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Effective Simulations for PAPR Reduction using RCF with Hard Clipping, Smooth and Dynamic Clipping for QPSK Modulation

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Abstract

In this research paper, a variation of clipping ,RCF and tone reservation/injection techniques are examined with proper analysis of clipping ratio (CR) and depth factor(Alpha) in fine tuning of a PAPR reducing system. By exploiting the sparsity of clipping events in the time domain relative to predefined clipping threshold and generate the OFDM bins of the incoming broadband channel into narrow band channel. The concept of OFDM is to send the large amount of digital data in parallel using high speed modems which satisfies the mathematical definition of orthogonality for complex exponential functions over the interval [0, TOFDM] resulting in spectral efficient with flexible bandwidth allocation but not power efficient technique. This makes the OFDM for its robustness against the multipath fading channels. With the theme of power efficient drawback the gateway has open for the PAPR analysis in OFDM with different techniques in research for the power amplifier at the receiver in battery back off. In amplifier with nonlinear characteristics will cause undesired distortion of the in-band and out-of-band signals. The distortion-based techniques reduce the PAPR of the OFDM symbol with the price of adding distortion to the signal points in the subcarriers. Direct clipping simply suppresses the time-domain OFDM signals of which the signal powers exceed a certain threshold. The penalty is the significant increase of out-of-band energy. Peak windowing or filtering after direct clipping can be used to reduce the out-of- band energy. After the filtering operation, the peak of the time-domain signal may re-grow. Hence, recursive clipping and filtering (RCF) can be used to suppress both the out-of-band energy and the PAPR. RCF can be modified by restricting the region of distortion to obtain improved error performance. On the other hand, estimation of the clipping noise at the receiver can be used to improve the error performance of direct clipping, smooth clipping or RCF. The redundancy-based technique includes coding, selective mapping (SLM), partial transmit sequences (PTS), tone reservation (TR) and tone injection (TI) etc. The results has been analysis with CCDF calculations for N=128,256 with effective variation of CR{=0.4,0.6,0.8,1, 1.2,1.4,1.6,1.8,2}, depth factor(alpha=0.1,0.2,0.3,0.4,0.5,1,5,10,15) with clipping and RCF analysis with additional signal power ,mean power, peak power for classical clipping, smooth clipping and dynamic clipping for certain no of iterations. For better data rate communication we did the simulations of the tone reservation and tone injection with effective PAPR analysis.

Index Terms— CR, RCF, OFDM, PAPR, TR, TI, CCDF

1 INTRODUCTION

In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver. There is a precise mathematical relationship between the frequencies of the carriers in the system. The orthogonality also allows high spectral efficiency, with a total symbol rate near the Nyquist rate for the equivalent baseband signal. Almost the whole available frequency band can be utilized. OFDM generally has a nearly 'white' spectrum, giving it electromagnetic interference properties with respect to other co-channel users.

Consider the time-limited complex exponential signals $\{e^{j2\pi f_k t}\}_{k=0}^{N-1}$ which represent the different subcarriers at $f_k = \frac{k}{T_{sym}}$ in the OFDM signal, where $0 \le t \le T_{sym}$ [1].

These signals are defined to be orthogonal if the integral of the products for their common (fundamental) period is zero, that is,

$$\frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi f_k t} e^{-2\pi f_1 t} dt =$$

$$\frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi \frac{k}{T_{sym}}_k t} e^{-2\pi \frac{i}{T_{sym}}_1 t} dt \text{ .... (1)}$$

$$= \frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi \frac{(k-t)}{T_{sym}}_k t} dt \text{.. (2)}$$

$$= \begin{cases} 1, & \forall integer\ k = i \\ 0, & otherwise \end{cases} \text{ .... (3)}$$

Taking the discrete samples with the sampling instances at t = n$T_s = \frac{nT_{sym}}{N}$, n=0,1,2,3............,N-1, Equation can be written in the discrete time domain as

$$= \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi \frac{k}{T_{sym}}.nT_s} e^{-j2\pi \frac{1}{T}.nT_s} =$$

$$= \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi \frac{k}{T_{sym}}.\frac{nT}{N}} e^{-j2\pi \frac{i}{T_{sym}}.n\frac{T_{sym}}{N}} \text{ .... (4)}$$

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$$=\frac{1}{N}\sum_{n}^{N-1} e^{j2\pi\frac{(k-i)}{N}n} \ldots\ldots\ldots\ldots (5)$$

$$=\begin{cases}1 & \forall\, integer, k=i \\ 0 & otherwise\end{cases} \ldots\ldots\ldots (6)$$

The above orthogonality is an essential condition for the OFDM signal to be ICI-free.

