A LOW COMPLEXITY PARTIAL TRANSMIT SEQUENCE SCHEME FOR BETTER PAPR REDUCTION IN OFDM SYSTEMS

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Abstract

The main drawback of OFDM system is the high Peak to Average Power Ratio (PAPR) of the transmitted signals. Partial transmit sequence scheme is a promising algorithm to reduce the peak-to-average power ratio (PAPR) in orthogonal frequency division multiplexing (OFDM). The Partial Transmit Sequence (PTS) consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS. A phase sequence applied to the PTS Scheme reduces its complexity but at the expense of slight degradation in PAPR reduction. In this paper, for further reduction of PAPR the peak clipping of the OFDM signal is introduced along with the PTS with new phase sequence scheme. Since clipping is one of the simplest techniques of PAPR reduction, it does not increase the complexity of the system much and a better PAPR reduction is obtained with the combined effect of clipping and PTS with New Phase Sequence. But the clipping technique introduce some distortion in the signal, however peak clipping of signal below a particular threshold can maintain the BER in the tolerable range. The clipping threshold selected will be different for different OFDM systems.

Index Terms: *OFDM, Peak to Average Power Ratio (PAPR), Partial Transmit Sequence (PTS), Clipping.*

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1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is one of the prominent multicarrier modulation technique used for high speed data transmission in communication system. Immunity to Interferences and fading makes it a more promising method for next generation communication systems. But the major problem one faces, while implementing an OFDM system, is the high peak to average power ratio (PAPR) of the system. OFDM consist of large number of independent sub carriers, as a result of which the amplitude of such a signal can have high peak values. To transmit signals with such high PAPR, power amplifiers with very high power scope is required. These kinds of amplifiers are very expensive and have low efficiency cost. Hence PAPR reduction is necessary for an efficient OFDM system [1], [2], [3].

Previous works in this field results in many PAPR reduction schemes to overcome this problem [1],[4].The various PAPR reduction techniques are Peak Windowing, Scaling, Clipping and Filtering, Block Coding, Block Coding with error correction, Selective Mapping (SLM), Interleaving, Tone Reservation, Tone injection, PTS etc. [1].

Peak windowing, scaling and clipping are simple methods of PAPR reduction but at the cost of slight interference. These methods introduce distortion in the OFDM signal. To reduce the interference, the clipped signal undergoes filtering. Block coding technique reduces PAPR without any distortion of OFDM signal and Block coding with error correction technique provide error correction capability in addition to PAPR reduction, but these methods are suitable for short code words [1],[4]. The SLM scheme performs well with any number of sub carriers and the major drawback with this scheme is that the overheads of the side information should be transmitted to the receiver but the interleaving is a simple method of PAPR reduction which does not induce any signal distortion, however this method does not give any assurance on the result [3],[5],[6]. Tone reservation is a less complex method but it can result in data rate reduction whereas Tone injection method achieves PAPR reduction of OFDM signals with no data rate loss [7]. Requirement of side information for decoding signal at the receiver side and causes complex extra IFFT operation are the drawbacks of this method [1],[4].

The concentration of this paper is the Partial transmit Sequence (PTS) scheme, which is one of the most efficient methods for PAPR reduction and is much better than SLM and other techniques [7]. However the computational complexity of this method is very high and also phase sequence applied to the PTS scheme reduces its complexity but the PAPR reduction degrades slightly [2],[3]. This paper introduces a combination of PTS scheme with new phase sequence and the clipping technique. As the clipping technique is a simple method of PAPR reduction, the introduction of this technique to the system of PTS with new phase sequence does not increase the complexity. But the application of peak clipping technique introduces some distortion in the signal. However the slight clipping of peak of the signal at a particular value gives better PAPR reduction at the cost of small distortion of signal.

Simulations are performed with QPSK modulation with OFDM signal. The tool used for the simulation is Matlab R2012a. PAPR is described by its complementary cumulative distribution function (CCDF). OFDM system with QPSK modulation is implemented to plot the Bit Error Rate Vs SNR of the original OFDM signal and the clipped OFDM signal. Also the PAPR of the OFDM system before and after the application of the PAPR reduction techniques are analyzed.
This paper is organized as follows. Section II includes the OFDM system and signals generation, Section III presents the PAPR, its causes and effects. Section IV presents the PTS, PTS with new phase sequence and low complexity PTS with clipping schemes. Section V and VI discuss the simulation results and conclusions respectively.

2. OFDM

OFDM is an efficient method of high data rate transmission in communication systems. OFDM system consists of large number of independent sub carriers. These closely spaced orthogonal sub carriers are used to carry data.

