PAPR Performance Evaluation Using LDPC for MIMO-OFDM Transmission Systems

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Abstract: Multiple Input Multiple Output (MIMO) wireless technology in combination with Orthogonal Frequency Division Multiplexing (OFDM) is an attractive air-interface for next generation Wireless Local Area Network (WLAN) and Wireless Fidelity (Wi-Fi) Systems. These techniques are well adapted to various MIMO communication technologies. To achieve better Capacity with minimum error performance, Low Density Parity Check Codes (LDPC) is used extensively in most wireless systems. In this paper, LDPC encoding technique is employed to reduce Peak-to-Average-Power-Ratio (PAPR) of the MIMO-OFDM Signal.

Keywords: LDPC, MIMO, MIMO-OFDM, OFDM, PAPR.

I. Introduction

In recent years, high data rate wireless communication has attracted research in the context of WLANs and other indoor multimedia networks which has specifically been made possible by the employment of multiple antennas at both the transmitter and the receiver, which is called as Multiple Input Multiple Output (MIMO) technique. Fig. 1 shows the block diagram of a MIMO system used in modern electronic communications. MIMO has advantages of increased Channel Capacity and Transmission Link Reliabilitycoupled with, increase in Spectral Efficiency through Spatial Multiplexing Gain [1], [2]. MIMO has been adopted by various IEEE standards which include IEEE 802.11 for Wi-Fi (Wireless Fidelity), IEEE 802.11n extensively adopted in MIMO communications, IEEE 802.6e has been incorporated in MIMO communications for various configurations such as 2x1 4x4.

Orthogonal Frequency Division Multiplexing (OFDM) has a promising future as a new technology in many next generation wireless communicationsystems. OFDM has the ability to support high data rates for multi-path effects over frequency selective channels [3], [4], [5], for the coverage of wide area, robustness to multipath fading and channel equalization.

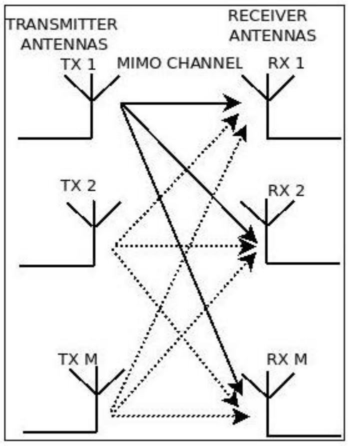

Fig. 1: Block Diagram of MIMO System

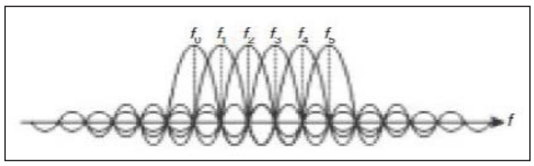

Fig. 2: Illustration of OFDM Principle

OFDM is an effective Multi-Carrier modulation technique which is based on the principle of Frequency Division Multiplexing (FDM). It is a digital modulation technique and implemented using Inverse Fast Fourier Transform (IFFT) at the transmitter and Fast Fourier Transform (FFT) at the receiver, for modulation and demodulation respectively. The data is split into parallel stream, this is done in order to split the wideband frequency selective channel into the narrow band frequency selective channel with a low data rate streams are transmitted over the one sub channel. OFDM has a number of advantages over Single Carrier modulation technique. It has high spectral efficiency, is immune to the multipath effects, narrow band interference and moreover implementation of OFDM system is easy [3]. Fig. 2 shows the principle of OFDM.

The major drawback encountered in an OFDM system is that it suffers from high Peak-to-Average-Power-Ratio (PAPR) at the transmitter. PAPR manifests itself as large peaks present at the transmitter side which force the amplifier to go into saturation, thus resulting in signal distortion, which leads to degradation of the system performance. Fig. 3 shows the schematic of MIMO-OFDM system [6].