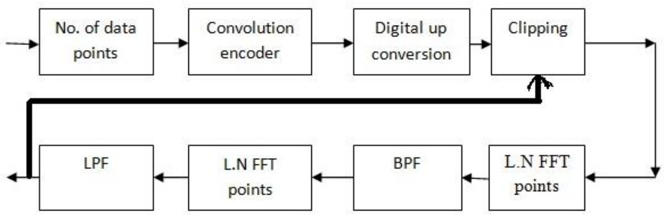
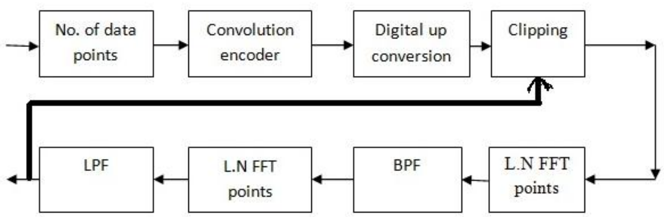


Fig. 1.Clipping and filtering



2 PAPR

PAPR is defined as

$$\text{PAPR} = \frac{\max|x(t)|^2}{E[x(t)^2]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where E[ ] denotes the expectation operator.

2.1 Distribution of PAPR

When the number of sub-carriers in an OFDM system is high, conventional OFDM signals can be regarded as Gaussian noise like signals; their variable amplitude is approximately Rayleigh-distributed, and the power distribution has a cumulative distribution function given by

$$F(z) = 1 - e^{-z} \qquad (8)$$

Commonly CCDF of PAPR is plotted as a performance parameter instead of CDF because it emphasizes the peak amplitude excursions, while CDF emphasizes minimum values.[9][10]

2.2 Effect of High Papr

High PAPR corresponds to a wide power range which requires more complicated analog-to-digital (A/D) and digital-to- analog (D/A) converters in order to accommodate the large range of the signal power values. Therefore, high PAPR increases both the complexity and cost of implementation. The power amplifiers at the transmitter need to have a large linear range of operation. When considering a system with a transmitting power amplifier, the nonlinear distortions and peak amplitude limitation introduced by the high power amplifier (HPA) will produce inter-modulation between the different carriers and introduce additional interference into the system. This additional interference leads to an increase in the bit error rate (BER) of the system. One way to avoid such non-linear distortion and keep low BER low is to force the amplifier to work in its linear region. Unfortunately such solution is not power efficient and thus is not suitable for wireless communication. Hence a high PAPR in the system design should be restricted.[2]

There are many factors that should be considered before a specific, PAPR reduction technique is chosen.

2.3 PAPR Reduction Capability

Clearly this is the most important factor in choosing a PAPR reduction technique. Careful attention must be paid to the fact that some techniques result in other harmful effects. For example the amplitude clipping technique clearly removes the time domain signal peaks but results in in-band distortion and out-of-band radiation

2.4 Power Increase In the Transmit Signal

Some techniques require a power increase in the transmitted signal after using PAPR reduction techniques. For example Tone reservation (TR) requires more signal power because some of its power must be used for the peak reduction carriers (PRC). Tone injection (TI) uses a set of equivalent constellation point for an original constellation point to reduce PAPR. Since all the equivalent constellation points require more power than the original constellation points, the transmit signal will have more power after applying Tone injection (TI). When the transmit signal power should be equal to or less than that before using a PAPR reduction technique, the transmit signal should be normalized back to the original signal power level resulting in BER performance degradation for these techniques.

2.5 Ber Increase at the Receiver

This is also an important factor and closely related to the power increase in the transmit signal. Some technique may have an increase in BER at the receiver if the transmit signal power is fixed or equivalently may require large transmit power to maintain the BER after applying the PAPR reduction techniques. For example the BER after applying Active constellation Extension (ACE) will be degraded if the power of transmitted signal is fixed. In some techniques such as SLM, PTS and Interleaving, the entire data block may be lost if the side information is received in error. This also may increase BER at the receiver.

