Performance analysis of SLM technique in MIMO OFDM using Turbo codes

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Abstract: The multiple inputs multiple outputs orthogonal frequency division multiplexing (MIMO-OFDM) is transmission technique which is recently considered in many wireless techniques. MIMO-OFDM techniques are used to enhance the system performance. High peak to average power ratio (PAPR) is a big problem of OFDM signal. SLM scheme can reduce the peak to average power ratio efficiently. SLM requires side information bits to detect the original data bits at receiver is main problem. Since SLM without side information for the detection of signal is proposed in this method. In the proposed method, turbo coding is used with SLM scheme. Turbo coding ensures the error detection and error correction between the transmitted and received phase sequences. Simulation result shows that the SLM scheme reduces PAPR and BER.

Keywords: Peak to average power ratio(PAPR), orthogonal frequency division multiplexing(OFDM), bit error rate(BER), cumulative complementary distribution function(CCDF)

I. INTRODUCTION

MIMO-OFDM is a transmission technique for high speed communication applications that provides high spectral efficiency, resistance to frequency selective fading channels and power efficiency. It is mainly considered as air interface for applications of wireless broadband such as wireless local area networks and 4G broadband wireless communications. MIMO is used with OFDM to enhance the system performance and also it is a method which multiplies the capacity of the radio link using multiple transmit and receive antennas. For wideband digital communication OFDM has developed into trendy technique, which is employed to carry data on numerous parallel data streams and channels. Every subcarrier is get modulated by conventional modulation method at low bit rate.

In MIMO-OFDM transmitter input bits are divided into frames of bit. The huge drawback of MIMO-OFDM system is that OFDM signal show high peak to average power ratio (PAPR) [2]. For finding out the PAPR problem in the OFDM, many techniques can be divided into two classes as distortion based techniques and redundancy based techniques. Distortion based techniques can reduce the PAPR of the OFDM symbol by adding some distortions to the signal points in the subcarriers [3]. Recursive clipping and filtering operation can be used to suppress both the out of band and PAPR [4]. Redundancy based coding include coding, tone injection (TI), selected mapping (SLM), partial transmit (PTS) [5]. Various methods are proposed to reduce the PAPR but either complexity or redundancies are high or only small gains in PAPR are achieved [6], [7],[8]. Though SLM and PTS have same profits, SLM is better than PTS regarding the data vectors. If number of sub-blocks is increased then PTS complexity rises [9]. SLM is more favourable among all methods since it is simple to implement and not announces any distortions in the transmitted signal as well as can get satisfactory PAPR reduction [10].Turbo codes hiring iterative decoding are channel codes are used to yield significant error correction plus to make decoding easy. By using turbo codes the data transmission efficiency of digital communication system is enhanced [11].

In this proposed paper, we have focused on PAPR reduction from the MIMO-OFDM as well as BER performance of the system. A sequential phase rotated sequence SLM based MIMO-OFDM transceiver which reconstructs the original transmitted phase sequence is proposed. Maximum likelihood is used at receiver to detect the original phase sequences. An error between transmitted and received phase sequence can be detected by this system.

II. MIMO-OFDM STBC System

In MIMO-OFDM, the serial input data stream is divided in frames of number of bits. These bits are grouped into N groups, where N indicates number of subcarriers. These numbers of bits in every group determines the constellation size of the specific subcarrier. For obtaining the vectors of the bits inverse fast Fourier transform (IFFT) is used. Let a block of N symbols X= $\{ X_k, k = 0, 1, 2, \ldots.. N-1 \}$ is created. The N subcarriers should be orthogonal. OFDM signal x_n of N subcarriers can be expressed in terms of discrete time domain given as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi kn/N} \quad , \quad 0 \le n \le N-1 \quad (1)$$

Where X_k, k=0, 1, 2….N-1 are the input symbols that are modulated by BPSK, QPSK or QAM and here n is the discrete time index.

The PAPR of OFDM signal can be described as the ratio of the maximum to the average power of the signal. PAPR can be expressed as

$$PAPR = \frac{P_{peak}}{P_{average}} (2)$$

PAPR can be measured in decibel (dB) and expressed as

$$PAPR = 10 \, log_{10} \frac{\max\{|x_n|^2\}}{E\{|x|^2\}} , 0 \le n \le N-1 (3)$$

Where E {.} denotes the expected value operation and x = $[x_1, x_2, x_3, \ldots x_{N-1}]^T$

Sometimes the symbol spaced sampling may miss some of the signal peaks, so oversampling is done to approximate the real PAPR by factor of L. The oversampled samples are obtained by LN-point IFFT of the data block with (L-1) N zero padding. So by setting L= 4 is ample to detain the peaks.