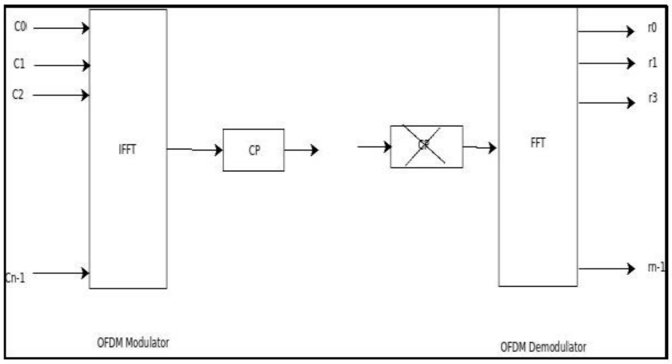

Fig. 3: Schematic Diagram of MIMO-OFDM System

MIMO-OFDM is widely used in modern communications due to its nature of robustness against multipath fading and robustness to the radio link by improving Signal-to-Noise-Ratio (SNR). MIMO-OFDM has applications in Wireless Local Area Network (WLAN) IEEE 802.11a [3], Wireless Metropolitan Area Network (WMAN) IEEE 802.16a [6], Digital Audio Broadcasting (DAB) Digital Video Broadcasting (DVB-T) [7] and also in wire line applications [8], [9].

LDPC is a Linear Block Code. These codes used in conjunction with MIMO-OFDM systems provide better discrimination to the problem of PAPR. These Codes have excellent Error Correcting and highly parallelizable decoding capabilities which ensure their use in the communications industry. LDPC codes have become a standard for the second generation satellite transmission of digital television [10] and have been proposed to be used in the next generation terrestrial television standards [11].

A combination of the two major technologies of MIMO and OFDM is found to be more advantageous than traditional communication systems. In MIMO-OFDM the PAPR is high and has deleterious effect on signal quality. Therefore, PAPR has to be minimized to improve system performance. A Considerable reduction in PAPR is observed by using LDPC encoding.

In this paper, PAPR reduction using LDPC for MIMO-OFDM has been investigated. The rest of the paper is organized as follows: A detailed description of the system model is presented in section II. The Simulation results are discussed in section III, followed by conclusions in section IV.

II. System Model

A. OFDM and PAPR

i. OFDM System

In OFDM systems, a high data rate stream is split into 'N' low rate streams which are transmitted simultaneously by each of the Subcarriers, where 'N' is the number of Subcarriers. Each of these Subcarriers are encoded independently using LDPC codes and modulated using M-ary PSK. IFFT technique at the transmitter generates an OFDM signal which is ready to be transmitted over the channel.

Consider an input block of data vector given by:

$$X = [X_0, X_1, X_2, X_3 \ldots\ldots X_{N-1}]$$

Each symbol in 'X' is modulated by one of the Subcarriers. These 'N' Subcarriers are Orthogonal to each other, and given by,

$$f_n = n\Delta f$$

Where $\Delta f = \frac{1}{NT}$ and 'T' is the Symbol Period.

The Complex Envelope of the corresponding OFDM signal is defined by,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi k f_n t}, 0 \le t \le NT \quad [12], [13] \tag{1}$$

where, X_n is the Data Symbol which is carried by the n^{th} Subcarriers and $T = 1/\Delta f$, is called Symbol Duration.

ii. Peak-to-Average-Power-Ratio (PAPR)

PAPR is defined as the ratio of Maximum Instantaneous Power to the Average Power, and mathematically defined as,

$$PAPR = \frac{\max_{0 \le x \le 1} |x(t)|^2}{E[|x(t)|^2]} \tag{2}$$

where, E [.] is the Average Power of *x(t)*.

B. Transmitter

At the transmitter of an MIMO-OFDM system, the data is generated using a Pseudo Random (PR) source. Block wise transmission of data is done at the transmitter. The size of the data generated is dependent upon the block size and the modulation scheme which is used in the modulator and to map the bits to symbols. The data which is generated is then passed to the LDPC Encoder.