2.6 Loss in Data Rate

Some techniques require the data rate to be reduced. In block coding technique one out of four information symbols is to be dedicated to controlling PAPR. In SLM and PTS and Interleaving, the data rate is reduced due to the side information used to inform the receiver of what has been done in the transmitter. These techniques the side information may be received in error, unless some form of protection such as channel coding is employed. When channel coding is used the loss in data rate due to side information is increased further.

2.7 Computational Complexity

Computational complexity is yet another important consideration in choosing a PAPR reduction technique. Technique such as PTS finds a solution for the PAPR reduced signal by using much iteration. The PAPR reduction capability of interleaving technique is better for large number of interleavers. Generally more complex techniques have better PAPR reduction capabilities.

3 PROPOSED TECHNIQUE

Clipping is the simplest PAPR reduction technique. OFDM system with clipping and filtering is shown in fig 1. In this system, the behaviour of clipper is represented by a clipping function $f_c(.)$ which changes according to the type of clipping technique used to reduce PAPR.

Rewriting the discrete-time OFDM signal X_n to polar coordinates gives $X_n = Rn^{e^{j\varphi_n}}$ where R_n represents the amplitude of X_n and represents the phase of X_n. The clipped signal C_n is expressed as:-

$$c_n = f_c(r_n)e^{j\varphi_n} \quad \text{...} (9)$$

where the clipping function $f_c(r_n)$ is according to the type of clipping used. After clipping operation, OFDM symbol X_n is transformed to C_n

We focus on three clipping-based PAPR reduction techniques:-

1. Classical-Clipping (CC) or Hard Clipping,
2. Deep-Clipping (DC) and
3. Smooth-Clipping (SC).

3.1 Classical Clipping (CC) Technique

The Classical Clipping (CC) is one of the most admired clipping techniques for PAPR reduction. It is sometimes also called hard clipping or soft clipping. In this technique, the signal having amplitude greater than a predefined threshold level A is limited to that level i.e. A and signal having amplitude lower than A are passed through undisturbed. The clipping function for CC technique is defined below and shown in fig. below.

$$f_c(r_n) = \begin{cases} r_n & if\ r_n \leq A \\ A & if\ r_n > A \end{cases} \quad \text{......................} (10)$$

3.2 Deep Clipping (Dc) Technique

One problem of Clipping and Filtering (CAF) is peak regrowth due to the filtering for the clipped signal. Deep clipping method is used suppress the peak re-growth and to reduce the Peak-to-Average power Ratio (PAR) of OFDM signals without iteration of CAF blocks. So, in DC technique, the clipping function is modified in order to “deeply” clip the high amplitude peaks. A parameter called clipping depth factor has been introduced in order to control the depth of the clipping.

$$f_c(r_n) = \begin{cases} r_n & if\ r_n \leq A \\ A - \alpha(r_n - A) & if\ A < r_n \leq \frac{1+\alpha}{\alpha}A \\ 0 & if\ r_n > \frac{1+\alpha}{\alpha}A \end{cases} \quad \ldots(11)$$

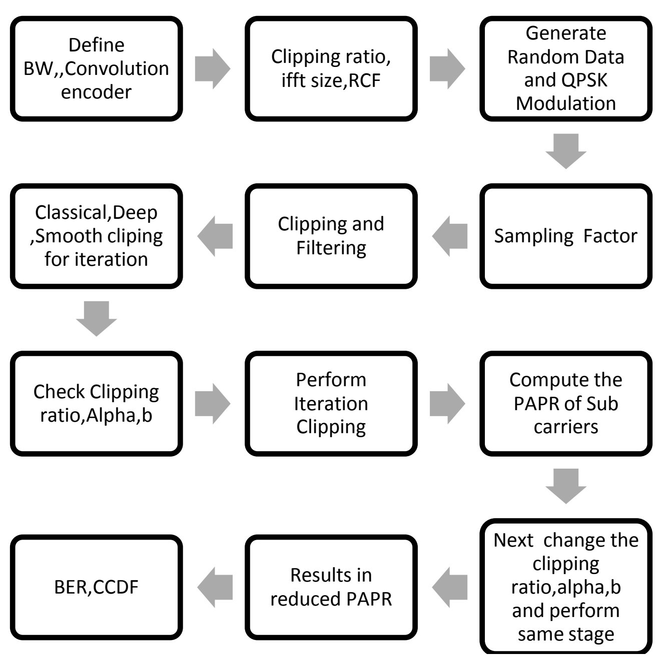
Where α is called the clipping depth factor. As the input amplitude values go beyond the threshold level, clipped values do not remains at the threshold level as in case of CC but decreases below that level, and rate of decrement to zero depends on the value of deep clipping factor (α). The effect of α on clipped output signal is shown in results, by taking different values. We observe that as we increase the values of α, the rate of decrement also increases. If we set α to zero, then DC will be same as of CC. so it can be said that CC is special case of DC.

