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UTILIZATION OF QCLDPC FOR PAPR REDUCTION IN OFDM SYSTEMS USING CONVOLUTION-XOR METHOD

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi-carrier modulation technique that uses many closely spaced sub-carriers to encode the digital data in the revolution of wireless communication systems. OFDM divides a radio channel into large number of closely spaced sub-channels to provide more reliable communications at high speeds and high data rates. The major drawback of OFDM system is the high peak to average power ratio (PAPR). Due to the presence of large number of independently modulated sub-carriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. The resulting high peaks increases the amount of inter modulation distortion and error rate. The proposed study is based on the reduction of PAPR by implementing the convolution of parity check matrix (H) in Quasi Cyclic Low Density Parity Check Codes(QCLDPC). The Quasi Cyclic LDPC is used for encoding the input bits before they are being modulated. Each sub carrier is modulated with a conventional modulation scheme (such as, QPSK and QAM) at a low symbol rate, maintaining total data rates similar to the conventional single carrier modulation schemes in the same bandwidth. The PAPR is calculated for different coding rates and spreading rates in the proposed system. Comparison of PAPR is carried out for QCLDPC using lower triangulation method and QCLDPC using convolution method. The proposed method shows a better results when compared to the existing method.

***Index Terms*—Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio(PAPR), And Quasi Cyclic Low Density Parity Check(QCLDPC) Codes, Quadrature Amplitude Modulation(QAM), Quadrature Phase Shift Keying(QPSK).**

1.Introduction

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, (i.e) they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other. The basic principle of OFDM is to split a high data streams into a number of lower data rate streams and then transmitted these streams in parallel using several orthogonal sub-carriers. Due to the parallel transmission the symbol duration increases, thus decreases the amount of dispersion in the time caused by multipath delay spread. OFDM can be seen as either a modulation technique or multiplexing technique. OFDM principle also lies in dividing the Frequency selective channel into Flat channels with uniform gain and ideal sampling such that each sub-channel is flat and so the fading it experiences is narrow and hence no ISI. Basically the transmission bandwidth is divided into many narrow sub-channels which are transmitted in parallel. OFDM has several advantages over single carrier modulation techniques. Some of the advantages are: Multipath delay spread tolerance which is highly immune to multipath delay spread that causes inter symbol interference in wireless channels, Immune to Frequency Selective Fading channels in which the lost data can be recovered using proper codes at the transmitter side, High Spectral Efficiency is achieved by allowing the sub-carriers which overlap in the frequency domain and modulation methods like FFT and IFFT are used for efficient modulation and demodulation purposes. This system is simple and has inherent robustness towards inter symbol interference.

The main drawback of OFDM system is high peak to peak average power ratio. Peak to Average Power Ratio is the ratio of peak power to the average power of a signal. It signifies the relationship between the maximum power of a sample of given transmit symbol to the average power of that OFDM symbol respectively. High PAPR values will lead to intermodulation distortion and non-linear distortion. The reduction in the PAPR value will make the transmission of high average power for a fixed peak power and will improve the overall signal to noise ratio at the receiver [5]

PAPR in OFDM systems can be reduced by applying codes and transformations[3]. The proposed work is based on the utilization of Quasi Cyclic LDPC codes in which the cyclic structure allows decoding and encoding of data in parallel form that acts as the tradeoff between encoding complexity and speed[1]. QCLDPC has small memory requirement and due its linear time encodability its memory problem can be solved[7]. PAPR values are calculated and compared with the QCLDPC using lower triangulation method with QCLDPC using convolution method [2]. The power signals of both the methods are viewed in Complementary Cumulative Distribution Function (CCDF) plot. The result states that utilization of QCLDPC using convolution method attains a better reduction of typical PAPR values when compared with the QCLDPC using lower triangulation method.