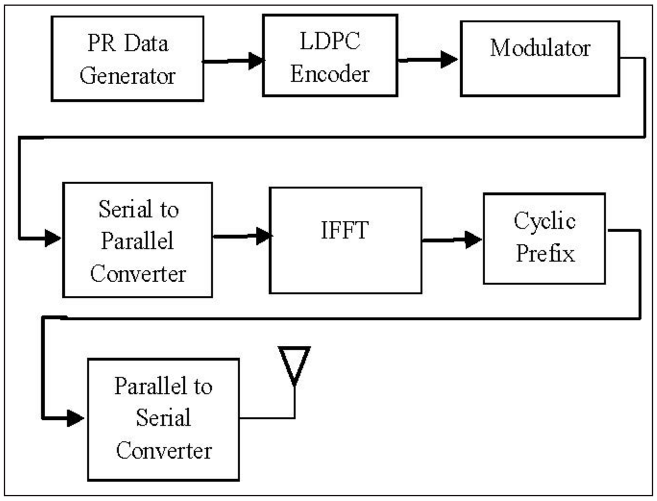

Fig. 4: Block Diagram of the Transmitter

C. LDPC Encoder

In this paper, LDPC, a form of encoding technique is used to *encode* the data. It was first discovered by Gallager in early 1960s [14], [15]. These codes were forgotten by the coding researchers for almost 20 years. In 1981, Tanner provided a different interpretation of LDPC codes by using models and graphs. Tanner's work was also ignored by the coding theorists for almost 14 years. By 1990, coding theorists started reinvestigating these codes based on graphs and iterative coding. Their research resulted in the rediscovery of the Gallager's LDPC codes and its generalization.

An LDPC Code is defined as the *Null Space of a Parity Check Matrix H*, which has the following structural properties [4]:

- Each row consists of α 1's.
- Each column consists of β 1's.
- The number of 1's in common between any two columns is denoted by is no greater than 1 i.e.,. $\gamma = 0$ or $\gamma = 1$.
- Both and are small compared to the length of the code and the number of rows in H [14], [15].

Gallager codes are constructed using linear codes which are specified by their Parity Check Matrices.

Let 'k' be any positive integer which is greater than 1.

Form a $[k\alpha \times k\beta]$ matrix H which consists of $k\beta \times k\alpha$ sub matrices, H_1, H_2, H_3, H_4,… …, H_β. Each row consists of $\alpha 1'$s and each column a single 1. Hence each sub matrix has a total of $k\alpha$ 1's.

For $1 \leq i \leq k$, the i^{th} row of H_1 consists of all its α 1's in columns. $(i-1)\alpha + 1$ to $i\alpha$. The other sub matrices are obtained by using the column permutation of H_1.

$$H = \begin{bmatrix} H_1 \\ H_2 \\ . \\ . \\ H_\beta \end{bmatrix} \quad (3)$$

The code word is obtained by multiplying the data and the Parity Check Matrix. TheLDPC Codes are used in satellite based Digital Video Broadcasting (DVB) and long haul Optical Communications Standards.

D. Inverse Fast Fourier Transform (IFFT) and Cyclic Prefix(CP)

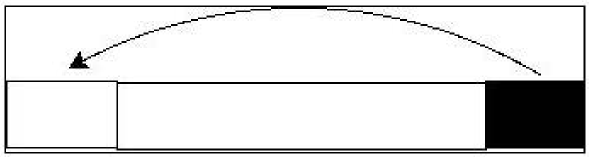

Fig. 5: Addition of Cyclic Prefix

Fig. 5 shows the addition of Cyclic Prefix (CP) in OFDM symbol [16]. CP is added to the OFDM symbol which is used to reduce Inter Symbol Interference (ISI).

CP is the last copy of the last part of OFDM symbol and it has to be long enough such that it can accommodate the delay spread of the channel.

The use of Cyclic Prefix in OFDM symbol turns the action of the transmitted signal from Linear Convolution into Circular Convolution and also helps to reduce the effect of Inter Symbol Interference (ISI). The overall transfer function can be normalized by the usage of the IFFT at the transmitter and the FFT at the receiver. This makes the Frequency Selective Channel to be converted into the Parallel Flat Fading Channel which simplifies the task of Equalization. CP carries the redundant information which sometimes results in loss of the Spectral Efficiency.

III. Experimental Results

The performance evaluation of PAPR in MIMO-OFDM was carried out using MATLAB R2015a. The environmental set up and parameters selected are as follows:

- *Input Data:* Pseudo Random (PR) data of length 64-bits.
- *LDPC Encoder:* The data is LDPC encoded using the Gallager method which is used to generate Parity Check Matrix H.

- *Modulation:* The Modulation technique used is 4-PSK.
- *Serial-to-Parallel Conversion:* Modulated data is converted from Serial to Parallel, depending on the number of Subcarriers.
- *Inverse Fast Fourier Transform (IFFT):* IFFT is carried out after serial to parallel conversion at the transmitter.
- *Cyclic Prefix (CP):* CP of data is carried out after the IFFT operation.
- *Parallel-to-Serial Conversion:* After performing Cyclic Prefix, the data is converted from Parallel-to-Serial.

