SLM Technique for PAPR (Peak to Average Power Ratio) Reduction for OFDM Communication Systems

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Abstract: **To explore a novel effective Peak-to-Average Power Ratio (PAPR) reduction scheme for OFDM system based on conventional Selective Mapping Method (SLM) with regards to the Bit Error Rate (BER) performance. The Orthogonal frequency division multiplexing (OFDM) modulation technique [1] is a multicarrier wireless communication system used for transmitting large amount of data and promises to deliver high data rate with simple receiver structure. It is more spectral efficient and has been recommended to be used by many standards. One major drawback of OFDM systems is the high peak to average power ratio (PAPR) which leads to power inefficiency and signal distortion with practical power amplifiers used at the transmitter. Selective Mapping Method (SLM) is a distortion less technique that can reduce PAPR efficiently without increase in power requirement and incurring data rate loss. There are several techniques to reduce PAPR of OFDM system. In this paper we have done simulation of Selective Mapping Method (SLM) for PAPR reduction for 4 QAM baseband signal for 64, 128, 256, 512 and 1024 number of subcarriers. The simulation result shows that proposed SLM technique has better PAPR reduction performance.**

Index Terms – OFDM; SLM, PAPR, BER, QAM

1. INTRODUCTION

The modern mobile communication systems require high data rate by a linear power amplifier with extremely low power consumption and long battery life. In telecommunications, Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. This digital modulation scheme whose range is four times greater than that of single carrier modulation scheme. To meet out the requirement of higher data rates and high spectral efficiency a new digital multicarrier modulation scheme is developed in communication field which is suitable for both wired and wireless environment. The multicarrier transceiver with improved transmission rate, long term evolution (LTE) and LTE advanced (LTE-A) standards [2] have been recommended for the use of OFDM modulation technique to achieve higher bit rates. It has proven to be one of the most promising schemes used for transmission of signals mainly in wireless system based on IEEE 802.IIa and IEEE 802.IIg standards [3]. It is based on the principle of splitting the data stream into large number of narrowband subcarriers which are orthogonal to each other with an inverse discrete Fourier transform (IDFT) operation [4]. It has several advantages compared to traditional communication systems. Important among them are being spectrally efficient, it uses simple receiver as turns the frequency-selective fading channel into a flat fading channel and it is most suitable for multimedia communications. OFDM also suffers from being sensitive to timing and frequency synchronization errors and high peak-to-average power ratio (PAPR). High PAPR is an undesirable characteristic, which is caused due to multiple subcarriers showing Rayleigh distribution pattern. It produces undesirable distortions and increases non-linearity of power amplifiers. There are different techniques to reduce PAPR value such as clipping and filtering (C&F), selective mapping (SLM), partial transmit sequence (PTS), single carrier frequency division multiple accessing (SCFDMA), pulse shaping, tone reservation (TR), tone injection (TI), dummy sequence insertion (DSI) technique, etc. Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi carrier transmission which has found its application in a number of wireless and wire-line systems. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal such that there is a very compact spectral utilization. Multicarrier modulation schemes divide the computer file into bands upon that modulation is performed and multiplexed into the channel at totally different carrier frequencies so info is transmitted on every of the sub carriers, specified the sub channels area unit nearly distortion less. In typical OFDM system, IFFT/IDCT and FFT/DCT area unit accustomed multiplex the signals along and rewrite the signal at the receiver severally. During this system, the Cyclic Prefix is added before transmittal the signal to channel. This paper is organized as section II describes Litarature review and in section III discussed about Proposed System and Section IV describes shows the simulation results and comparison between existing and proposed methods and section V concludes the paper followed by references.

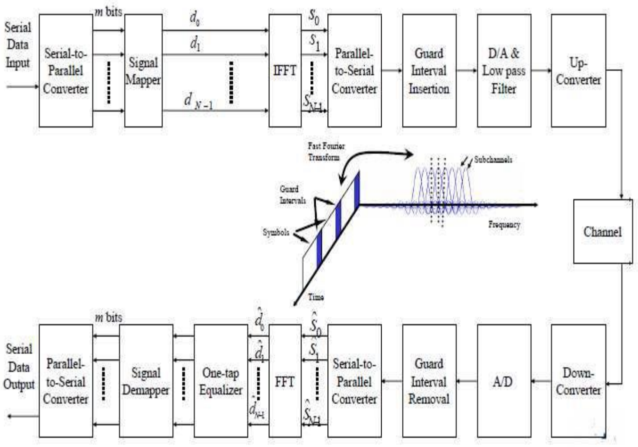

Fig.1 OFDM Block Diagram Process

2. SYSTEM MODEL

For OFDM system implementation, Inverse Fast Fourier Transform (IFFT) is usually being utilized to modulate multiple sub-band signals in an OFDM. In OFDM system, the information data symbol are passed through serial to parallel convertor and modulated using different modulation schemes like Quadrature Amplitude Modulation (QAM), Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK) to form a complex vector of size N. Here single signal bit is divided into N different parallel routes An N point FFT or IFFT operation is used to modulate and demodulate the data [5].

