RESEARCH ARTICLE OPEN ACCESS

The LFSR Based SLM Technique with Clipping for PAPR Reduction in OFDM Systems

Anusha Chacko*, J. Jeevitha**, Merin Elsa Mathew***, Reethu. K ****
*(Department of Electronics and Communication Engineering, Karunya University, Coimbatore)
** (Department of Electronics and Communication Engineering, Karunya University, Coimbatore)
*** (Department of Electronics and Communication Engineering, Karunya University, Coimbatore)
**** (Department of Electronics and Communication Engineering, Karunya University, Coimbatore)

ABSTRACT
Orthogonal Frequency Division Multiplexing is a widely accepted technology in wireless communication. High peak-to-average power ratio is the main disadvantage in OFDM systems. Selected Mapping is an efficient technique to reduce PAPR. But it requires transmission of side information for the recovery of data. And this affects the bandwidth efficiency and data rate of OFDM systems. The Linear Feedback Shift Register based Selected Mapping technique finds solution for this limitation. The LFSR based SLM technique does not require the explicit transmission of side information. And the LFSR based SLM with clipping results in further reduction in PAPR.
Keywords – OFDM, PAPR, SLM, PTS, HPA, ADC, DAC, CCDF

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing is an efficient technology in wireless communication [1]. OFDM is a multicarrier modulation technique [2]. In the case of single carrier modulation schemes the symbol duration gets reduced as the data rate of communication increases. And the small symbol duration results in serious inter symbol interference.

In OFDM the high data rate streams are divided into several slow data rate streams. This results in large symbol duration and high data rate. And thus inter symbol interference can be avoided [3]. And all the streams are send parallel to achieve the same speed of transmission. Each subcarrier in OFDM system is orthogonal to each other. Orthogonality requires subcarrier spacing between each subcarrier. If there are thousand subcarriers in a system and subcarrier spacing is 1 kHz, then the band width requirement of the system is 1MHz.

OFDM signal has wide range of amplitude. This is the cause of high peak-to-average power ratio. Non linear high power amplifiers are used in communication systems for high power efficiency. But in the case of OFDM systems we cannot go for non linear high power amplifier [4]. The use of non linear HPA results in adjacent channel interference and in-band distortion. The high PAPR demands linear high power amplifier with wide amplitude range. But this requires high implementation cost. And linear high power amplifiers have low efficiency in amplification. The efficiency of an amplifier is very important in a communication system, since it decides even the range of communication.

The solution to these problems is the reduction of high peak-to average power ratio in OFDM signal. There are many techniques introduced for the reduction of PAPR in OFDM system [5].

Selected Mapping is one of the efficient techniques for the reduction of PAPR. In SLM several numbers of signals which carry same information are generated and from these signals the signal with minimum PAPR is selected for transmission.

But Selected Mapping technique reduces band width efficiency since it requires the transmission of side information. The Linear Feedback Shift Register based selected Mapping technique overcomes this problem. This is achieved by utilizing the properties of the sequence generated from LFSR circuit. The sequences generated from LFSR circuits are called m-Sequence. These are pseudo random sequences. The design of each Linear Feedback Shift Register depends on a generator polynomial.

II. PEAK-TO-AVERAGE POWER RATIO

Peak-to-Average Power Ratio is the ratio of instantaneous value of peak power to average power. The high PAPR is the major disadvantage of orthogonal frequency Division Multiplexing [6]. OFDM signal has wide amplitude range and these results in high peak-to-average power ratio. The high PAPR forces the High Power Amplifier to work in linear region of operation. Usually in communication systems non linear HPAs are used.

The efficiency of linear high power amplifier is very low. OFDM requires linear high power amplifier with large dynamic range. The cost of implementation of such high power amplifier is very high.

III. PAPR REDUCTION TECHNIQUES

There are many PAPR reduction techniques in the case of Orthogonal Frequency Division Multiplexing. Clipping, Selected Mapping, Partial Transmit Sequence, Coding Scheme and Non-linear Companding are the commonly known PAPR reduction techniques.