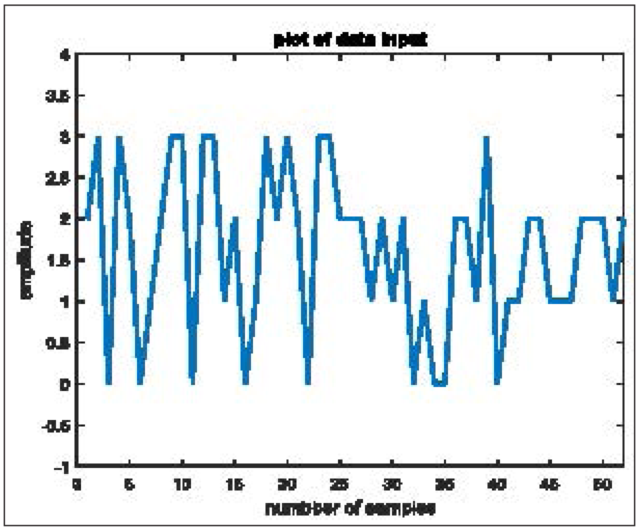

Fig. 6: Data Input

Fig. 6 shows the plot of the Number of Samples with the amplitude of Pseudo Random (PR) data source.

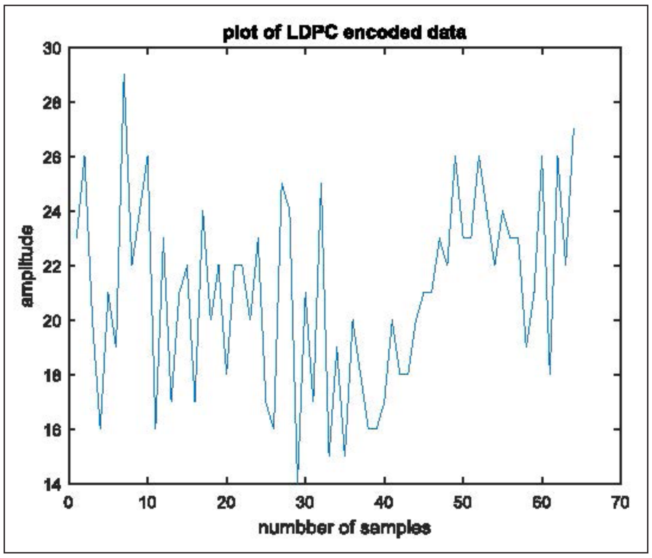

Fig. 7: Plot of LDPC Encoded Data

Fig. 7 shows the plot of FFT Samples encoded using Gallager LDPC method.

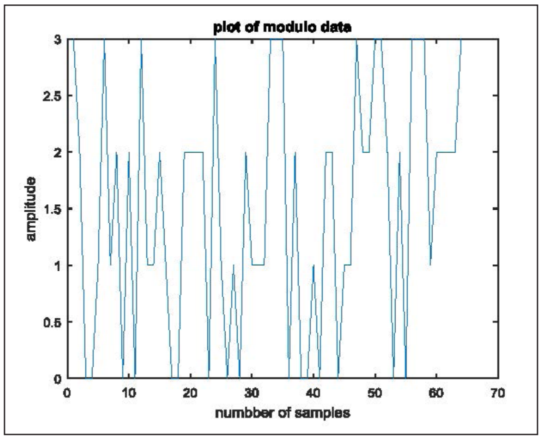

Fig. 8: Plot of Modulo-4 Data

Fig. 8 shows the plot of the number of samples with the amplitude of the signal. Here the signal is encoded using modulo-4 operation. This is done in order to bring the modulated data to the desired range.