The Complex vector is written as:

$$X = [X_0, X_1, X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_{N-1}]^T \qquad (1)$$

Complex vector X is passed through IFFT block. After IFFT transform the signal can be written as

$$x_n = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X_k {W_N}^{nK} \qquad (2)$$

Here x_n represents the transmitted OFDM signal, N is the number block size.

2.1 Peak Average Power Ratio (PAPR)

The Peak to Average Power Ratio of OFDM signal is defined as the ratio between average signal power and the maximum peak power. Theoretically the large number of peak in OFDM system can be expressed by using parameter peak to average power ratio (PAPR) and it is mathematically expressed as [6]

$$\mathrm{PAPR} = \frac{P_{Peak}}{P_{Average}} = 10\log_{10} \frac{\max[|x_n|^2]}{E[|x_n|^2]}$$

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \; W_N^{nk} \qquad (3)$$

where P_{PEAK} represents the peak power of OFDM signal and $P_{AVERAGE}$ represents the average power of OFDM signal.

In OFDM when baseband signal reaches its maximum theoretical value then PAPR is defined as

$$\mathrm{PAPR\ (db)} = 10\log(N) \qquad (4)$$

One of the another important parameter commonly used in OFDM system is Crest factor which is used to evaluate the range of continuous time OFDM signal and envelop fluctuation where the value of PAPR is equal to square of crest factor i.e. PAPR = $(CF)^2$. The Crest Factor (CF) is defined as the ratio between maximum amplitude of OFDM signal s(t) and root mean square (RMS) of the waveform [7].

$$\mathrm{CF}(s(t)) = \frac{\max[|s(t)|]}{E[|s(t)^2|]} = \sqrt{PAPR} \qquad (5)$$

2.2 Complementary Cumulative Distribution CCDF of PAPR in OFDM

The Complementary Cumulative Distribution Function (CCDF) is one of the most widely used parameter which is used to evaluate the performance of any PAPR reduction technique. Normally we use Complementary CDF in place of Cumulative Distribution Function (CDF) [8]. The cumulative distribution function of the peak power per OFDM symbol can be found based on the assumption of the uncorrelated samples. This parameter is helpful to find out the probability that PAPR of particular data block exceed a certain threshold value [9].The Cumulative Distribution Function of sampled valued signal is expressed as:

$$F(z) = 1 - \exp(-z) \qquad (6)$$

Assuming that multicarrier OFDM system contain same data bits that are mutually independent with each other and free from oversampling operation, In this case if the probability distribution function for PAPR less than certain threshold value is therefore defined as:

$$P(\mathrm{PAPR})\ F(Z)^N = (1 - \exp(z))^N \qquad (7)$$

If the probability of PAPR exceed a certain threshold value than "Complementary Cumulative Distribution Function" can be mathematically represented as:

$$P(\mathrm{PAPR}>Z) = 1 - P(\mathrm{PAPR} \leq Z) = 1 - F(Z)^N = 1 - (1 - \exp(-Z)^N) \qquad (8)$$

For better approximation of the PAPR of continuous-time OFDM signals, OFDM signal samples are obtained by L times oversampling is given by

$$\mathrm{PAPR}\{x[n]\} = \frac{\max_{0 \leq n \leq NL} \Sigma |x[n]|^2}{E[|x[n]|^2]} \qquad (9)$$