Low-Density Parity Check codes are the linear error correcting codes in which the message can be transmitted over a noisy transmission channel [9]. LDPC codes have wide range of applications in requiring the efficient and reliable information transfer over bandwidth in the noise corruption channel[8]. Quasi-Cyclic Low Density Parity Check have been applied to reduce the complexity over LDPC codes [6]. It has the advantage of linear encoding time and reduced complexity in decoding.

The encoding method of QCLDPC is based on the parity check matrix 'H' which is shown in the Figure 1 , which it can be constructed by applying the circulant matrices 'M'. The parity check matrix 'H' is sparse in which the matrix consists of 0's and 1's. M×N is the construction of sparse matrix where N>M and M=N-K such that 'M' defines the message bits, 'K' defines the parity bits and 'N' defines the number of encoded bits in the data i.e.(M+K). LDPC has two types of classes namely, regular and irregular LDPC. This study is based on the regular LDPC in which the rows and columns of the sparse matrix have uniform weights. The size of the parity check matrix is $P_1 \times P_2$, where P_1 and P_2 represents the size of row and column in parity check matrix. The number of 1's in a row and column is stated as row weight and column weight denoted as 'w_r' and 'w_c', where I_1 and I_2 are identity matrices, 'Z' is known to be zero matrix and 'g' is a gap matrix that is used to change the given matrix into upper triangular matrix [4].

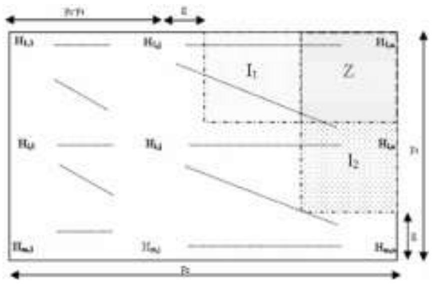

Figure. 1: Parity check m atrix 'H'

Here the size of the parity check matrix is considered as (3, 6), where $P_1 = 6$ and $P_2 = 12$ and g =2;

$$H = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

2. Proposed System

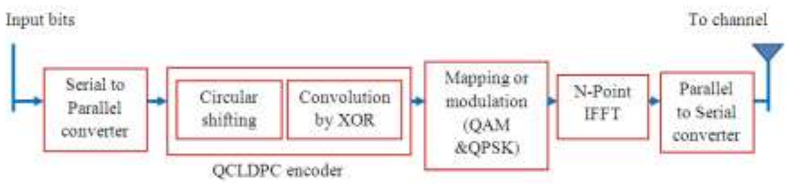

Figure 2. Block diagram of the Proposed System

The above Figure 2 depicts the transmitter block diagram of the proposed OFDM system. The randomly generated information data bits are sent to serial to parallel converter which converts serial data bits into parallel form. The converted data is applied to the encoder block which encodes the information bits by using QCLDPC codes. In that block the parity check matrix is circular shifted and then convoluted with the temporary bits by using XOR operation. The resultant matrix is encoded with input data bits and the modulation schemes are applied to the encoded data bits. The modulated data is sent to the N-point IFFT where the frequency domain data is converted to time domain data. Here the 'N' defines the number of sub-carriers in the system. The data is the converted back to serial form by passing the data to parallel to serial converter.

The sequence of operation is explained as follows. Initially, the row vector of hundred values between 1 to 50 will be generated. The general H matrix with the size of 6×12 is taken, which is assigned to be zero for all the elemental positions. Depending on the value of rows and columns, each position is filled with either one's or zero's respectively.

$$H = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$H = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The above matrix depicts the general H matrix with the elementary positions placed with 0's and 1's.The resultant matrix is shifted two times using circulant shift procedure. After all shifting the resultant matrix is,

$$H = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The size of resultant matrix (6×12) is assigned to two variables namely convolution factor (conv_fact) and convolution vector (conv_vec). If the conv_fact is equal to the assigned inrandbits the temporary correlation bits are generated which is convoluted with shifted H matrix.

