International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal | www.ijtsrd.com
ISSN No: 2456 - 6470 | Volume - 2 | Issue – 6 | Sep – Oct 2018

ZCT Precoding Based SLM Technique for PAPR Reduction

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ABSTRACT
High Peak to Average Power Ratio (PAPR) is the major drawback of Orthogonal Frequency Division Multiplexing (OFDM) system. In this paper, we propose Zadoff-Chu matrix Transform (ZCT) precoding Selected Mapping (SLM) based OFDM (SLM-OFDM) system for PAPR reduction. This technique is based on precoding the constellation symbols with ZCT precoder matrix (row-wise) after the multiplication of phase rotation factor and before the Inverse Fast Fourier Transform (IFFT) in the SLM based OFDM (SLM-OFDM) Systems. At the clipping rate of 10-3, simulation results show that our proposed system can reduce the PAPR up to 6.8 dB with N=64 or 256 (System subcarriers) and V=16 (Dissimilar phase sequences) for 4QAM modulation. ZCT based SLM-OFDM system can avoid signal degradation in performance when passes through a nonlinear High-Power-Amplifier (HPA).

Keywords: *Peak to Average Power Ratio (PAPR), Orthogonal Frequency Division Multiplexing (OFDM), Zadoff-Chu matrix Transform (ZCT), Selected Mapping (SLM), SLM based OFDM (SLM-OFDM)*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi carrier modulation technique and commonly used in wireless communication. This is due to OFDM provides high speed date rates, high spectral efficiency, frequency selective fading and robustness against narrow band interference[1].

With the introduction of OFDM can reduced the Inter symbol Interference (ISI) and the delay spread of the signal. This increased the spectral efficiency of system. Due to the few advantages provided by OFDM, thus it is widely used in variety of digital communications over the past several years such as Wireless Local Area Networks (WLAN), Wide Area Networks (WAN), Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) and etc[2].

However, the Peak to Average Power Ratio (PAPR) is still one of the major problems of OFDM signal that restricted the development of OFDM[3]. High PAPR normally produced at transmitter part during the process of modulation. There is a multiple subcarriers added together to form the signal to be transmitted, the large PAPR is given at the same time. When the sinusoids of the subcarriers added together, the peak magnitude will be increased which rely on the amount of sinusoids[4]. So the average magnitude might be quite low as the destructive interference between the sinusoids. High PAPR will result in increased complexity of the analog-to-digital (A/D) and digital-to-analog (D/A) converters, high power consumption, lower efficiency and expensive devices.

Therefore, we have to proposed several techniques to improve the performance of OFDM system which in turn reduce PAPR. Nowadays, many techniques have been introduced for PAPR reduction and the techniques are categorized into two groups: signal scrambling techniques and signal distortion techniques. Examples of scrambling techniques are Block Codes, Tone reservation (TR) and Tone Injection (TI), Partial Transmit Sequence (PTS), Selective Mapping (SLM) and so on. Whereas the examples of signal distortion techniques are Clipping and Filtering, Peak Windowing, Peak Reduction Carrier and etc[5].

In this paper, we propose a ZCT precoding based SLM technique for PAPR reduction. In the proposed technique, the SLM technique is focus on phase rotation. After that, the ZCT based precoder is applied after the multiplication of phase rotation factor and before the IFFT in the SLM-OFDM systems. This paper is organized as follows: Section II describes the basics of different precoding based OFDM systems, In Section III we present the proposed system model for PAPR reduction, and Section IV presents computer simulation results and section V describe the conclusion.

II. BASICS OF DIFFERENT PRECODING BASED OFDM SYSTEMS

A. Zadoff-Chu (ZC) Sequences

Zadoff-Chu (ZC) sequences are class of poly phase sequences that having the ideal periodic autocorrelation function and the optimum periodic cross correlation function. Referring to [6], the Zadoff-Chu (ZC) sequences of length N is defined as

$$a_n = \begin{cases} e^{\frac{j2\pi r}{N}\left(\frac{k^2}{2}+qk\right)} & for\ N\ Even \\ e^{\frac{j2\pi r}{N}\left(\frac{k(k+1)}{2}+qk\right)} & for\ N\ Odd \end{cases} \qquad (1)$$

Where$k = 0, 1, 2 \ldots N-1$, q is any integer, r is any integer relatively prime to N and $j = \sqrt{-1}$.