3.4 Smooth Clipping (SC) Technique

A Smooth Clipping technique used to reduce the OFDM PAPR is described by the function based-clipping for SC technique which is defined below:

$$f_c(r_n) = \begin{cases} r_n - \frac{r_n^3}{b} & r_n \leq 3A/2 \\ A & r_n > 3A/2 \end{cases} \quad \text{................} (12)$$

Where b = $\frac{27}{4}A^2$



International Journal of Scientific & Engineering Research Volume 4, Issue 7, July-2013
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Fig. 2.Algorithm for iterative clipping ang filtering

4 SIMULATIONS

Simulation 1:

The simulations are done on MATLAB with 128 data points for the different techniques of clipping techniques with recursive filtering and smooth clipping and dynamic clipping. The research analysis is done with the variation of clipping ratio for tuning the reduction in peak average power ratio. Simulations are performed with the QPSK modulation with the designed parameters considering the effect of IFFT and FFT in a baseband and pass band transmission for high date rate parallel transmission. In this analysis we investigated the effect of clipping ratio value which determined by the CCDF computations, the probability of PAPR is analysed in which if the CCDF plots tends towards the axis then the conclusion is more reduction in peak power which is better results compare to the other techniques.

In this paper, we have simulated the results of recursive clipping and filtering, smooth and dynamic clipping. Among them recursive clipping and filtering gives the best probability of PAPR reduction values in terms of dB which as shown in table and graphs.

The other conclusion says about the nature of smooth and dynamic clipping, among this two techniques dynamic clipping gives the better results with the variation of clipping ratio for the values of CR{2,1.8,1.6,1.4,1.2,1}

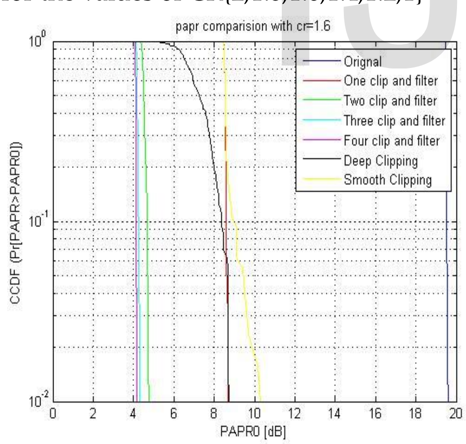

Fig. 3.PAPR calculation using CR=1.6 with 4 iterations

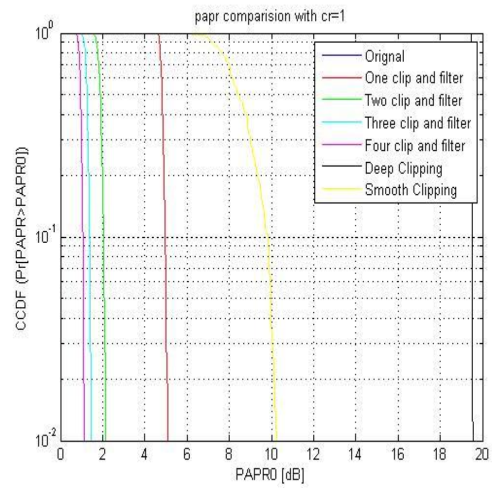

Fig. 4.PAPR calculation using CR= 1 with 4 iterations

Variation in clipping ratio(CR)	First clip and filter	Second clip and filter	Third clip and filter	Fourth clip and filter	Deep clipping with alpha factor	Smooth clipping with alpha factor
CR=2	11	6.7	6.1	6	8.6	11
CR=1.8	9.7	5.8	5	5	8.7	10.4
CR=1.6	9	5.5	4.4	4.2	8.5	10.4
CR=1.4	7.8	4	3.7	3.3	7.8	10.4
CR=1.2	6.3	3.7	2.5	2.2	6.5	10.2
CR=1	5	2.2	1.8	1.3	6.3	10.2

Simulation 2:

Smooth clipping is better compare to deep clipping method for these simulations. In the above simulations we have observed that the smooth clipping is better technique compare to the deep clipping as the value of Clipping Ratio decrease from CR=1 to 0.2 as shown CCDF plot.