For example the temporary correlation bits are [1 0 0 1 1 0 1 1 0 1 0 1]

The combined matrix is given below:

$$\begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Each row of the shifted matrix is convoluted with the temporary correlation bits by using the XOR operation.

2.1 XOR Operation:

The XOR gate (sometimes EOR gate, or EXOR gate and pronounced as Exclusive OR gate) is a digital logic gate that gives a true (1 or HIGH) output when the number of true inputs is odd. An XOR gate implements an exclusive or; that is, a true output results if one, and only one, of the inputs to the gate is true. If both inputs are false (0/LOW) and both are true, a false output results. XOR represents the inequality function, i.e., the output is true if the inputs are not alike otherwise the output is false. A way to remember XOR is "one or the other but not both".

XOR can also be viewed as addition modulo 2. As a result, XOR gates are used to implement binary addition in computers. A half adder consists of an XOR gate and an AND gate. Other uses include subtractors, comparators, and controlled inverters.

The algebraic expressions $(A \bullet \overline{B} + \overline{A} \bullet B)(A \bullet \overline{B} + \overline{A} \bullet B)$ and(A+B) $\bullet$ $(\overline{A} + \overline{B})$ both

represent the XOR gate with inputs A and B. The behavior of

XOR is summarized in the truth table.1 shown below,

INPUT		**OUTPUT**
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

Table No 1. Truth table of XOR

Logic symbol for XOR gate is shown in Figure 2.1,

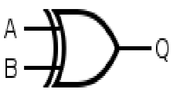

Figure 2 .1 Logic symbol of XOR

Consider the first row of the matrix and the XOR operation is given below:

A = [0 1 0 1 0 0 1 1 0 0 1 1]

B = [1 0 0 1 1 0 1 1 0 1 0 1]

[(0•0)+(1•1)] → [1]

[(1•1) + (0•0)] → [1]

[(0•1)+(1•0)] → [0]

[(1•0)+(0•1)] → [0]

[(0•0)+(1•1)] → [1]

[(0•1)+(1•0)] → [0]

[(1•0)+(0•1)] → [0]

[(1•0)+(0•1)] → [0]

[(0•1)+(1•0)] → [0]

[(0•0)+(1•1)] → [1]

[(1•1) + (0•1)] → [1]

[(1•0) + (0•1)] → [0]

Result Q = [1 1 0 0 1 0 0 0 0 1 1 0]

Consider the second row of the matrix and the XOR operation is given below:

A = [0 0 1 0 1 1 0 1 1 0 0 1]

B = [1 0 0 1 1 0 1 1 0 1 0 1]

[(0•0) + (1•1)] → [1]

[(0•1) + (1•0)] → [0]

[(1•1) + (0•0)] → [1]

[(0•0) + (1•1)] → [1]

[(1•0) + (0•1)] → [0]

[(1•1) + (0•0)] → [1]

[(0•0) + (1•1)] → [1]

[(1•0) + (0•1)] → [0]

[(0•0) + (1•1)] → [1]

$[(1\bullet 1) + (0\bullet 0)] \Rightarrow [1]$

$[(0\bullet 1) + (1\bullet 0)] \Rightarrow [0]$

$[(1\bullet 0) + (0\bullet 1)] \Rightarrow [0]$

Result Q = [1 0 1 1 0 1 1 0 1 1 0 0]

The resultant matrix after XOR operation is,

$$H = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

The above matrix is converted into sparse matrix to reduce the memory requirement. The converted sparse matrix is used to create the encode object to encode the randomly generated input bits. The randomly generated serial bits are converted to parallel form by using the serial to parallel converter. Using the encoder object the converted the random inputs and the above sparse matrix is encoded to obtain the encode data for further operations.

The encoded data is modulated by both QAM and QPSK mapping techniques. The modulated data is transformed from frequency-domain to time-domain by using IFFT operation since all the analyses are made in time-domain. Now the parallel data is converted back to serial data.