MIMO-OFDM has most important drawback high PAPR. The high PAPR usually occurs when the maximum number of given OFDM signals are out of phase with each other. High PAPR degrades the signal quality by changing the constellation nature of the transmit signal. When an MIMO-OFDM signal having high PAPR is passed through a non linear power amplifier, the signal undergoes through a non linear distortion [12]. This results in band distortion and out band radiation which causes system performance degradation and adjacent channel interference (ACI) respectively. To reduce this distortion, a linear power amplifier having large dynamic range is considered necessary. Complementary Cumulative Distribution function (CCDF) is considered to evaluate performance of many PAPR reduction techniques [8]-[13].

$$CCDF= 1-(1-e^{-PAPR_0})^N (4)$$

In the SLM method, U statistically independent phase sequences, $P^{(u)} = \left[P_0^{(u)}, P_1^{(u)}, P_2^{(u)}, \ldots \ldots P_{N-1}^{(u)}\right]^T$ are generated, where $P_k^{(u)} = e^{j\emptyset_k^{(u)}}$, $\emptyset_k^{(u)} \in [0,2\pi]$, k= 0, 1, 2 ….U. After this, data block X= $[X_0, X_1, X_2, \ldots.. X_{N-1}]^T$ is multiplied component wise with each one of U phase sequences, which result in set of U various data blocks,

$$X^u = \left[X_0 P_0^{(u)}, X_1 P_1^{(u)}, X_2 P_2^{(u)}, \ldots \ldots X_{N-1} P_{N-1}^{(u)}\right]^T .$$

Then IFFT is carried out to obtain the time domain of all U alternate data blocks, where x^u are expressed as the candidate signals. At last the one having minimum PAPR is selected for transmitting, shown in Fig 1.

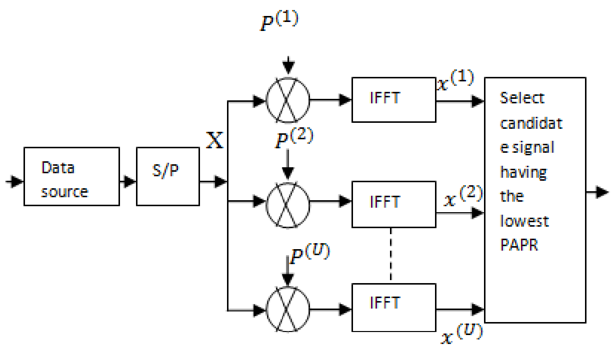

Figure1. Block diagram of SLM technique

In order to recover the received signals successfully, the receiver requires side information.$[log_2 U]$ bits are required to represent this side information whenever binary bits are used [7]. The side information must be transmitted with transmitting signal.

III. SLM SCHEME WITH TURBO CODING

SLM scheme is dependent on the probability of the MIMO-OFDM signal [10]. If the probability of PAPR of the MIMO-OFDM signal surpasses after some threshold say γ then it is expressed as

$$P_r\{PAPR > \gamma\} = 1 - (1 - e^{-\gamma})^N \quad (5)$$

So in SLM scheme, U statistically in independent alternative sequences is generated in proper way.

Turbo codes are the parallel concatenated convolutional codes [14]. In these codes all information bits are encoded by a recursive systematic convolutional code (RSC). Then they are passed through an interleaver which is used to increase the free distance between codes since to avoid errors and again encoded by another RSC code. The encoder is said to be recursive, when input does not directly change the memory state of the encoder because of the occurrence of feedback loop given in the RSC code. Here rate ½ RSC code is used in the turbo encoder. Without puncturing and multiplexing the code rate and PAPR will be high. So it is used for the better performance of the system without increasing complexity. Turbo encoder follows conventional convolutional method. Turbo encoder is shown in fig. 2