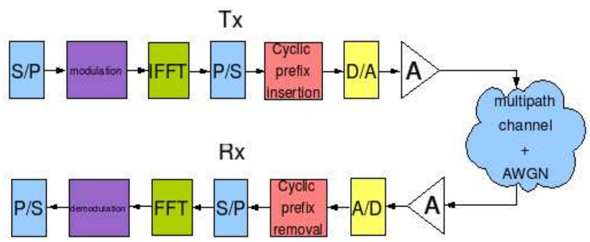

Fig -1: Block Diagram of an OFDM system

At the transmitter section the data is divided into several parallel streams of channels, one for each sub carriers. These sub carriers are modulated by phase-shift keying (PSK) or quadrature amplitude modulation (QAM) mapping techniques. Transfer of signal over a channel is only possible in its time-domain. For which IFFT is performed on this modulated signal, to convert the OFDM signal in frequency domain to time domain. Then cyclic prefix is inserted. The cyclic prefix is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation. The different sub carriers are added up to form the OFDM signal.

The signal is amplified using a power amplifier to overcome the fading effects and passed through the AWGN channel where the signal undergoes distortion from white Gaussian noise and multipath effects. At the receiver section the vice versa of the operations at transmitter side is performed.

An OFDM symbol is made of sub-carriers modulated by constellations mapping. For an OFDM system with N sub-carriers, the high-speed binary serial input stream is denoted as$\{a_i\}$. After serial to parallel (S/P) conversion and constellation mapping, a new parallel signal sequence $\{d_0,d_1,d_2,\ldots.d_i,\ldots d_{N-1}\}$ is obtained, d_i is a discrete complex-valued signal. When QPSK mapping is used, d_i $\{\pm1, \pm i\}$ and when BPSK is used d_i $\{\pm1\}$. Each element of parallel signal sequence is supplied to N orthogonal sub-carriers for modulation, respectively. Finally, modulated signals are added together to form an OFDM symbol. Use of discrete Fourier transform simplifies the OFDM system structure. The complex envelope of the transmitted OFDM signals can be written as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{j2\pi k\Delta f t}, \; 0 \le t \le T \quad (1)$$

where *X(k)* is the data symbol of k-th sub carrier, *N* is the number of sub carriers, Δf is the frequency difference between sub carriers and *T* is the OFDM symbol duration [8].

3. PEAK TO AVERAGE POWER RATIO

The PAPR of OFDM signals x(t) is defined as the ratio between the maximum instantaneous power and its average power [4]. The PAPR (in dB) of the transmitted OFDM signal can be defined as:

$$PAPR = \frac{\max_{0\le t\le T}[|x(t)|^2]}{E[|x(t)|^2]} \quad (2)$$

Where *E[.]* is the expected value operator. In an OFDM system the different sub carriers are added together to form the OFDM symbol. That is the system output is the superposition of multiple sub-carriers. In this case some instantaneous power output might increase greatly and become far higher than the mean power of system. This causes high PAPR in an OFDM system. High PAPR signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency. If no measure is taken to reduce the high PAPR, OFDM system could face serious restriction for practical applications.

PAPR is a random variable because it is a function of the input data, and the input data are random variable. Therefore PAPR can be calculated by using level crossing rate theorem that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution of the OFDM output signals, it is easy to compute the probability that the instantaneous amplitude will be above a given threshold and the same goes for power. This is performed by calculating the complementary cumulative distribution function (CCDF) for different PAPR values as follows

$$CCDF = \Pr\,(PAPR > PAPR_0) \quad (3)$$

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. The CCDF helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

4. LOW COMPLEXITY PTS WITH CLIPPING

The PTS, PTS with new phase sequence schemes and the computational complexity equations are based on paper [2].

4.1 Partial Transmit Sequence Scheme (PTS)

The basic idea of partial transmit sequence scheme is to divide the original OFDM sequence into several sub sequences and for each sub sequence multiplied by different weights until an optimum value is chosen [3],[9]. For implementing PTS scheme possible phase factors or weights are to be generated depending on the mapping used. Every subsequence is multiplied with every weights generated and PAPR is calculated each time. The phase factors for which subsequence-weight product signals with minimum PAPR is obtained is chosen as the optimum values for weight. Thus the signals with low PAPR is obtained.