B. Zadoff-Chu matrix Transform (ZCT)

The ZC sequence undergoes matrix transform to form ZCT. The ZC sequence can be reshaping by $k = m + lL$ (column-wise) or $k = mL + l$ (row-wise) to form the ZCT kernel column wise filling and row wise filling respectively, A, of size $N = L\ x\ L$ as shown in Eq. 2[7].

$$A = \begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0(L-1)} \\ a_{10} & a_{11} & \cdots & a_{1(L-1)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(L-1)0} & a_{(L-1)1} & \cdots & a_{(L-1)(L-1)} \end{bmatrix} \qquad (2)$$

Refer to both equations $k = m + lL$ and $k = mL + l$, m indicates row variable and l represents column variable. In other phrases, the $N = L^2$ point long ZC sequence fills the kernel of the matrix column-wise or row-wise. When variables m and l fulfill the equation $k = m + lL$, the k values in the kernel of the matrix column-wise is shown in Eq. 3, and the k values in the kernel of the matrix row-wise is stated in Eq. 4.

$$k_{A_{column-wise}} = \begin{bmatrix} 0 & L & \cdots & L(L-1) \\ 1 & L+1 & \cdots & L(L-1)+1 \\ \vdots & \vdots & \ddots & \vdots \\ L-1 & L+(L-1) & \cdots & L(L-1)+(L-1) \end{bmatrix} \qquad (3)$$

$$k_{A_{row-wise}} = \begin{bmatrix} 0 & 1 & \cdots & L-1 \\ L & L+1 & \cdots & L+(L-1) \\ \vdots & \vdots & \ddots & \vdots \\ L(L-1) & L(L-1)+1 & \cdots & L(L-1)+(L-1) \end{bmatrix} \qquad (4)$$

C. ZCT precoding based OFDM (ZCT-OFDM) system

Figure 1 shows the block diagram of ZCT precoding based OFDM system. In ZCT precoding based OFDM system, a set of binary data sequence undergoes constellation mapping and S/P convertor which generates a complex vector of size L that can be written as $X = [X_0\ , X_1, X_2 \ldots X_{L-1}]^T$[8].

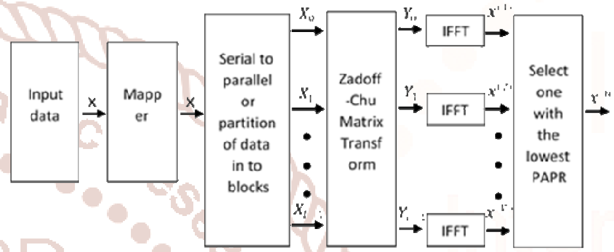

Fig.1. Block diagram of ZCT precoding based OFDM system

ZCT with row wise precoder matrix or ZCT with column wise precoder matrix,A of size LxL is applied on this complex vector,X which can transform this complex vector into new vector of same length L. This new vector of length L can be written as $Y = AX = [Y_0\ , Y_1, Y_2 \ldots Y_{L-1}]^T$. The new vector is also can written as:-

$$Y_m = \sum_{l=0}^{L-1} a_{m,l} X_l \qquad m = 0,1 \ldots L-1 \qquad (5)$$

Variables m and l in the $a_{m,l}$ are represented m^{th} row and l^{th} column of the ZCT precoder matrix. Eq. 5 is expanding by using either column-wise sequence reshaping $k = m + lL$ or row-wise sequence reshaping $k = mL + l$ and inserting r=1 and q=0 into the Eq. 1, then we get:

$$Y_{m_{column-wise}} = \sum_{l=0}^{L-1} \left(e^{j\frac{\pi(m+lL)^2}{L^2}} \right) X_l$$

$$= e^{j\frac{\pi m^2}{L^2}} \sum_{l=0}^{L-1} X_l e^{j\pi l^2} e^{j\frac{2\pi ml}{L}} \qquad m = 0,1, \ldots, L-1 \qquad (6)$$

Or

$$Y_{m_{row-wise}} = \sum_{l=0}^{L-1} \left(e^{j\frac{\pi(mL+l)^2}{L^2}} \right) X_l$$

$$= e^{j\pi m^2} \sum_{l=0}^{L-1} X_l e^{j\pi\left(\frac{l}{L}\right)^2} e^{j\frac{2\pi ml}{L}} \qquad m = 0,1,\dots,L-1 \quad (7)$$