3. PAPR REDUCTION TECHNIQUES

At present there are number of different techniques have been proposed by different authors to dealing with the problem of PAPR [10] [11].These techniques vary according to the need of system depend upon the number of factors such as PAPR reduction capacity and spectral efficiency. There are number of factors which are considered important while adopting any PAPR reduction technique increasing transmit signal power, loss in data rate, computational complexity, and increased bit error rate at receiver end. These techniques are basically divided in to two parts signal scrambling and signal distortion techniques. The purpose of signal scrambling technique is to scramble OFDM signal with different variation of codes or scrambling sequence and eliminates the peaks to achieve PAPR reduction and select one which has lowest PAPR value for transmission [12]. Different coding techniques Barker codes, M sequences, Golay Complementary and Shapiro-Rudin sequences have been used for reduction of PAPR. The main problem associated with these techniques is that as numbers of carrier's increases while searching for best code the associated overhead will also increases exponentially. This type of approach include: Selective Mapping (SLM), new phase SLM and Partial Transmit Sequences (PTS. SLM) method applies scrambling rotation to all sub-carriers independently while PTS method only takes scrambling to part of the sub-carriers. In SLM or PTS there will be no restriction on type of modulation and number of subcarriers. In new phase SLM scheme the SLM and PTS schemes are combined and the rows of the normalized Riemann matrix are used as phase sequence set for PAPR reduction. Signal distortion techniques include Peak windowing, envelop scaling etc.

3.1 Selective Mapping Technique

SLM PAPR reduction technique has been first proposed by Bamul.et.al. Selective mapping is a simple PAPR suppression method for OFDM signals. The SLM technique is basically implemented from the idea of symbol scrambling. In this scheme, a set of candidate signals are generated to represent the same information, then the signal with lowest PAPR is selected for transmission [14]. The information about the selection of these candidate signals need to be explicitly transmitted along with the selected signal as side information [13].

Selected mapping technique needs to transmit the information to receiver, with the selected signal, as side information. If there is any error in the received information, then it is difficult for the receiver to recover the information from the transmitted selected signal. Due to this problem a strong protection is needed regarding side information. If the receiver has these side information then the process of decoding become very simple. The SLM PAPR reduction technique can be employed for larger number of sub-carriers with moderate complexity.

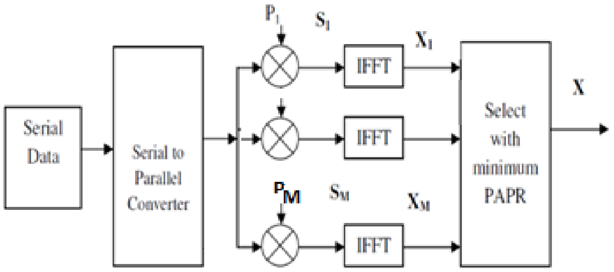

Fig.2 Block Diagram of Selective mapping technique

The technique contains codes only for PAPR reduction and does not include error correction. The complexity is increased in this scheme due to the multiple numbers of IFFT operations. The need for transfer of side information to the receiver without any margin for transmission errors is very crucial under the fading channels.

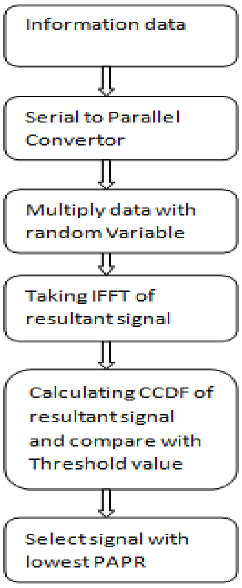

Fig.3 Flow chart for SLM technique.

Algorithm of Selective mapping technique:

a) Divide the input data in to number of sub blocks and converted into parallel form by using convertor.

b) Then the input data sequences are multiplied by phase sequence to generate input symbol sequence.

c) IFFT operation is made on each of input resultant symbol sequence.

d) Calculate CCDF of resultant signal and compare it with threshold value.

e) Data with lowest PAPR is selected for transmission.

4. PROPOSED SYSTEM

In this proposed system we are applying the PAPR reduction scheme only for those signals which exceed the PAPR threshold level. We keep an array of *U* scramblers to change a higher PAPR sequence into a lower PAPR sequence. Once the PAPR of the scrambled sequence goes below the threshold, the scrambling may be terminated and the scrambled sequence is transmitted, reducing the computational Complexity.