Finally, the PAPR value is estimated and then the threshold value is fixed. Further the estimated PAPR values are compared with the fixed threshold values. The comparison is plotted and viewed by CCDF characteristics. The encoded data is transmitted over the channel.

3.PAPR Calculation

The OFDM Signal obtained is in the form of parallel bits. The Average power is obtained using the formula below.

Average power=Sum of the magnitude of all the symbols/No. of symbols…(7)

The Peak power is obtained by calculating the maximum of magnitude of all the symbols.

PAPR is obtained using the formula

PAPR= Peak power/Average power…………………..(8)

The threshold value ranges from zero to maximum value. The formula for calculating the threshold value is as follows.

Threshold = 0: (maximum PAPR-minimum PAPR)/maximum PAPR: maximum PAPR

For example let the maximum value be 10, minimum value be 5.Therefore,

Threshold = 0: (10-5)/10:10

= 0: 0.5:10

The threshold values are 0, 0.5, 1, 1.5 ….10.

4. Algorithm for Proposed Method

Step 1: Start the program

Step 2: Generate the input bits randomly.

Step 3: Convert the serial data into parallel data.

Step 4: Generate the row vector of 100 values between 1 to 50.

Step 5: Construct the H matrix for different coding rate.

Step 6: Specify the shift offset value.

Step 7: Circular shift the H matrix.

Step 8: Assign the matrix size for two variables (conv_vect, conv_fact)

Step 9: If conv_fact is equal to the inrand bit then go to step 10 else proceed with step 23.

Step 10: Temporary correlated bit streams is generated and it is combined with H matrix.

Step 11: Convolute both the matrices by XOR operation on the bit streams.

Step 12: The resultant matrix is converted into sparse matrix

Step 13: Encode the input bits.

Step 14: Modulated the inputs signal using QAM16 or QPSK modulation.

Step 15: Compute IFFT for the mapped sequence.

Step 16: Convert the parallel data into serial bits.

Step 17: Calculate the PAPR value and determine the threshold value.

Step 19:Check whether PAPR> threshold value and increment the count value.

Step 21: Draw the CCDF plot i.e. threshold vs. probability of PAPR.

Step 22: Compare the result of no coding and quasi cyclic LDPC coding for different coding rate and spreading rate.

Step 23: Stop the program.

5. Simulation and Results

Peak to Average Power Ratio (PAPR) is reduced by using coding techniques such as Quasi Cyclic LDPC codes based on circulant procedure and convolution methods. This is implemented in MATLAB coding. The simulation was carried out by using MATLAB R2013a software. The simulation is carried out for coding rate 1/2 and 1/3 with different spreading rate namely 2 and 3 with the generated polynomial g=[1 1 1:1 0 1]. The modulation techniques used here is QAM 16 and QPSK. Hundred signals are considered for calculating the average power and PAPR. Simulation results for different coding rate and spreading rate is obtained from the CCDF plot.