Equation 6 and Equation 7 represent the ZCT precoded constellations symbols. The complex baseband ZCT-OFDM signal with L subcarriers which undergoes IFFT operation can be written as:-

$$x_n = \frac{1}{\sqrt{L}} \sum_{m=0}^{L-1} Y_m e^{j2\pi\frac{n}{L}m} \qquad n = 0,1,\dots,L-1 \quad (8)$$

The PAPR of ZCT-OFDM signal in Eq. 8 is calculated and written as:-

$$PAPR = \frac{\max\limits_{n=0,1,\dots,N-1}[|x_n|^2]}{\frac{1}{M}\sum_{n=0}^{N-1}[|x_n|^2]} \qquad (9)$$

D. SLM based OFDM (SLM-OFDM) system

Figure 2 shows the block diagram of SLM based OFDM system. The SLM is one of the PAPR reduction technique which is based on the phase rotations. In this SLM based OFDM system, a complex vector of length N, $X = [X_0, X_1, X_2 \dots X_{N-1}]^T$ is generated by the constellation mapping and S/P convertor.

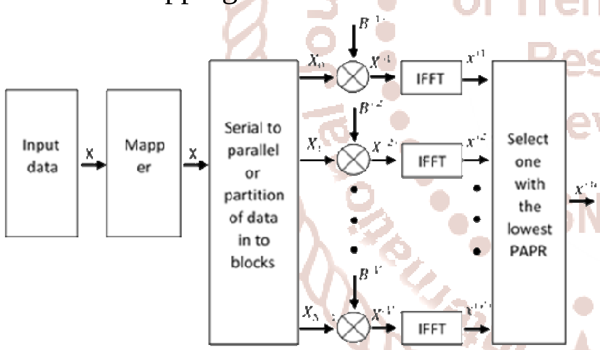

Fig.2. Block diagram of SLM based OFDM system

There is a set of V dissimilar phase sequences of length N can be defined as $B^{(v)} = \left[b_{v,0}, b_{v,1}, \dots, b_{v,N-1}\right]^T (v = 1,2 \dots V)$. Then, every data block is required to multiply with V dissimilar phase sequences which results in $X^{(v)} = \left[X_0 b_{v,0}, X_1 b_{v,1}, \dots, X_{N-1} b_{v,N-1}\right]^T (v = 1,2 \dots V)$ or written as:-

$$X_n^v = X_n b_{v,n} \qquad v = 1,2,\dots,V \quad (10)$$

The SLM-OFDM signal with N subcarriers which undergoes IFFT operation can be defined as:-

$$x_n^{(v)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k^v e^{j2\pi\frac{n}{N}k} \quad (11)$$

Where $n = 0,1,\dots,N-1, v = 1,2,\dots,V$. The PAPR of SLM-OFDM signal in Eq. 11 is calculated and be written as:-

$$PAPR = \frac{\max\left|x_n^{(v)}\right|^2}{E\left[\left|x_n^{(v)}\right|^2\right]} \qquad (12)$$

E. SLM-ZCT precoding based OFDM (SLM-ZCT-OFDM) system

Figure 3 shows the block diagram of SLM-ZCT precoding based OFDM system. In this SLM-ZCT based OFDM system, a set of binary data sequence undergoes constellation mapping and S/P convertor which result in a complex vector of length L can be written as $X = [X_0, X_1, X_2 \dots X_{L-1}]^T$.

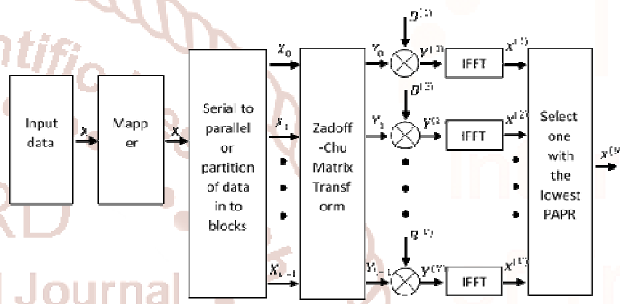

Fig.3. Block diagram of SLM-ZCT based OFDM system

This complex vector is then multiplied with the ZCT precoder matrix, A of size LxL to produce a new complex vector of same length L, $Y = AX = [Y_0, Y_1, Y_2 \dots Y_{L-1}]^T$ or can be written as:-

$$Y_m = \sum_{l=0}^{L-1} a_{m,l} X_l \qquad m = 0,1 \dots L-1 \quad (13)$$

After that, a set of V dissimilar phase sequences of length L, $B^{(v)} = \left[b_{v,0}, b_{v,1}, \dots, b_{v,L-1}\right]^T (v = 1,2 \dots V)$.