International Journal of Scientific & Engineering Research Volume 4, Issue 7, July-2013
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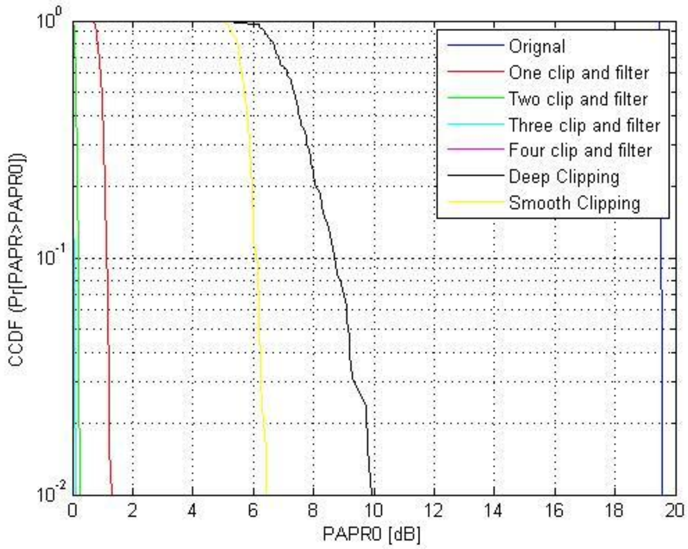

Fig. 5.PAPR calculations using CR=0.2 with 4 iterations

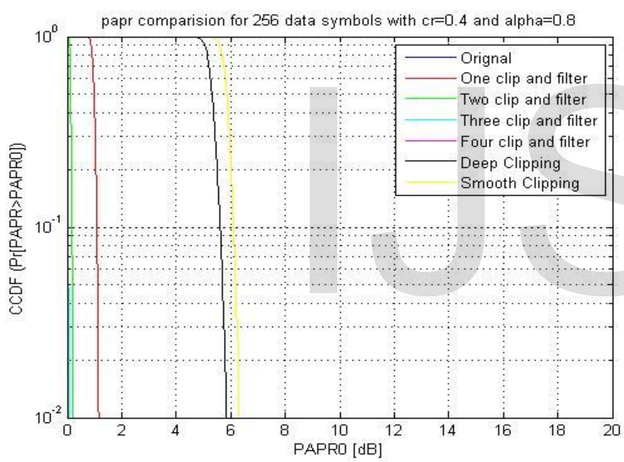

Fig. 6.PAPR calculations using 256 data symbols

Simulations 3:

The simulations are performed for 256 data points with QPSK modulation and convolutional encoder ½ is consider, size of OFDM symbol k=256.with the computations of CCDF we have examined as the no of iterations are increase the peak power is reducing and as the iterations are increased both the smooth clipping and dynamic clipping almost reaching to the maximum peak reduction which is almost equal to 6 value with the original PAPR of OFDM signal. CCDF plot signifies the more the PAPR reduces CCDF moves towards the origin. The probability of PAPR is achieved for both dynamic and smooth clipping technique with alpha=0.8 which is clipping depth factor

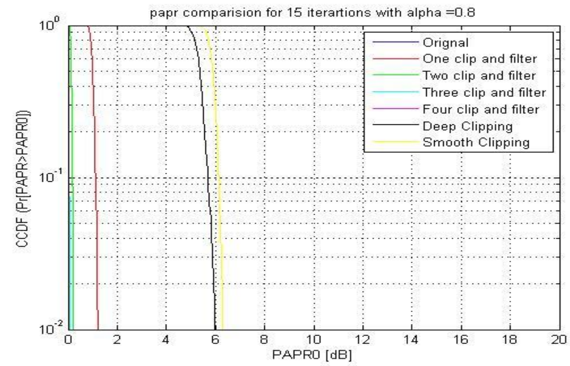

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Fig. 7.PAPR calculations using 15 iterations