The output results discussed are as follows, Figure.3 shows CCDF plot for QAM 16 modulation with coding rate 1/2 and spreading rate 2 ,there is a 1.87dB reduction in PAPR for QCLDPC using convolution method. There is a difference of 0.88dB compared to QCLDPC using lower triangulation method. Figure.4 shows CCDF plot for QAM 16 modulation with coding rate 1/2 and spreading rate 3 , there is a 1.79dB reduction for QCLDPC using convolution method. There is a difference of 0.89dB compared to QCLDPC using lower triangulation method. Figure.5 shows CCDF plot for QAM 16 modulation with coding rate 1/3 and spreading rate 2, there is a 1.92dB reduction for QCLDPC using convolution method. There is a difference of 1.80dB compared to QCLDPC using lower triangulation method. Figure.6. shows CCDF plot for QAM 16 modulation with coding rate 1/3 with spreading rate 3 ,there is a 1.80dB reduction for QCLDPC using convolution method. There is a difference of 1.12dB compared to QCLDPC using lower triangulation method. Figure.6 shows the CCDF plot for QPSK modulation with coding rate 1/2 and spreading rate 2,there is a 1.48dB reduction for QCLDPC using convolution method. There is a difference of 2.4dB compared to QCLDPC using lower triangulation method. Figure.7 shows CCDF plot for QPSK modulation with coding rate 1/2 and spreading rate 3 there is a 1.49dB reduction for QCLDPC using convolution method. There is a difference of 2.35dB compared to QCLDPC using lower triangulation method. Figure.8 shows CCDF plot for QPSK modulation with coding rate 1/3 and spreading rate 2 there is a 1.65dB reduction for QCLDPC using convolution method. There is a difference of 3.14dB compared to QCLDPC using lower triangulation method. Figure.9 shows CCDF plot for QPSK modulation with coding rate 1/3 with spreading rate 3 there is a 1.93dB reduction for QCLDPC using convolution method. There is a difference of 2.63dB compared to QCLDPC using lower triangulation method.