This vector of V dissimilar phase sequences is multiplied by the complex vector Y which result in $Y^{(v)} = \left[Y_0 b_{v,0}, Y_1 b_{v,1}, \dots, Y_{L-1} b_{v,L-1}\right]^T (v = 1,2 \dots V)$.

The matrix multiplication of Y and $B^{(v)}$ can be written as:-

$$Y_{i,k}^{(v)} = \sum_{j=0}^{L-1} B_{i,j}^{(v)} Y_{j,k} \qquad k = 0,1,2,\dots,L-1 \quad (14)$$

Where $i = 0,1,2,\dots,L-1$. The SLM-ZCT-OFDM signal with L subcarriers which undergoes IFFT operation can be defined as:-

$$Y_n^{(v)} = \frac{1}{\sqrt{L}} \sum_{k=0}^{L-1} Y_k^v e^{j2\pi\frac{n}{L}k} \qquad n = 0,1,\dots,L-1 \quad (15)$$

Where $v = 1,2,\dots,V$. The PAPR of SLM-ZCT-OFDM signal in Eq. 15 is calculated and be written as:-

$$PAPR = \frac{max\left|Y_n^{(v)}\right|^2}{E\left[\left|Y_n^{(v)}\right|^2\right]} \qquad (16)$$

III. ZCT PRECODING SLM BASED OFDM (ZCT-SLM-OFDM) SYSTEM

Figure 4 shows the block diagram of the proposed ZCT precoding SLM-OFDM system[9].

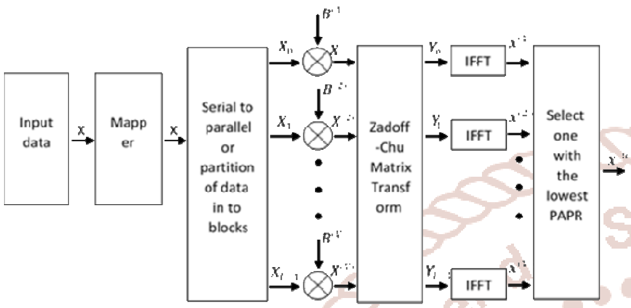

Fig.4. Block diagram of ZCT-SLM based OFDM system

At the beginning of this ZCT-SLM-OFDM system, a set of binary data is passed through constellation mapping and S/P convertor to generate complex vector of length L, $X = [X_0\ , X_1, X_2 \dots X_{L-1}]^T$. SLM system based on phase rotations, so there is a set of V dissimilar phase sequences of length L, $B^{(v)} = \left[b_{v,0}, b_{v,1}, \dots, b_{v,L-1}\right]^T (v = 1,2 \dots V)$. Each data block is multiplied with the set of phase sequences, then it produced

$X^{(v)} = \left[X_0 b_{v,0}, X_1 b_{v,1}, \dots, X_{L-1} b_{v,L-1}\right]^T (v = 1,2 \dots V)$.

The result can be simplified as

$$X_l^v = X_l b_{v,l} \qquad l = 0,1 \dots L-1 \qquad (17)$$

Where $v = 1,2,3 \dots V$. After that, the signal in Eq. 17 is passed through the ZCT precoder matrix of size LxL, thus the new complex vector is

$$Y_m^v = \sum_{l=0}^{L-1} a_{m,l} X_l^v \qquad m = 0,1 \dots L-1 \qquad (18)$$

The variables m and l in the $a_{m,l}$ are represented m^{th} row and l^{th} column of the ZCT precoder matrix. By using either column-wise sequence reshaping $k = m + lL$ or row-wise sequence reshaping $k = mL + l$ and inserting r=1 and q=0 into the Eq. 1, then expand the Eq. 18 and the resultant equation as shown below.

$$Y_{m_{column-wise}}^v = \sum_{l=0}^{L-1}\left(e^{j\frac{\pi(m+lL)^2}{L^2}}\right) X_l^v$$

$$= e^{j\frac{\pi m^2}{L^2}} \sum_{l=0}^{L-1}\left(\left(e^{j\pi l^2}.X_l^v\right).e^{j\frac{2\pi ml}{L}}\right) \qquad m = 0,1,\dots,L-1 \quad (19)$$