A. Clipping

Clipping is the simplest method for PAPR reduction in OFDM systems [7]. In clipping the amplitude of signal above a particular threshold value is clipped [8]. And the signals with amplitude below the threshold value remain as same.

Clipping introduces in-band distortion and out-of band radiation. The out-of band radiation can be avoided by filtering after clipping [9]. The clipping is performed in the transmitter side. To recover the clipped data the receiver side must know the amount of clipping and position of clipping. But getting these information are very difficult.

B. Selected Mapping

The main idea in Selected Mapping is the formation of several sequences which carry the same information. This can be achieved by multiplying the data block with number phase sequences. The PAPR value of each signal is calculated. And then the signal with minimum peak-to-average power ratio is selected for transmission.

C. Partial Transmit Sequence Technique

The Partial Transmit Sequence is a signal scrambling technique. In PTS approach the input data block X is partitioned into K disjoints sub blocks [10]. These sub blocks are then transformed into K time domain Partial Transmit Sequences. This transformation can be achieved with the help of Inverse Fast Fourier Transform.

The generated partial sequences are then independently rotated by phase factors. Then the K sub blocks are optimally combined to obtain the time domain OFDM signals with the lowest PAPR. The optimization techniques can be used for reducing the complexity of the technique. Particle Swarm Optimization is the commonly adopted optimization technique.

D. Coding Scheme

If N signals are added in phase, they produce high peak power which is N times the average power. This is the reason of high PAPR. The main idea behind coding scheme is to reduce the occurrence probability of same phase signals. The major disadvantage of coding scheme is that the better performance of PAPR reduction is achieved only at the cost of coding rate loses.

E. Non-linear Companding Transform

Nonlinear Companding Transforms enlarge the small signals and compress the large signals to increase the immunity of small signals from the noise. The first nonlinear companding transform is the μ-law companding [11].

And it gives better performance than the clipping method. μ -law mainly focuses on enlarging signals with small amplitude and keeping peak signals unchanged. NCT may lead to significant distortion and performance loss due to companding noise.

IV. LINEAR FEEDBACK SHIFT REGISTER CIRCUIT

The linear feedback shift register (LFSR) circuit is used to generate the maximum length shift register Sequences (m-Sequences) [14]. The m-Sequences are pseudo random sequences. Figure 1 shows the LFSR circuit. An LFSR circuit with m-stages can generate a sequence of period. Each LFSR circuit is associated with a generator polynomial [12].

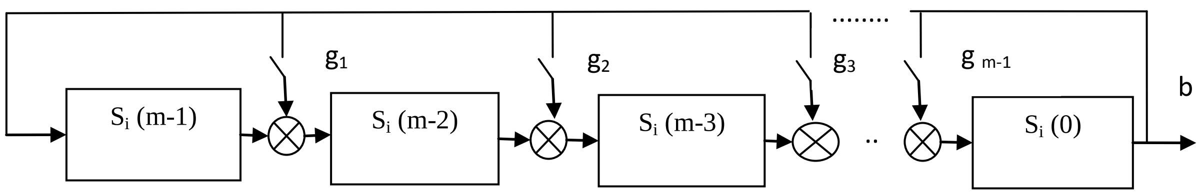

Fig. 1: Linear Feedback Shift Register Circuit

Consider the general form of generator polynomial as, $g(\alpha) = g_m\alpha^m+g_{m-1}\alpha^{m-1}+\ldots.g_1\alpha+g_0$ (1)

Each of the m-stages contains 0 or 1, so there are 2^m possible states are present. Output sequence will be all zero when all zero state happens. So by removing that state the maximum possible period is 2^m-1. The properties of m-sequences are,

The Window Property: By sliding a window of width m along an m-sequence, the number of 2^m-1 fold windows are extracted, each of which is seen exactly once.

The Run Property: In the m-sequence, a run of 1s of length m happens exactly once. A run is defined as a sequence of all 1s or a sequence of all 0s. Z-locations: Each m-sequence includes 2^{m-1}-1 0s. If the position of run of 1s of length m becomes distinguished, the locations of 2^{m-1}-1 0s will be specified.