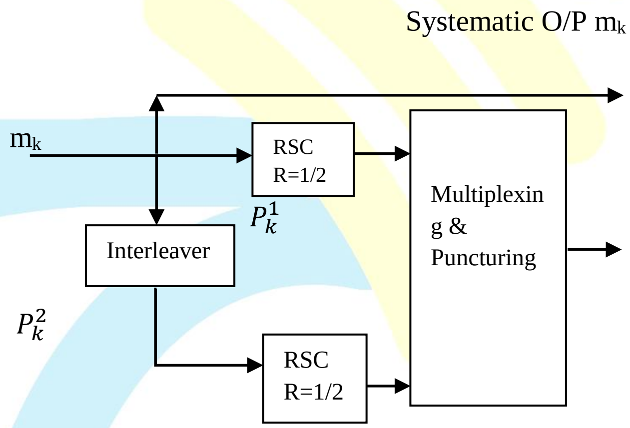

Figure 2: Turbo Encoder

Turbo decoder is used to recover the transmitted signal at the receiver part. The decoder consists of deinterleaver, soft input and soft output (SISO) i.e MAP decoders and interleaver. Turbo decoder follows the iterative decoding process. The interleaver at encoder side generates block of data and at decoder side it will correlates the two decoders in order to correct errors. Maximum likelihood is used by decoder is known as Maximum a-posteriori probability (MAP) in which trellis structure is applied. Turbo decoder is shown below in fig. 3. The encoders decide the capability of error correction and actual performance is determined by decoder. An iterative algorithm, Maximum A-posteriori technique is used.

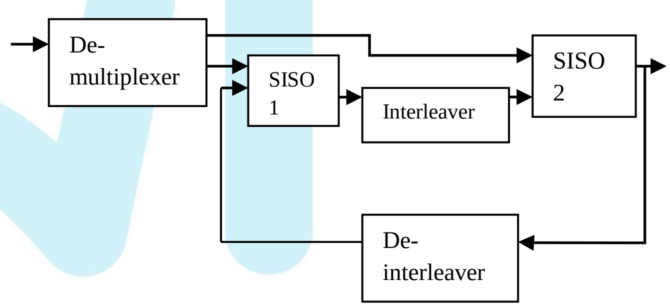

Figure 3: Turbo Decoder

The proposed MIMO-OFDM system is shown in figure 4. The block diagram of the transmitter and receiver explains about the process about the process that is carried out. In this work, N=128 subcarriers and quadrature amplitude modulation are employed to get the accurate results. First signal is provided at the input and then it is passed through the turbo encoder to get the systematic codes. Then QAM modulation is done in the mapping block. After that output of mapping block is given to the serial to parallel converter to get parallel codes.

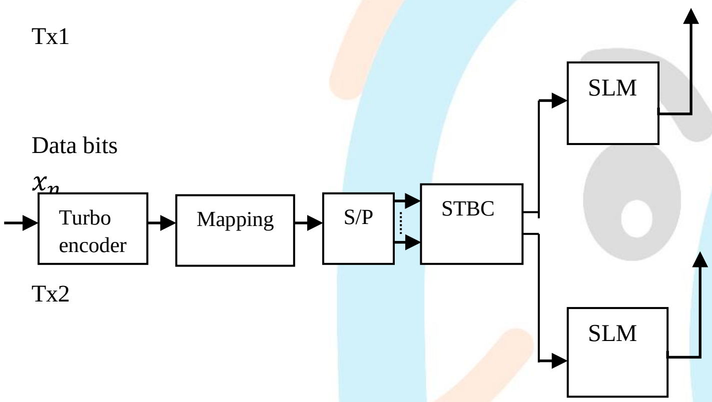

Figure 4: Proposed MIMO-OFDM transmitter

Then codes are passed through the space time block coding block which generates block codes that are important in the MIMO system and the output from it is given to the SLM block in which phase sequences are multiplied with the block codes. Since the correct symbol having lowest PAPR will be selected for the transmission. For the transmission of the symbol two antennas are employed at the output side of the SLM. The most popular Additive white Gaussian noise is assumed. Fig. 5 shows the proposed MIMO-OFDM system block diagram.

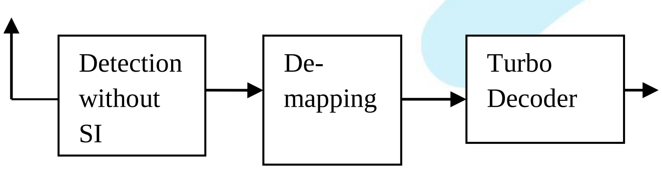

Figure 5: Proposed MIMO-OFDM receiver

At the receiver side, the signals are detected by SLM. After that STBC demapping is done using maximum likelihood detection approach which will extract that one desired original signal having lowest PAPR. Turbo decoder at receiver side will decode that sequence and finally it will give out the original signal at the receiver output.