Or

$$Y_{m_{row-wise}}^v = \sum_{l=0}^{L-1}\left(e^{j\frac{\pi(mL+l)^2}{L^2}}\right) X_l^v$$

$$= e^{j\pi m} \sum_{l=0}^{L-1}\left(\left(e^{j\pi\left(\frac{l}{L}\right)^2}.X_l^v\right).e^{j\frac{2\pi ml}{L}}\right) \qquad m = 0,1,\dots,L-1 \quad (20)$$

Equation 19 and Equation 20 represent the ZC precoded signal. The complex baseband ZCT-OFDM signal with L subcarriers which undergoes IFFT operation can be written as:-

$$x_n^{(v)} = \frac{1}{\sqrt{L}} \sum_{m=0}^{L-1} Y_m^v . e^{j2\pi\frac{n}{L}m} \qquad n = 0,1,2 \dots L-1 \quad (21)$$

Where $v = 1,2,\dots,V$. The PAPR of ZCT-SLM-OFDM signal in Eq. 21 can be written as below

$$PAPR = \frac{max\left[\left|x_n^{(v)}\right|^2\right]}{E\left[\left|x_n^{(v)}\right|^2\right]} \quad (22)$$

IV. SIMULATION RESULTS

Simulations in MATLAB have been carried out to evaluate the performance of our proposed ZCT precoding SLM based OFDM system. To analysis the PAPR performance of proposed system, the data with 10^5 OFDM blocks is generated randomly then modulated by QPSK or QAM. We evaluate the PAPR statistically using Complementary Cumulative Distribution Function (CCDF). The CCDF of the PAPR for different system's signals are used to express the probability of exceeding a given threshold$PAPR_0$ $CCDF = Prob(PAPR > PAPR_0)$). We compared the result of proposed system which contains ZCT with column wise precoder matrix (ZCT-C-SLM-OFDM) with conventional OFDM system. It also used the same way in ZCT with row wise precoder matrix (ZCT-R-SLM-OFDM). In this comparison, both using 16QAM modulation, N=64 with V=16.

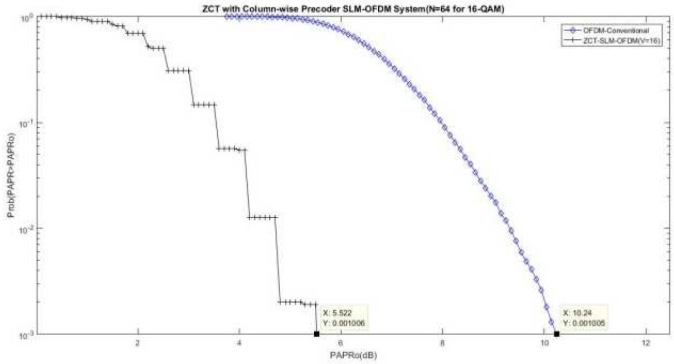

Fig.5. CCDF vs PAPRo of conventional OFDM and ZCT-C-SLM-OFDM with *V*=16

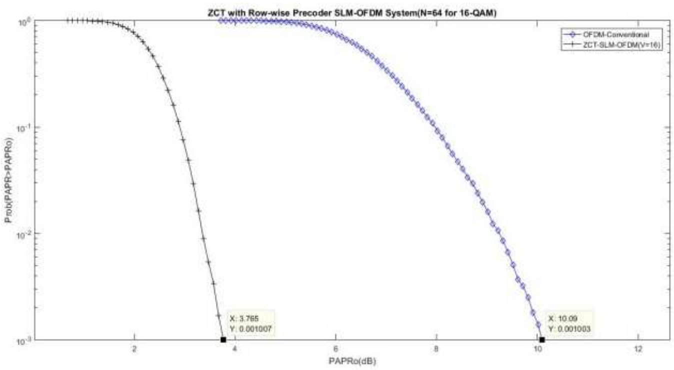

Fig.6. CCDF vs PAPRo of conventional OFDM and ZCT-R-SLM-OFDM with *V*=16

Figure 5 shows the CCDF comparisons of ZCT-C-SLM-OFDM system and conventional OFDM with 16QAM modulation for *N*=64 with *V*=16. At clip rate of 10^{-3}, the PAPR is 10.24dB and 5.522dB for conventional OFDM and ZCT-C-SLM-OFDM respectively.