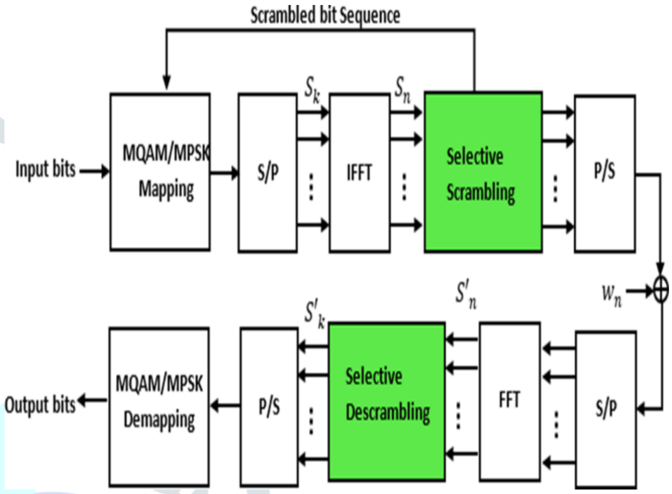

Fig.3 Proposed System block diagram

OFDM system with SLM algorithm to reduce the PAPR with mathematical expression:

Let the input data is defined as:

$$X=[X_0, X_1, X_2, X_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . X_{N-1}]^T \tag{10}$$

Each data block is multiplied with U different phase factor; then Phase rotated sequence due to phase rotation factor Bv^u can be written as:

$$X^{vu} = \mathrm{IFFT}(X \otimes B^{(vu)})$$

where

$$B^u=[bv_0{}^u, bv_1{}^u, bv_2{}^u, bv_3{}^u \ldots\ldots\ldots\ldots . b_{vN-1}{}^u]^T \tag{11}$$

With phase sequence with $|bv_n{}^u| = (n=0, 1, N-1)$
We are usually selected ±1 for avoiding complexity for complex multiplication or to add unmodified data in to modified data.

After that multiply input data with U different phase factor the modified data for U phase sequence can be written as:

$$X^u=[X_0\, bv_{u,0}, X_1 bv_{u,1}, X_2 bv_{u,2} \ldots \ldots X_{N-1} bv_{u,N-1}] \tag{12}$$

where u=0, 1, 2……..U-1.
After the PAPR comparisons among the U data sequence x(u), the optima mapped one x with the minimum PAPR is selected for transmission.

$$\hat{x} = \arg\min_{0\le U\le U}[\mathrm{PAPR}(X^{(vu)})]$$

PAPR reduction effect will be better U is increased. SLM method can effectively reduce PAPR without any signal distortion.

5. RESULTS AND SIMULATION

The complementary cumulative distribution function (CCDF) of the PAPR is the most commonly used performance measures for PAPR reduction techniques. In this paper selective mapping PAPR reduction technique is analyzed by using different number of sub-blocks. The simulations were performed in Matlab (version7.8).

PAPR is a measure of fluctuations in the output of the OFDM signal and calculated as the ratio of peak to average power of the complex valued signal. The equations (13) and (14) give the average power and peak power for a given sample $\{x_m\}$ of an OFDM signal respectively.

$$P_{av} = \frac{1}{F_s} \sum_{n=0}^{F_s-1} x_m{}^2 \qquad (13)$$

$$P_{peak} = \max_{m}\{x_m{}^2\} \qquad (14)$$

To find out the probability that the PAPR exceeds a particular value complementary cumulative distribution function (CCDF) is used as given in equation (15)

$$\tilde{F}z_{max}(z) = 1 - (1 - e^{-})^N \qquad (15)$$

The baseband modulated 16-QAM input data is first converted from serial to parallel form. The resulted parallel data is given by equation (16)

$$X[N] = \{X[0], X[l], X[2] \ldots\ldots\ldots\ldots X[N-1]\} \qquad (16)$$

These input data block is multiplied with each phase sequence as given by equation (17) and the resultant data block is represented by equation (18).

$$P^N = \{P^0, P^1, P^2, \ldots\ldots. P^{N-1}\} \qquad (17)$$

$$X_0^N = \{X_0^u, X_1^u X_2^u, \ldots\ldots. X_{N-1}^u\} \qquad (18)$$

Now N-point IFFT is taken for each data block represented in equation (18) which is shown by equation (19).

$$S_u^N = \{S_0^u, S_1^u S_2^u, \ldots\ldots. S_{N-1}^u\} \qquad (19)$$

It is to be mentioned that data block, S_0^N represented by equation (19) is N-point time domain sequence giving PAPR value due to individual phase factor, P^N.

Among which the one sequence S_{min} = S_0^u with the lowest PAPR is selected for transmission as given in equation (20).

$$S_{min} = \underset{[u=1,2,\ldots U]}{\arg\min} \left(\max_{n=0,1,\ldots N-1} | S_0^u[n] | \right) \qquad (20)$$

Information about the selected phase sequence P^N is transmitted as side information in order to recover the original data block. It requires N-IFFT operations for the implementation of SLM technique and requires $\log_2 N$ bits of side information for each data block.