V. SELECTED MAPPING

Selected Mapping (SLM) is an efficient method for peak-to-average power ratio reduction in OFDM systems. In SLM technique the data sequence is multiplied with each phase sequences generated [13]. And thus sequences which carry same information are formed. From these signals the signal with minimum PAPR is selected for transmission.

In SLM technique the original data block is multiplied with L phase sequences [14]. Thus 'L' sequences which carry the same information are generated. And from the generated L sequences the sequence with minimum PAPR is selected for transmission [15]. Along with the data the side information is also transmitted. Side information indicates the phase sequence which minimized the PAPR [16].

VI. LFSR BASED SELECTED MAPPING

The LFSR based SLM technique is similar to the conventional Selected Mapping technique. The only difference is in the case of phase sequences generated. In LFSR based SLM technique the m-sequence generated are used as phase sequences.
Here some locations of the transmitted data block will be expanded to indicate the side information. The phase sequences are generated from m-sequences. The 1s in the m-sequence are mapped into a constant C>1 and the 0s are mapped to 1s [16]. The phases of the elements are selected randomly as in conventional SLM. The main difference of LFSR based SLM from the Conventional SLM is in the generation of phase vectors. In LFSR based SLM the phase vectors are the sequences which are generated with the help of linear feedback shift register circuit. Each linear feedback shift register circuit is based on a generator polynomial.

The feedbacks in the LFSR circuit are according to the corresponding generator polynomial. After the phase vector generation LFSR based SLM acts as Conventional SLM. That is the data block is multiplied with the phase vector element by element. And finally the sequence with minimum PAPR is selected for transmission.

The receiver section knows the value of 'm' and the generator polynomial. Receiver is also aware that among the 2^m-1 symbol, 2^{m-1}symbols are expanded by a factor C and the other 2^{m-1}-1symbols are not expanded [14]. The receiver can recover the side information by finding the locations of the expanded symbols. This can be finding by determining the position of run 1s in the m-sequence. The occurrence of run of 1s in each m-

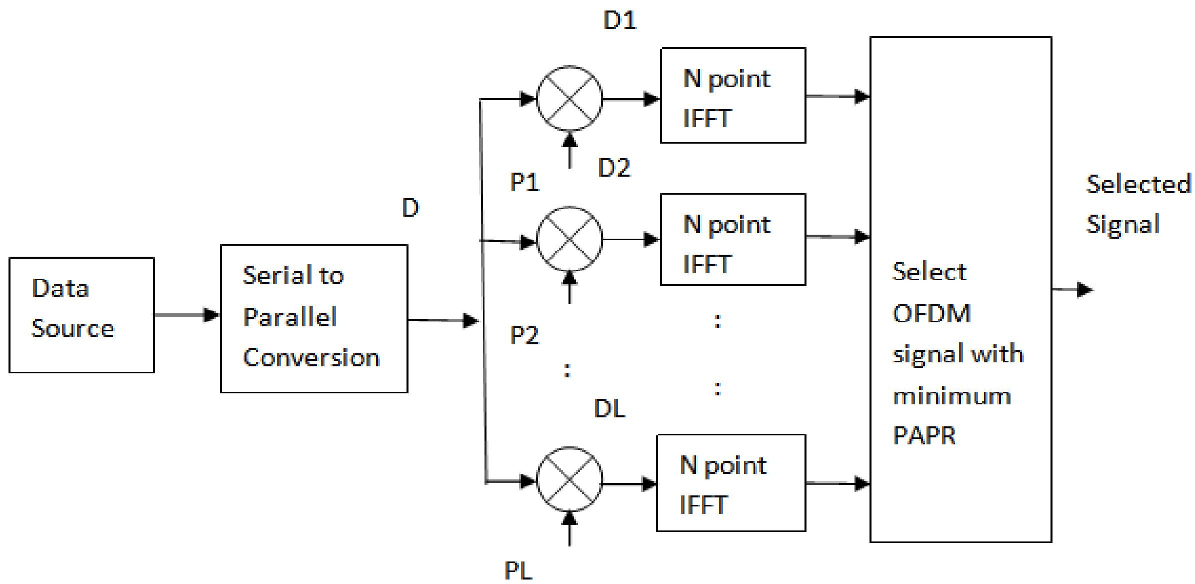

Fig. 2: LFSR Based Selected Mapping

sequence is unique. Finding the position of run of 1s is equivalent to the determination of phase sequence.