Figure 6 shows the CCDF comparisons of ZCT-R-SLM-OFDM system and conventional OFDM with 16QAM modulation for *N*=64 with *V*=16. At clip rate of 10^{-3}, the PAPR is 10.09dB and 3.765dB for conventional OFDM and ZCT-R-SLM-OFDM respectively.

From the results obtained, ZCT-R-SLM-OFDM can reduce PAPR up to about 6.3dB whilst ZCT-C-SLM-OFDM can reduce PAPR up to about 4.7dB only. Thus, proposed system with ZCT row wise precoder matrix is preferred to use as it can reduce more PAPR. The following simulation results are included conventional OFDM system, ZCT-OFDM system, SLM-OFDM system, SLM-ZCT-OFDM system and ZCT-SLM-OFDM system for *N*=64 and 256 with *V*=4, 8 and 16.

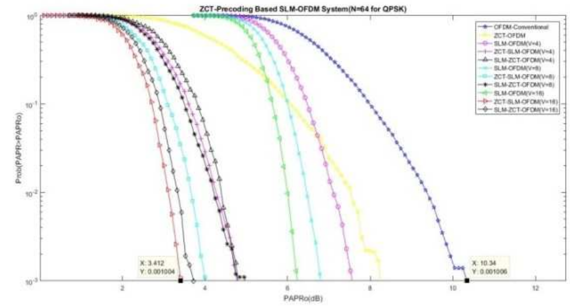

Fig.7. CCDF vs PAPRo with *N*=64 & *V*=4, 8, 16 for QPSK modulation

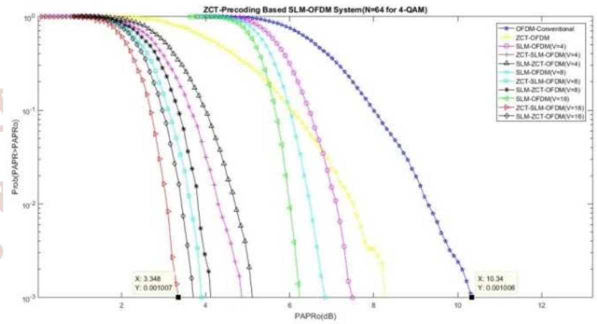

Fig.8. CCDF vs PAPRo with *N*=64 & *V*=4, 8, 16 for 4QAM modulation

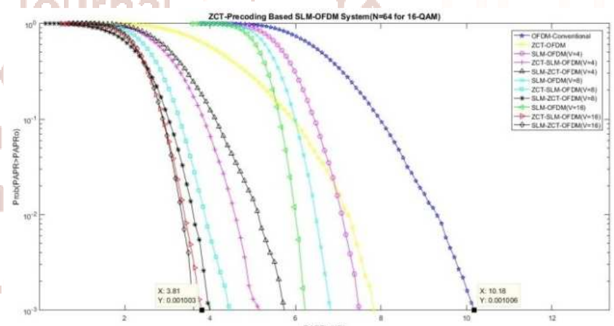

Fig.9. CCDF vs PAPRo with *N*=64 & *V*=4, 8, 16 for 16QAM modulation

Figure 7, Figure 8 and Figure 9 show CCDF vs PAPRo of conventional OFDM, ZCT precoded OFDM, SLM-OFDM, SLM-ZCT precoded OFDM and ZCT precoded SLM-OFDM with *N*=64 & *V*=4, 8, 16 for QPSK, 4QAM and 16QAM modulation respectively. The PAPR values is tabulated in Table 1.