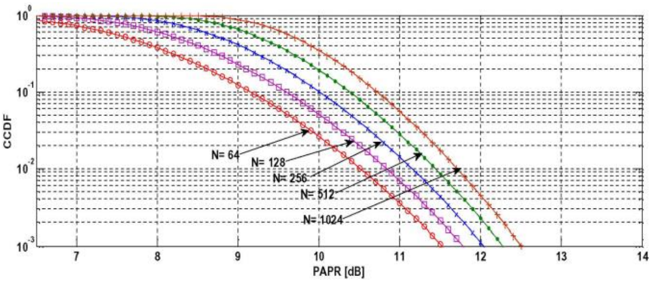

Fig.4 PAPR of 4 QAM Original OFDM Signal

Figure 4 gives the Matlab simulated value of PAPR for 4-QAM OFDM signal for 64, 128, 256, 512 and 1024 number of subcarriers. At 1O^{-3} of CCDF, the corresponding PAPR values are 7.5, 8.1, 8.5, 8.8 and 8.9 dB respectively.

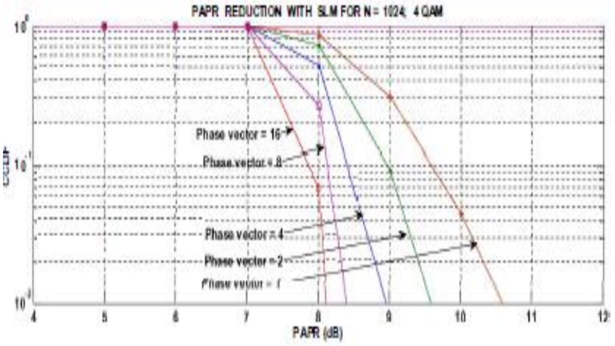

Fig. 5 PAPR of 4 QAM OFDM Signal with SLM Technique for N= 1024

Figure 5 gives the PAPR value obtained using SLM technique for 4-QAM OFDM signal with 1024 subcarriers and with different phase factors 1, 2, 4, 8 and 16. The corresponding PAPR at 1O^{-2} of CCDF are 8.2, 8.5, 8.9, 9.6 and 10.6 dB respectively.

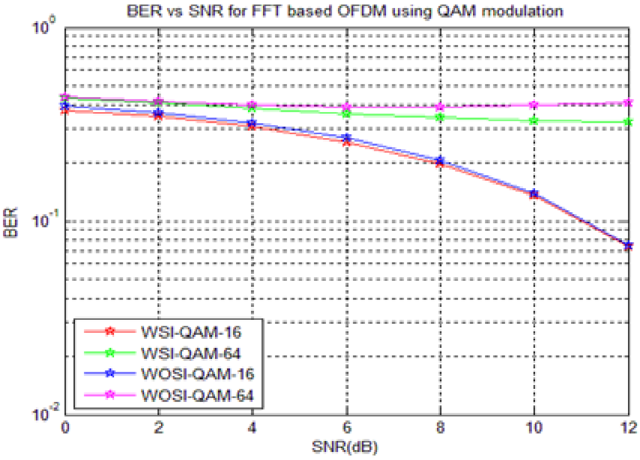

Fig.6 BER vs SNR for OFDM using QAM modulation

Table.2 depicts the PAPR values for 64, 128, 256, 512 and 1024 number of sub carriers with phase factors 1, 2, 4, 8 and 16. It is evident that as the number of phase factors increases the value of PAPR decreases. But the PAPR value decreases with increase in number of subcarriers.

Table.2: Existing System PAPR with Matlab Simulations

PAPR with MATLAB Simulations					
No of Carriers	N=64 (dB)	N=128 (dB)	N=256 (dB)	N=512 (dB)	N=1024 (dB)
Phase Factor U=1	10.4	10.6	10.9	11.2	10.7
Phase Factor U=2	8.7	9.2	9.5	9.8	10.6
Phase Factor U=4	7.5	8.1	8.5	8.8	8.9
Phase Factor U=8	6.6	7.3	7.8	8.3	8.4
Phase Factor U=16	6.1	6.7	7.3	7.8	8.3

