

F. Algorithm for PAPR reduction

1. The sequence of data bits are mapped to constellation points to produce sequence symbols X0,X1…
2. Each block [X0;X1…] is multiplied by different phase sequence vector that is by Riemann matrix
3. Transform to OFDM
4. Select best sequence that means, with minimum PAPR for transmission

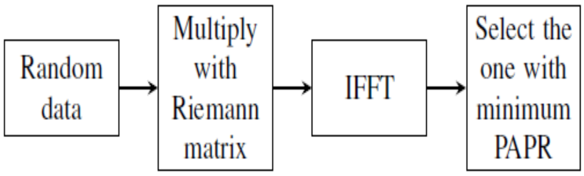

Fig. 4. Block diagram for PAPR reduction

F. PAPR Reduction with PTS

In Partial transmit sequence (PTS) method the input symbol sequence is partitioned into a number of disjoint symbol sub-blocks. IFFT is then applied to each symbol sub-blocks and the resulting signal sub-blocks are summed after being multiplied by a set of distinct rotating vectors. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. PAPR reduction with PTS is shown in figure 5.

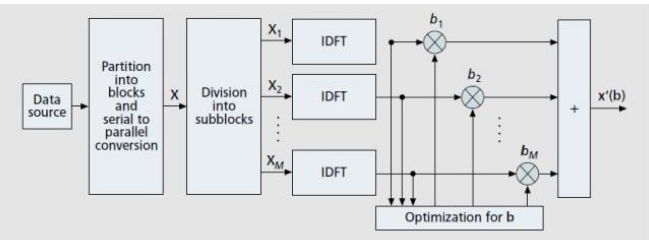

Fig. 5. PAPR reduction with PTS [Image Courtesy: 5]

III. EXPERIMENTAL RESULTS AND DISCUSSION

Objective of the work is to create a MIMO-OFDM system with reduced PAPR. For that a 2x2 MIMO-OFDM system is created and simulated using MATLAB 2015. A random data is generated and is encoded and modulated then PAPR reduction is done before transmission. Each section results are verified and shown below. PAPR reduction is done by using Riemann matrix multiplication in SLM method. Riemann matrix has a particular structure so the receiver can generate it easily. In the case of PTS distinct rotating vectors are multiplied to reduce the peak value of the signal. PAPR reduction results are verified using complementary cumulative distribution function and mean value of the data. Below figure shows random binary input of 64 bits. This data sequence is changed in each iteration. Generation of random data is based on the information to be transmitted.

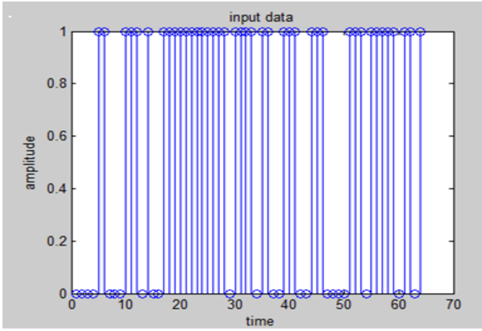

Fig. 6. Input Data

Table 1 summarizes the simulation parameters used for MIMO-OFDM.

Parameter	Specification
Input data size	64
FFT size	64
No. of carriers	64
Guard type	Cyclic extension
Constellation	QAM
MIMO structure	2x2

A. PAPR Reduction

In SLM method PAPR is reduced by multiplying Riemann matrix with input data. Riemann matrix has a particular structure so at the receiver it can be generated without any side information. MATLAB syntax for Riemann matrix is R = gallery (riemann, n). Where n represent the size of matrix, the size must be same as the size of input data. The result for SLM is shown in figure 7 and 8.

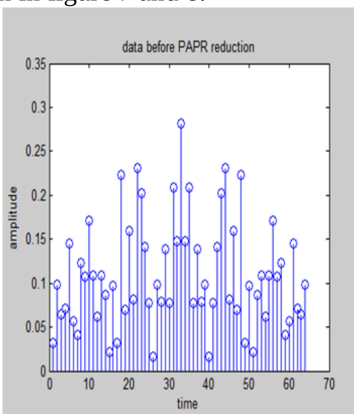

Fig. 7. Data before PAPR reduction

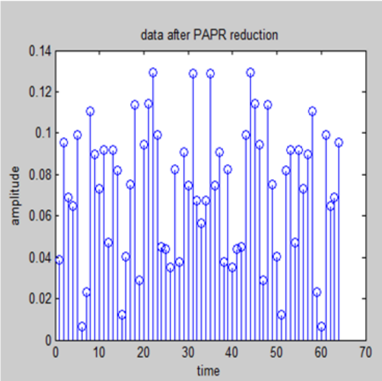

Fig. 8. Data after PAPR reduction

In the cause of PTS the input symbol sequence is partitioned into a number of disjoint symbol subsequences. IFFT is then applied to each symbol subsequence and the resulting signal subsequences are summed after being multiplied by a set of distinct rotating vectors. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. Below figure 9 shows the CCDF plot for PAPR reduction

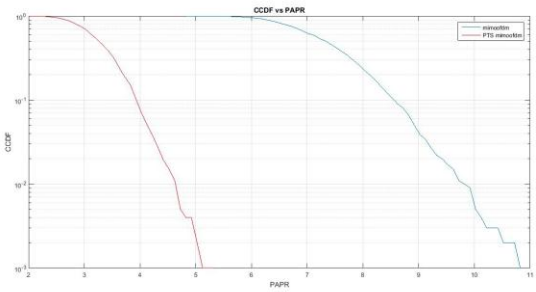

Fig. 9. CCDF plot for PTS PAPR reduction

IV. CONCLUSION

In today's wireless communication systems Orthogonal Frequency Division Multiplexing (OFDM) has been combined with Multiple Input Multiple Output (MIMO) technique to achieve better performance. OFDM is a form of multi carrier modulation and it consists of closely spaced orthogonal carriers. In practical Rayleigh channel is used for communicating transmitter to receiver. OFDM system suffers high Peak to Average Power Ratio (PAPR). Due to high PAPR, Hardware complexity and power consumption increases. There are several methods used for reducing PAPR such as clipping, selective mapping (SLM) and partial transmit sequence (PTS). Clipping cause data loss and PTS is a good method but it requires complicated operations. Phase sequence multiplication is important in SLM for reducing PAPR. Here uses Riemann matrix as phase sequence matrix. By using Riemann matrix no need of side information. The experimental results show that there is an effective reduction done in PAPR by using both of the two methods, among them SLM is a simple method.

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