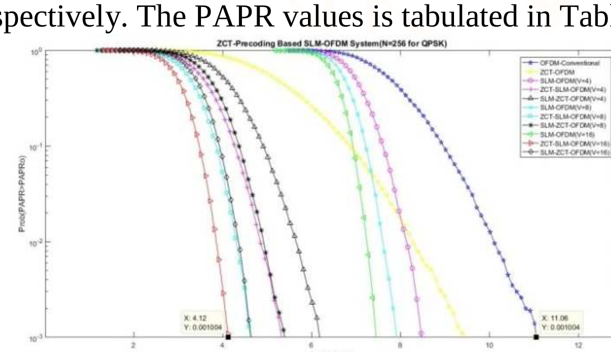

Fig.10. CCDF vs PAPRo with *N*=256 & *V*=4, 8, 16 for QPSK modulation

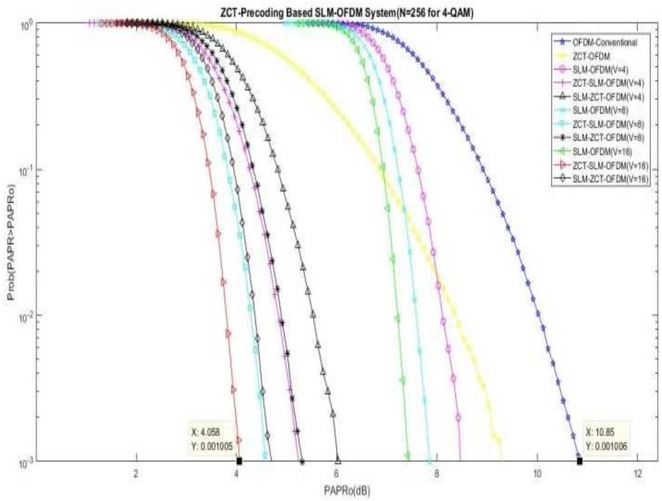

Fig.11. CCDF vs PAPRo with N=256 & V=4, 8, 16 for 4QAM modulation

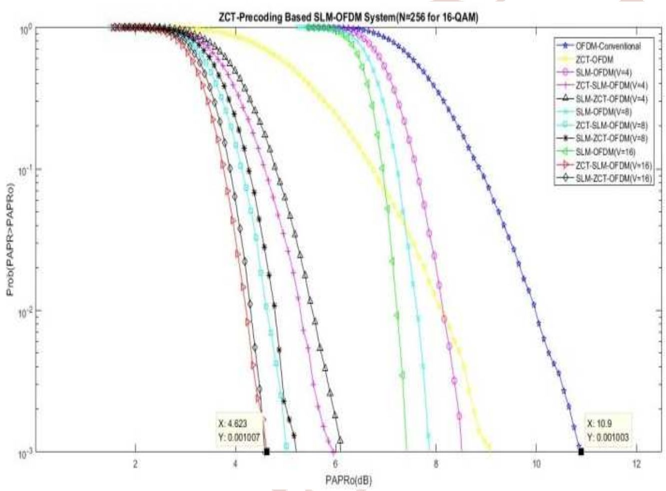

Fig.12. CCDF vs PAPRo with N=256 & V=4, 8, 16 for 16QAM modulation

Figure 10, Figure 11 and Figure 12 show CCDF vs PAPRo of conventional OFDM, ZCT precoded OFDM, SLM-OFDM, SLM-ZCT precoded OFDM and ZCT precoded SLM-OFDM with N=256 & V=4, 8, 16 for QPSK, 4QAM and 16QAM modulation respectively. The PAPR value is tabulated in Table 2.

Table 1 and Table 2 shows the PAPR analysis of the ZCT-SLM-OFDM system, SLM-ZCT-OFDM system, ZCT-OFDM system, SLM-OFDM system and the conventional OFDM systems, at clip rate of 10^{-3} with N=64 and 256 respectively. It can be seen that our proposed ZCT-SLM-OFDM technique with V=16 shows better PAPR reduction (PAPR gain) as compare to SLM-ZCT-OFDM system, ZCT-OFDM system, SLM-OFDM system and conventional OFDM system.

TABLE I. PAPR ANALYSIS AT CLIP RATE OF 10^{-3} WITH N=64

Systems	PAPR in dB		
	N=64		
	QPSK	**4QAM**	**16QAM**
Conventional OFDM	10.34	10.34	10.18
ZCT-OFDM	8.245	8.264	7.834
SLM-OFDM (V=4)	7.563	7.493	7.493
SLM-OFDM (V=8)	6.798	6.847	6.813
SLM-OFDM (V=16)	6.236	6.230	6.223
SLM-ZCT-OFDM (V=4)	4.786	5.110	5.737
ZCT-SLM-OFDM (V=4)	4.779	4.859	5.157
SLM-ZCT-OFDM (V=8)	4.963	4.121	3.995
ZCT-SLM-OFDM (V=8)	4.015	3.900	4.447
SLM-ZCT-OFDM (V=16)	3.724	3.702	3.618
ZCT-SLM-OFDM (V=16)	3.412	3.348	3.809