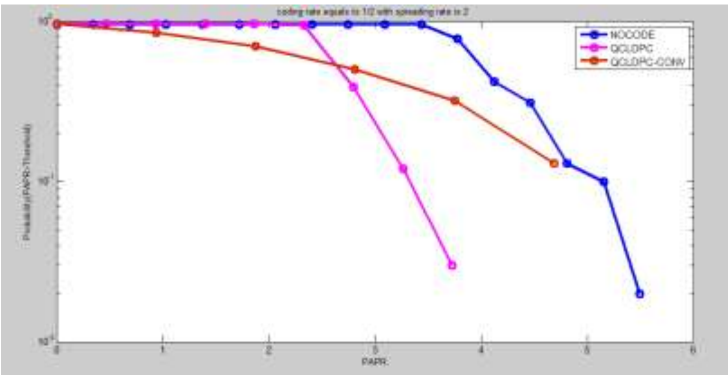

Figure 3: CCDF plot - QAM16 -1/2 coding rate - spreading rate 2

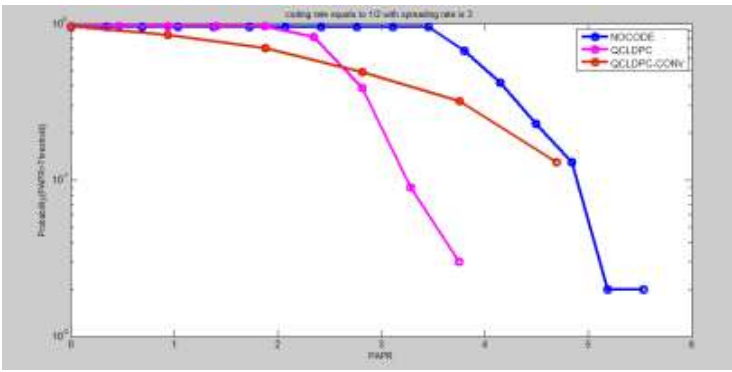

Figure 4 : CCDF plot - QAM16 -1/2 coding rate - spreading rate 3

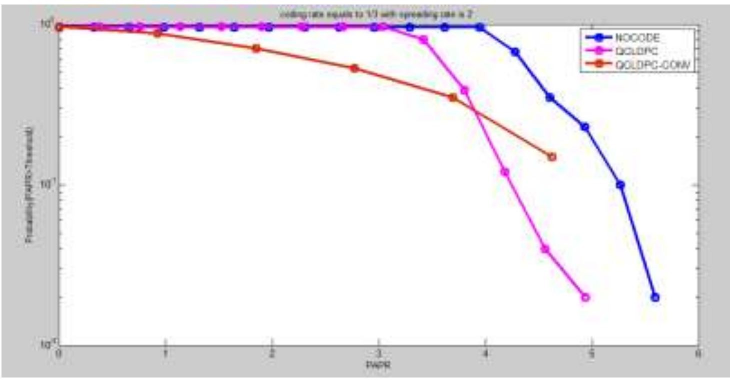

Figure 5: CCDF plot - QAM16 -1/3 coding rate - spreading rate 2

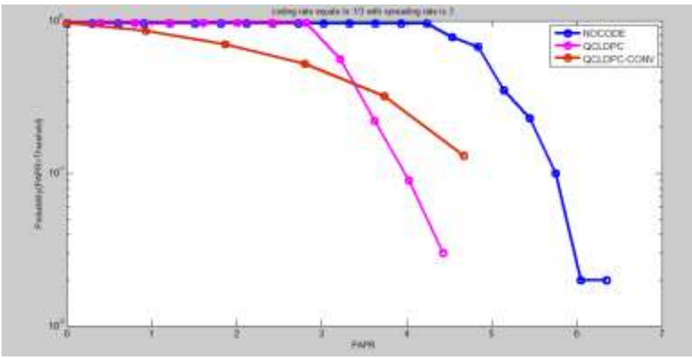

Figure 6: CCDF plot - QAM16 -1/3 coding rate - spreading rate 3

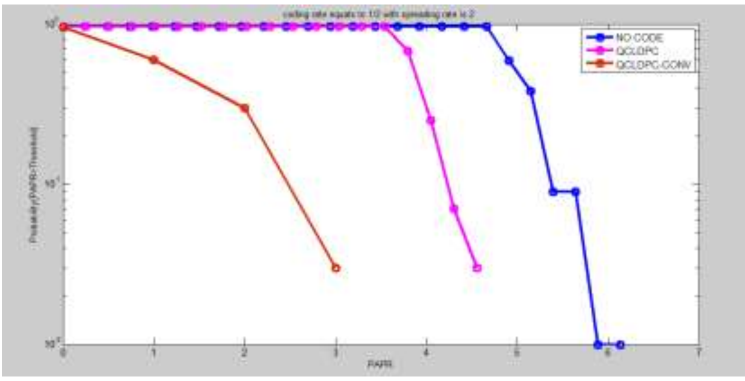

Figure 6 : CCDF plot- QPSK - 1/2 coding rate -spreading rate 2

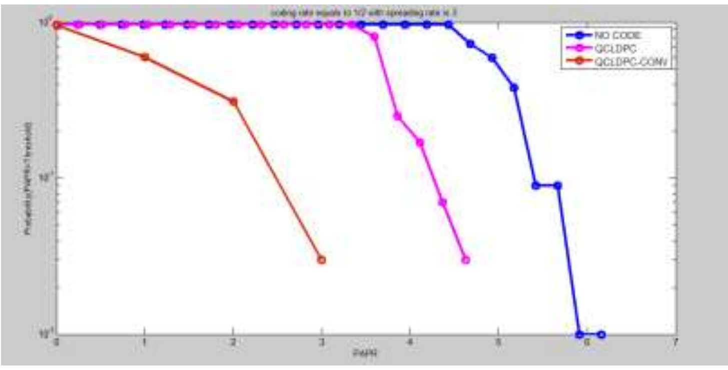

Figure 7 : CCDF plot- QPSK - 1/2 coding rate -spreading rate 3

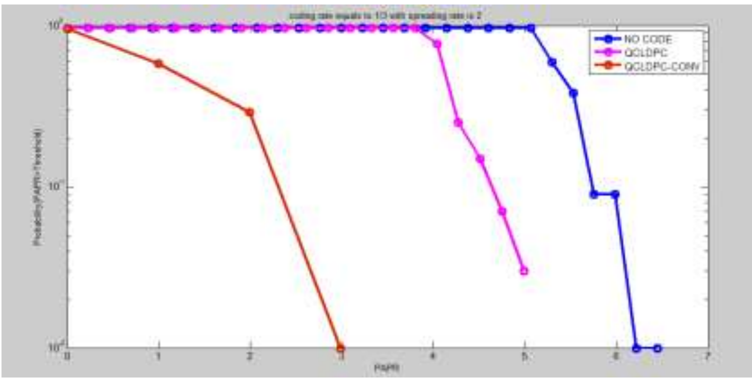

Figure 8: CCDF plot- QPSK - 1/3 coding rate -spreading rate 2

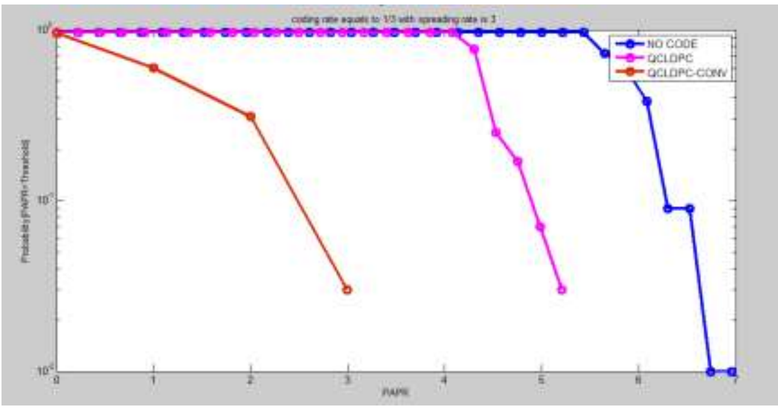

Figure 9: CCDF plot- QPSK - 1/3 coding rate -spreading rate

The PAPR of different methods are analyzed and studied. The comparison table is given below from the obtained results.

Mapping	Coding rate	PAPR for no coding(dB)		PAPR for QCLDPC coding(dB) Lower Triangulation Method		PAPR for QCLDPC coding(dB) Convolution Method	
		Spreading rate 2	Spreading rate 3	Spreading rate 2	Spreading rate 3	Spreading rate 2	Spreading rate 3
QAM 16	1/2	4.21	4.14	2.75	2.68	1.87	1.79
	1/3	5.18	4.39	3.72	2.92	1.92	1.80
QPSK	1/2	5.09	5.05	3.88	3.84	1.48	1.49
	1/3	6.01	5.78	4.79	4.56	1.65	1.93

Table No 2. Comparison Table