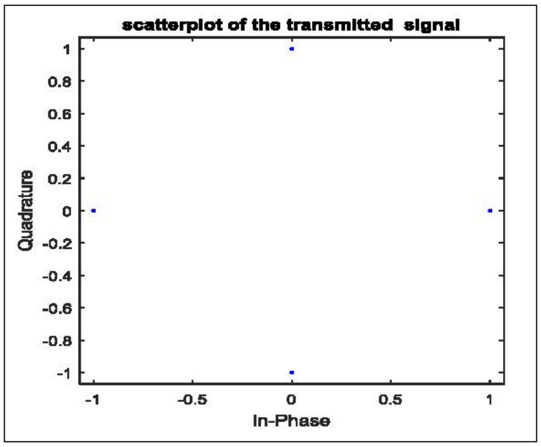

Fig. 9: Scatter Plot of Transmitted Data

Fig. 9 shows the Scatter Plot of the 4-bit PSK data. The data is placed in 4 different Constellations after LDPC encoding.

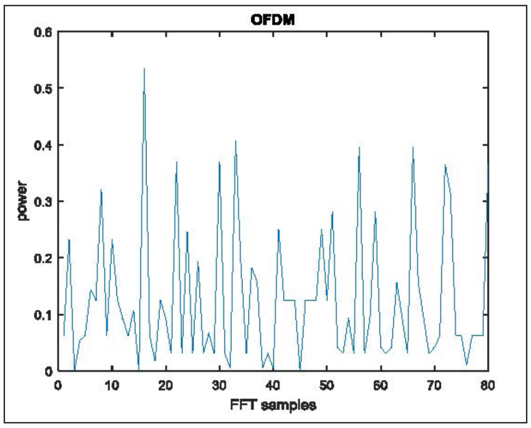

Fig. 10: Plot of OFDM Signal to Compute the Power Content

Fig. 10 shows the plot of the OFDM signal by which the power of the signal is computed. The graph plotted against the number of FFT samples with the power of the OFDM signal.

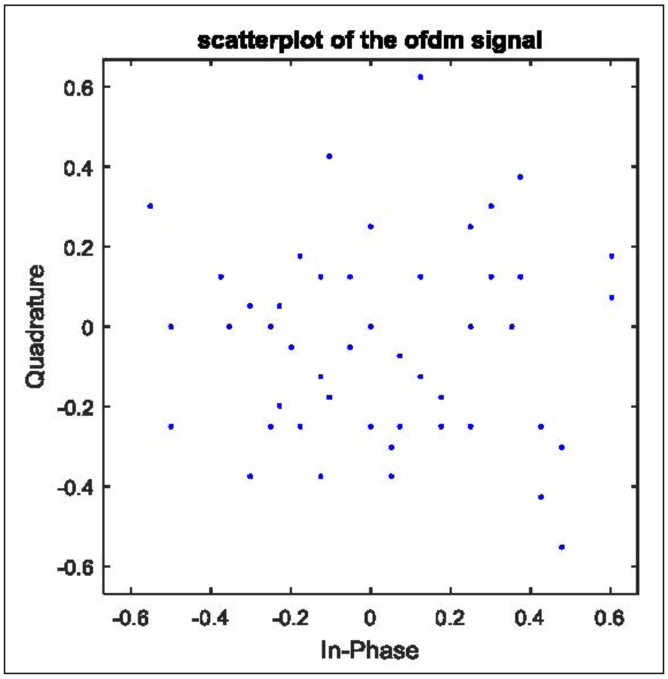

Fig. 11: Constellation Diagram of OFDM Signal

Fig. 11 shows the Constellation Diagram of OFDM signal for a block size of 8, and for the number of IFFT points equaling 64. To evaluate the performance of the LDPC code, MIMO-OFDM signal is generated using 4-ary PSK which has a block length of 8, bandwidth of the signal being 20 MHz, and size of IFFT points being 64. Gallager LDPC code is then generated by taking the Row Weight of 16 and Column Weight of 13 which is used to generate a data of size 52 bits.

The OFDM signal is encoded using Parity Check Matrix H. This signal under goes modulo 4 operation in order to bring the signal to the desired range of the data. Finally, the PAPR of the signal is computed for the LDPC coded MIMO-OFDM signal.

IV. Conclusion

MIMO-OFDM is a promising technology which can be used to implement various IEEE Standard and is well suitable for the present day communications. In this paper, LDPC technique has been used to implement the MIMO-OFDM system and to reduce the PAPR of the MIMO-OFDM Signal. This technique has been found to be beneficial in reducing the PAPR of MIMO-OFDM signal. The modulation technique used is 4-PSK which in association with LDPC encoding, ensures a considerable reduction in PAPR.

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