TABLE II. PAPR ANALYSIS AT CLIP RATE OF 10^{-3} WITH N=256

Systems	**PAPR in dB**		
	N=256		
	QPSK	***4QAM***	***16QAM***
Conventional OFDM	11.06	10.85	10.9
ZCT-OFDM	9.409	9.31	9.079
SLM-OFDM (V=4)	8.474	8.47	8.514
SLM-OFDM (V=8)	7.911	7.855	7.873
SLM-OFDM (V=16)	7.448	7.426	7.412
SLM-ZCT-OFDM (V=4)	6.181	6.026	6.099
ZCT-SLM-OFDM (V=4)	5.323	5.243	5.949
SLM-ZCT-OFDM (V=8)	5.389	5.316	5.209
ZCT-SLM-OFDM (V=8)	4.622	4.58	5.017
SLM-ZCT-OFDM (V=16)	4.639	4.701	4.582
ZCT-SLM-OFDM (V=16)	4.12	4.058	4.623

CONCLUSIONS

In this paper, we proposed ZCT precoding based SLM-OFDM system to reduce the high PAPR. From Fig. 6, the ZCT-SLM-OFDM technique use ZCT row wise precoder matrix can reduce more PAPR up to about 6.3dB which is more than by using ZCT column wise precoder wise. Thus, ZCT-R-SLM-OFDM system is preferred to use for PAPR reduction. Besides that, from Table I, it is concluded that at clip rate of 10^{-3}, N=64 and V=16, proposed ZCT-SLM-OFDM system with 4QAM modulation can reduce more PAPR up to about 6.9dB. While from Table II, it is concluded that at clip rate of 10^{-3}, N=256 and V=16, proposed ZCT-SLM-OFDM system with 4QAM modulation can reduce more PAPR up to about 6.7dB. Our proposed system can reduce more PAPR if the value of V is increased. The computational complexity is also increased with the increase in value of V. This proposed system is efficient, signal independent, it can prevent signal degradation and it does not require any complex optimization.

ACKNOWLEDGMENT

This paper is dedicated to everyone in the field of reducing PAPR by using ZCT precoding SLM based OFDM system. I would never finish this project without the guidance of my supervisor, support from my family and friends.

REFERENCES

1. I. Baig and V. Jeoti, “DCT precoded SLM technique for PAPR reduction in OFDM systems,” *2010 Int. Conf. Intell. Adv. Syst. ICIAS 2010*, 2010.
2. M. A. Khan and R. K. Rao, “PAPR Reduction in OFDM Systems using Differentially Encoded Subcarriers,” *27th IEEE Canadian Conference on Electrical and Computer Engineering*, pp. 1–5, 2014.
3. S. P. Vimal, “A New SLM Technique for PAPR Reduction in OFDM Systems,” *Eur. J. Sci. Res.*, vol. 65, no. 2, pp. 221–230, 2011.
4. Y. Wang, L.-H. Wang, J.-H. Ge, and B. Ai, “PAPR Reduction in OFDM Systems via Nonlinear Companding Transform,” *2012 8th Int. Conf. Wirel. Commun. Netw. Mob. Comput.*, vol. 9, no. 2, pp. 1–4, 2012.
5. T. Jiang and Y. Wu, “An overview: peak-to-average power ratio reduction techniques for OFDM signals,” *Broadcast. IEEE Trans.*, vol. 54, no. 2, pp. 257–268, 2008.
6. S. Nobilet, J.-F. Hélard, and D. Mottier, “Spreading sequences for uplink and downlink MC-CDMA systems: PAPR and MAI minimization,” *Eur. Trans. Telecommun.*, vol. 13, no. 5, pp. 465–474, 2002.
7. I. Baig and V. Jeoti, “A new ZCT precoded OFDM system with pulse shaping: PAPR analysis,” *IEEE Asia-Pacific Conf. Circuits Syst. Proceedings, APCCAS*, pp. 1131–1134, 2010.
8. I. Baig and V. Jeoti, “PAPR reduction in OFDM Systems: Zadoff-Chu matrix transform based pre/post-coding techniques,” *Proc. - 2nd Int. Conf. Comput. Intell. Commun. Syst. Networks, CICSyN 2010*, pp. 373–377, 2010.
9. I. Baig and V. Jeoti, “On the papr reduction in OFDM systems: A novel ZCT precoding based SLM technique,” *J. Eng. Sci. Technol.*, vol. 6, no. 3, pp. 359–370, 2011.