VII. LFSR BASED SLM WITH CLIPPING

In the proposed technique clipping is added before Linear Feedback Shift Register Based Selected Mapping technique. And here the side information detection is similar to LFSR based SLM since clipping is added before the technique. So in the proposed technique also there is no need of explicit transmission of side information as LFSR Based Selected Mapping.

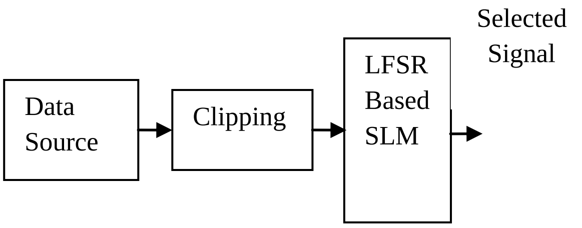

Fig. 3: LFSR Based Selected Mapping with Clipping

The addition of Clipping with LFSR Based SLM provides further reduction in PAPR. In clipping the signals above the threshold is clipped. The LFSR based SLM with clipping provides better PAPR reduction and it eliminate the explicit transmission of side information.

VIII. RESULTS

The results are simulated in Matlab. To show the PAPR reduction capability of the technique complimentary cumulative distribution function of PAPR is plotted. The x-axis shows the threshold values and in y-axis probability PAPR value is greater than the threshold is plotted.

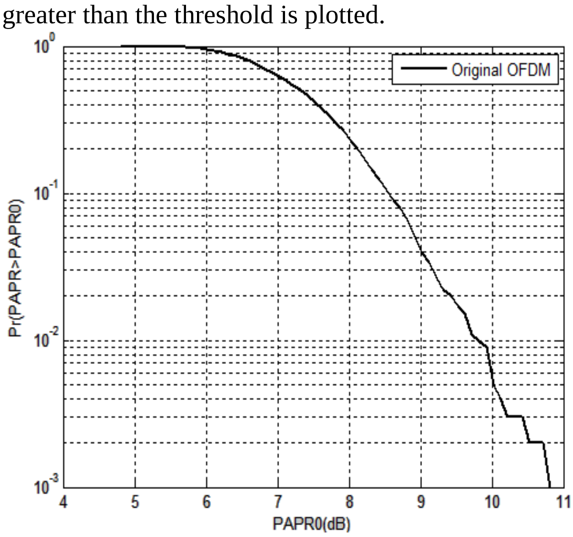

Fig. 4: CCDF of PAPR with no PAPR reduction technique applied

The figure 4 shows the peak-to-average power ratio plot of the OFDM signal. Here no PAPR reduction technique is applied. From the graph we can see that the PAPR of OFDM signal is very high.

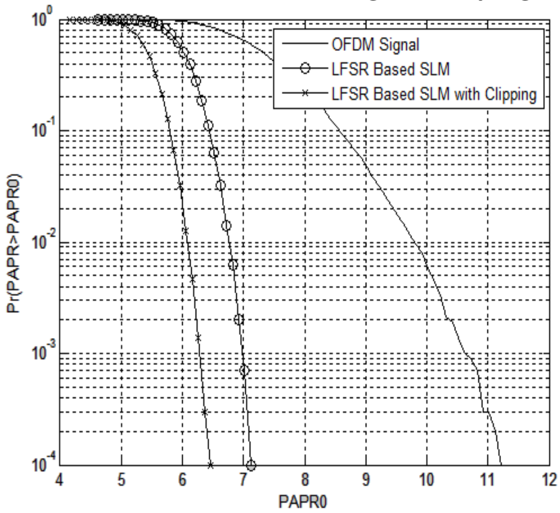

Fig. 5: Representation of CCDF of PAPR with no PAPR reduction technique applied, LFSR Based SLM and LFSR Based SLM with Clipping.

The figure 5 shows the CCDF plot of PAPR of original OFDM system, OFDM system with LFSR Based SLM and LFSR Based SLM with Clipping.