The comparison Table 2 states the PAPR reduction by applying Quadrature phase shift keying (QPSK) and QAM modulation techniques in OFDM systems. The utilization of QPSK modulation techniques attains a good PAPR reduction when compared to QAM 16. The simulation results and comparison table defines that QCLDPC codes using convolution method shows good PAPR reduction when compared to QCLDPC codes using lower triangulation method.

CONCLUSION

PAPR is one of the major drawbacks in OFDM systems. There are a lot of methods available to reduce it. We have used coding techniques. Two methods such as circulant procedure and convolution methods of Quasi cyclic LDPC codes are analysed for modulations such as QAM16 and QPSK for coding rates 1/2 ,1/3 and spreading rates 2,3 respectively. The QCLDPC with the convolution method have been used to reduce the PAPR effectively. The ciculant matrix is used to reduce the memory size required for storing the parity check matrices. Single array cyclic bits are replaced by set of matrix collection and convolution is happening. So that it is efficient when compared to the QCLDPC with triangulation method. We found that quasi cyclic LDPC codes using convolution based method showed better performance in reducing PAPR when compared to the other technique. By using QCLDPC codes with convolution method there is an average of 37% reduction of PAPR using QAM 16 modulation and 61% reduction of PAPR using QPSK modulation. In particular, QPSK modulation showed better results reducing PAPR. This project can be further extended by encoding using some other Error – Correcting codes and encoding algorithms/procedures. And also the work can be extended by increasing the coding and spreading rates with different modulating schemes.

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