Table.3: Proposed System PAPR with Matlab Simulations

PAPR with MATLAB Simulations					
No of Carriers	N=64 (dB)	N=128 (dB)	N=256 (dB)	N=512 (dB)	N=1024 (dB)
Phase Factor U=1	6.743563293	7.300041248	7.820469021	8.282573992	8.716354902
Phase Factor U=2	6.656885242	7.303271374	7.798517154	8.297210575	8.711045246
Phase Factor U=4	5.867150914	6.505681145	7.092950669	7.597157548	8.09804417
Phase Factor U=8	5.865961493	6.519295359	7.072362805	7.594403697	8.107931688
Phase Factor U=16	5.832179234	6.512918028	7.051490493	7.618631676	8.097026503

Table.4: Results of with side information QAM & WOSI

Modulation	BER
WSI-QAM-16	0.24125
WSI-QAM-64	0.367125
WOSI-QAM-16	0.251166667
WOSI-QAM-64	0.404806548

6. CONCLUSION

OFDM provides high data rate transmission capability with robustness to radio channel impairments. It has been widely accepted for future communication for different services. But, it suffers from high value of peak-to average power ratio. High PAPR drives high power amplifier into its saturation region and causes it to operate in the nonlinear region. There are several techniques to reduce PAPR of OFDM system. In this paper, we have done the implementation of Selective Mapping Method (SLM) for PAPR reduction for 4 QAM baseband signal for 64, 128, 256, 512 and 1024 number of subcarriers and calculating the bit error rate (BER). The results obtained have been compared with PAPR values obtained through mathematical analysis and MATLAB simulations and also with original signal.

REFERENCES

[1] Park D. H and Song H. K, A New PAPR Reduction Technique of OFDM System with Nonlinear High Power Amplifier, IEEE Transactions on Consumer Electronics, 53(2), pp. 327-332, 2007.

[2] Han S. H and Lee J. H, An Overview of Peak-To-Average Power Ratio Reduction Techniques for Multicarrier Transmission, IEEE Wireless Communications,12(2), pp. 56-65, 2006.

[3] Proakis J. G, Digital Communications, McGraw-HilI, New York, USA, 2000.

[4] Nee R.V. and Prasad R, OFDM for Wireless Multimedia Communications, Artech House Publishers, Norwood, MA, USA, 2000.

[5] Prasad R, OFDM for Wireless Communications Systems, Artech House Publishers, Norwood, MA, USA, 2004.

[6] Hara S. and Prasad R, Multicarrier Techniques for 4G Mobile Communications, Artech House Publishers, Norwood, MA, USA, 2003.

[7] Cho Y.S, Kim J, Yang W.Y and Kang C.G, MIMO-OFDM Wireless Communications with Matlab, IEEE Press, John Wiley and Sons (Asia) Pvt. Ltd. 2010.

[8] Bguml R.W, Fischer R.F. H and Huber J.B, Reducing the peak-to average power ratio of multicarrier modulation by selected mapping, Electronics Letters,32 (22), pp. 2056-2057, 1996.

[9] Wang C.L, Ku SJ and Yang CJ, A Low-Complexity PAPR estimation Scheme for OFDM Signals and Its Application to SLM Based PAPR Reduction, IEEE Journal of Selected Topics In Signal
Processing, 4(3), pp. 637-645, 2010.

[10] Goff S, Le Y. , Khoo B. K, Tsimenidis C. C. and Sharif B. S, A Novel Selected Mapping Technique for PAPR Reduction in OFDM Systems, IEEE Transactions on Communications, 56 (11), pp.1775-1779, 2008.

[11] Baxley R. J. and Zhou G. T, Comparing Selected Mapping and Partial Transmit Sequence for PAR Reduction, IEEE Transactions on Broadcasting, Vol 53(4), pp. 797-803, 2007.

[12] R.S. Bansode, B.K Mishra & Aqsa Temrikar, "Design, Simulation & Performance Evaluation of OFDM System to Reduce PAPR using SLM &LCM with FPGA Global Journal of Researches in Engineering Electrical and Electronics Engineering Volume 13 Issue 15 Version 1.0, 2013.

[13] B. Kamdar, D. Shah and S. Sorathia, "Hardware Implementation of PAPR Reduction Scheme for OFDM System", IEEE conference ICCICT, Mumbai, pp. 1-3 , 2012.

[14] S. Mohammady, R. M. Sidek, P. Varahram, M.N. Hamidon, N. Salaiman, "FPGA Implementation of the Proposed DSI-SLM Scheme for PAPR Reduction in OFDM Systems", IEEE 17th Asia Pacific Conference on Communications (APCC- 2011), Malaysia, pp. 484- 487, 2011.