IX. CONCLUSION

Orthogonal Frequency Division Multiplexing is an efficient technique in wireless communication. Selected Mapping is an effective technique to limit the peak-to-average ratio in OFDM system. But it requires transmission of side information to the receiver side. The LFSR based Selected Mapping does not require the explicit transmission of side information. Thus the band width efficiency is improved. The LFSR Based Selected mapping with Clipping achieves further reduction in PAPR.

X. ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to all those help with their valuable comments and support. Also we are grateful to The Almighty GOD for enabling us to complete this paper.

REFERENCES

[1] Byung Moo Lee, Youngok Kim, and Rui J.P de Figueiredo, *Performance Analysis of The Clipping Scheme with SLM Technique for PAPR Reduction of OFDM Signals in Fading Channels*, Wireless Personnel Communication, 2010,331-344.

[2] Seung Hee Han, Jae Hong Lee, *An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission*, IEEE Wireless Communications, 2005, 56-65.

[3] Byung Moo Lee, Youngok Kim, *An Adaptive Clipping And Filtering Technique for PAPR Reduction of OFDM Signals*, Circuits Syst. Signal Process., 2012, 1335–1349.

[4] Tao Jiang, Yiyan Wu, *An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM signals*, IEEE Transactions on Broadcasting, 54, 2008, 257-268.

[5] Jing gao, Jinkuan Wang, Xin Song, and Bin Wang, *PAPR Reduction With Low Computational Complexity For OFDM Systems*, Physics Procedia, 2012, 1401 – 1407.

[6] Xiao Yue, Bai WenLing, Dan LiLin, WU Gang and LI ShaoQian, Performance Analysis of Peak Cancellation in OFDM systems, Science China Information Sciences, 55, 2012, 789-794.

[7] Hideki Ochiai and Hideki Imai, *Performance Analysis of Deliberately Clipped OFDM Signals*, IEEE Transactions on Communications, 50, 2002, 89-101.

[8] Hideki Ochiai and Hideki Imai, *Performance of the Deliberate Clipping with Adaptive Symbol Selection for Strictly Band-Limited OFDM Systems*, IEEE journal on Selected Areas in Communication, 18, 2000, 2270-2277.

[9] Sandeep Bhad, Pankaj Gulhane, A.S. Hiwale, *PAPR Reduction Scheme for OFDM*, Procedia Technology, 2012, 109 – 113.

[10] Jun Hou, Jianhua Ge, and Jing Li, *Peak-To-Average Power Ratio Reduction of OFDM Signals Using PTS Scheme With Low Computational Complexity*, IEEE Transactions On Broadcasting, 57, 2011, 143-148.

[11] Yong Wang, Jianhua Ge, Linhua wang and Jing Li, *Reduction of PAPR of OFDM signals Using Nonlinear Companding Transform*, Wireless Pers Commun, 2012, 383-397.

[12] F. Jessie MAC Williams and Neil J. A. Sloane *Pseudo- Random Sequences and Arrays*, Proceeding of the IEEE,1976

[13] L. Yang, Y. M Siu, K. K Soo, S.W Leung and S. Q Li, *Low-Complexity PAPR Reduction Technique For OFDM Systems Using Widely Linear SLM Scheme*, Int. J. Electron. Commun., 2012, 1006-1010.

[14] Saber Meymanatabadi, Javad Musevi Niya, Bezad Mozaffari, *Selected Mapping Technique for PAPR Reduction Without Side Information Based on m-Sequence*, Wireless Pers. Commun., 2012.

[15] E. S Hassan, XU Zhu, S. E El-Khamy, M. I Dessouky, S. A El-Dolil, F.E Abd El-Samie, *Peak-to-average power ratio reduction using selective mapping with unequal power distribution*, J. Cent. South Univ.,2012, 1902-1908.

[16] Stephane Y. Le Goff, Boon Kien Khoo, Charalampos C. Tsimenidis, and Bayan, S. Sharif, *A Novel Selected Mapping Technique for PAPR Reduction in OFDM Systems, IEEE transactions on Communications, 56, 2008, 1775-1779.*