IV. SIMULATION RESULTS

The performance evaluation of the proposed schemes has been done through MATLAB simulations. In proposed technique, the PAPR reduction performance can be approximated in terms of complementary cumulative distribution function (CCDF) which can be defined as the PAPR of a block is larger than a certain level. The comparison of CCDFs with respect to the PAPR distribution for original OFDM scheme without any PAPR reduction scheme is done with SLM technique. The modulation type considered here is QAM. It has been observed that original PAPR for OFDM is very high. This proposed work is executed by using following parameters.

Table1: Simulation Parameters for proposed work

Parameters	Values
Sampling Frequency	10KHz
FFT size	128
Modulation techniques	QAM
Transmit antennas	2
Receive antennas	2
Number of Phases	4
Quantity of OFDM symbols	10000
Quantity of sub carriers	128
SNR range	1-13dB

Table2: Comparison of results of two schemes

Schemes	No. of Subcarriers	PAPR at 10^{-3}	BER at 1.2dB

			SNR
Original without PAPR reduction	N=128	8.5dB	$10^{-2.9}$
SLM without turbo codes	N=128	7.9dB	$10^{-3.1}$
SLM with turbo codes	N=128	7dB	$10^{-3.9}$

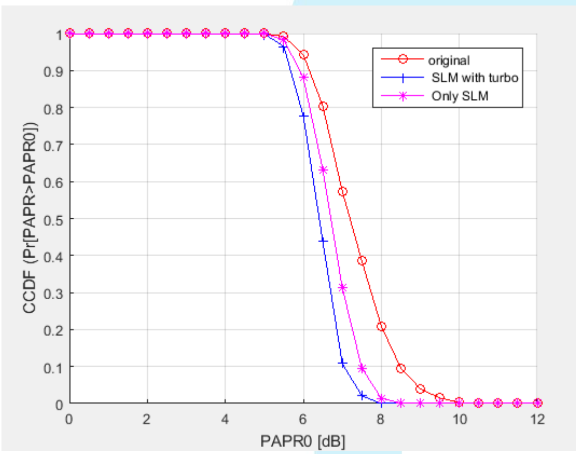

Figure 6: PAPR reduction with and without SLM scheme using Turbo codes

Figure 6 shows the graphs for three cases in which the PAPR of original signal, SLM scheme with and without turbo codes are compared. From this study, three cases have been compared. The CCDF graph shows that SLM technique with turbo codes helps in reducing PAPR significantly. When N=128, at 0.1 CCDF PAPR of SLM is 7.9 dB where as PAPR of SLM with turbo codes is 7 dB. Results indicate the difference between two graphs is 0.9 dB. By using turbo codes PAPR performance is slightly improved due to benefits of turbo codes.

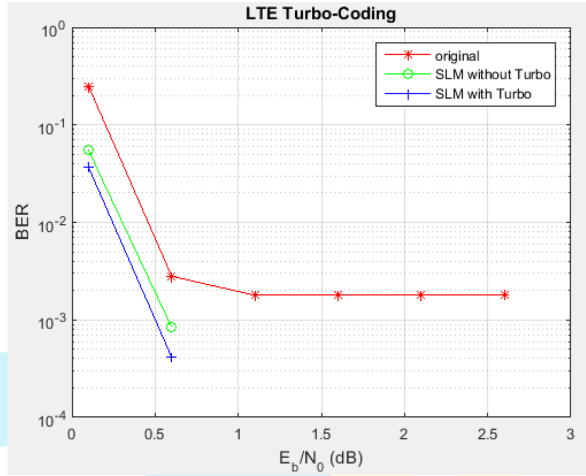

Fig 7: BER Performance for MIMO-OFDM system

Figure 7 gives the BER versus SNR graph which shows relation between BER and SNR with varying FFT size for QPSK when U=4 it shows that, for achieving higher SNR new method gives better BER reduction. Figure 7 shows that three cases for the BER performances of original signal, SLM withand without turbo codes. As we have applied turbo coding it will decrease the bit error rate of the system. If we compare the results regarding original signal and SLM with turbo coding signal then we came to know that at 0.6dB SNR we get less bit error rate i.e. $10^{-3.7}$ with N=128 subcarriers.

V. CONCLUSION

The proposed method incorporates the features of turbo coding and give remarkable results with MIMO-OFDM. Turbo coding is beneficial for reducing the PAPR at particular level. To study the performance of the proposedmethod regarding PAPR reduction and BER a recursive systematic encoder is required in turbo encoder. In this examination, it is analyzed that for perfect OFDM PAPR using SLM with turbo codes, results depends on the size of subcarriers, RSC encoder and turbo decoding algorithm. From this proposed system the errors between the transmitted and received sequence could be achieved successfully.

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