4 Conclusion

The simulations are done on MATLAB with 128 data points for the different techniques of clipping techniques with recursive filtering and smooth clipping and dynamic clipping. The research analysis is done with the variation of clipping ratio for tuning the reduction in peak average power ratio. Simulations are performed with the QPSK modulation with the designed parameters considering the effect of IFFT and FFT in a baseband and pass band transmission for high date rate parallel transmission. In this analysis we investigated the effect of clipping ratio value which determined by the CCDF computations, the probability of PAPR is analysed in which if the CCDF plots tends towards the axis then the conclusion is more reduction in peak power which is better results compare to the other techniques. Among them recursive clipping and filtering gives the best probability of PAPR reduction values in terms of dB which as shown in table, graphs. The other conclusion says about the nature of smooth and dynamic clipping, among this two techniques dynamic clipping gives the better results with the variation of clipping ratio for the values of CR{2,1.8,1.6,1.4,1.2,1}. Similarly we have observed that the smooth clipping is better technique compare to the deep clipping as the value of Clipping Ratio decrease from CR=1 to 0.2 as shown CCDF plots.

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REFERENCES

[1] Tellambura Chintha and Jayalath Dhammika (2001), "PAR reduction of an OFDM signal using partial transmits sequences". In Proceedings IEEE VTS 54th Vehicular Technology Conference, 2001 (VTC 2001 Fall). 2, pages pp. 465-469, Atlantic City, NJ, USA.

[2] Heung-Gyoon Ryu, Byoung-ll Jin and In-Bae Kim (2002), "PAPR REDUCTION USING SOFT CLIPPING AND ACI REJECTION IN OFDM SYSTEM" IEEE Transactions on Consumer Electronics, Vol. 48, No. 1

[3] Tao Jiang, Yang Yang, and Yong-Hua Song (2005), "Exponential Companding Technique for PAPR Reduction in OFDM Systems" IEEE TRANSACTIONS ON BROADCASTING, VOL. 51, NO. 2, JUNE 2005.

[4] Trung Thanh Nguyen and Lutz Lampe (2006), " On Partial Transmit Sequences for PAR Reduction in OFDM Systems" IEEE Transactions on Wireless Communications, November, 2006.

[5] H. Sakran, M. Shokair, and A. Abou Elazm (2009), "COMBINED INTERLEAVING AND COMPANDING FOR PAPR REDUCTION IN OFDM SYSTEMS" Progress In Electromagnetics Research C, Vol. 6, 67–78, 2009.

[6] Kitaek Bae, IEEE, Jeffrey G. Andrews, and Edward J. Powers (2010), "Quantifying an Iterative Clipping and Filtering Technique for Reducing PAR in OFDM" IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 9, NO. 5, MAY 2010.

[7] P. Mukunthan, P.Dananjayan (2010), "Modified PTS with FECs for PAPR Reduction of OFDM Signals" International Journal of Computer Applications (0975 – 8887) Volume 11– No.3, December 2010.

[8] Hyun-Bae Jeon, Jong-Seon No and Dong-Joon Shin (2012), "A New PAPR Reduction Scheme Using Efficient Peak Cancellation for OFDM Systems" 0018-9316/$31.00 © 2012 IEEE.

[9] Gurpreet Singh Walia, Charanjit Singh (2012), "Comparative Study of Peak-to-Average Power Ratio Reduction Techniques for OFDM System" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.2594-2598.

[10] K.Muralibabu, Dr. K.Rama Naidu, Dr. S.Padmanabhan, G.Praveen kumar (2012), " PAPR Reduction using combined LDPC and DCT with Companding Transform in OFDM System" International Journal of Engineering Research and Development e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 3, Issue 12 (September 2012), PP. 33-38.

[11] Ghanim Abd AL Kareem (2012), "Proposed Combined PTS with Clipping and Filtering Technique for PAPR Reduction in OFDM System" Eng. & Tech Journal, Vol. 30, No. 12,2012.

[12] Seyran Khademi, Alle-Jan Van der Veen, Thomas Svantesson (2012), "PRECODING TECHNIQUE FOR PEAK-TO-AVERAGE-POWER-RATIO (PAPR) REDUCTION IN MIMO OFDM/A SYSTEMS" ©2012 IEEE.

[13] Neelam Dewangan (2102), " Improved SLM Technique using Reiman matrix for PAPR Reduction of LTE-OFDM Networks" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 4, July-August 2012, pp.255-257.

[14] Tellado-Mourelo, J. (Sep. 1999) Peak to average power reduction for multicarrier modulation, Ph.D. Dissertation, Stanford Univ.