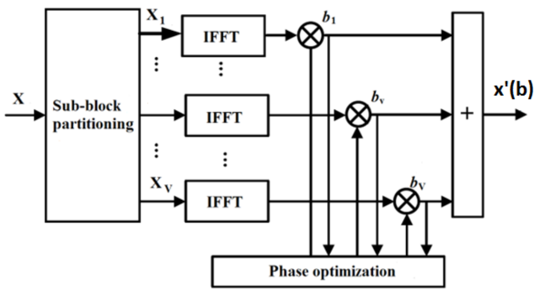

Fig -2: Block Diagram of PTS Scheme

Let X is the random input signal in frequency domain with a length of N. X is divided into V disjoint sub blocks.

$$X_v = \left[X_{v,0}, X_{v,1}, \ldots\ldots, X_{v,N-1}\right]^T \quad (4)$$

Where $v = 1,2, \ldots\ldots V$. The partitioning of input signal in to sub blocks is such that the summation of these sub blocks gives the input signal X, ie.

$$\sum_{v=1}^{V} X_v = X \quad (5)$$

Then these sub blocks are combined in time domain. The sub block partition is based on interleaving in which the computational complexity is less compared to adjacent and Pseudo-random, however it has the worst PAPR performance among them. Then apply the phase rotation factor 'b_v' to the IFFT of each of the sub blocks.

$$b_v = e^{j\theta_v} \quad (6)$$

Where v=1,2,…, V. The time domain signal after combining is given by:

$$x'(b) = \sum_{v=1}^{V} b_v x_v \quad (7)$$

Where $x'(b) = [x'_0(b), x'_1(b), \ldots\ldots x'_{NL-1}(b)]^T$ and L is the over sampling factor. The optimum signal $x'(b)$ with the lowest PAPR is to be found out.

Both b and x can be shown in matrix form as follows:

$$b = \begin{bmatrix} b_1, b_1, \ldots\ldots, b_1 \\ \vdots \quad \vdots \quad \vdots \\ b_V, b_V, \ldots\ldots b_V \end{bmatrix}_{V X\, N} \quad (8)$$

$$x = \begin{bmatrix} x_{1,0}, x_{1,1}, \ldots\ldots, x_{1,NL-1} \\ \vdots \quad \vdots \quad \vdots \\ x_{V,0}, x_{V,1}, \ldots\ldots x_{V,NL-1} \end{bmatrix}_{V X\, NL} \quad (9)$$

It should be noted that all the elements of each row of matrix b are of the same values in this method. In order to have exact PAPR calculation, at least 4 times over sampling is necessary. As the over sampling of x, add zeros to the vector, hence the number of phase sequence to multiply to matrix x will remain the same.

The PTS consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS.

4.2 PTS with New Phase Sequence

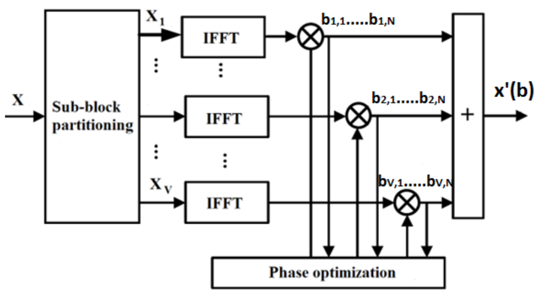

Fig -3: Block Diagram of PTS with new phase sequence

In this scheme, new phase sequence is generated from the possible phase factors. The possible phase factors or weights depend on the mapping used as in PTS. For example in the case of number of allowed phase factors *W*=4(QPSK), then phase sequence can be chosen from {1,j,-1,-j} and let the phase sequence consist of N random values. The phase sequences can be random, adjacent or interleaved [10]. The random phase sequence provides better PAPR reduction compared to the adjacent and interleaved phase sequences [1],[4]. The new phase sequences form the phase sequence matrix. Thus the new phase sequence matrix has different values in each row.

The phase sequence matrix can be as follows

$$b = \begin{bmatrix} b_{1,1}, b_{1,2}, \ldots\ldots, b_{1,N} \\ \vdots \quad\quad \vdots \quad\quad \vdots \\ b_{V,1}, b_{V,2}, \ldots\ldots b_{,N} \end{bmatrix}_{(VX\,N)} \quad (10)$$

Where *N* is the number of sub carriers and *V* is the number of sub blocks. The matrix ‘x’ has ‘V x NL’ elements and each row consists of NL elements.

$$x = \begin{bmatrix} x_{1,0}, x_{1,1}, \ldots\ldots, x_{1,NL-1} \\ \vdots \quad\quad \vdots \quad\quad \vdots \\ x_{V,0}, x_{V,1}, \ldots\ldots x_{V,NL-1} \end{bmatrix}_{(VX\,NL)} \quad (11)$$

The new phase sequences are multiplied with each of the sub sequences correspondingly to obtain the time domain signal. The phase factors from the phase sequences which produce the signals with smallest PAPR is chosen as the optimum values. Instead of an exhaustive search for phase factors here phase sequence matrix is applied to PTS, hence the complexity of this method is lower than that PTS but as the optimum weight selection is restricted from the generated phase sequence matrix, there is slight degradation in performance [2].

For comparison with the PTS, the phase sequence matrix of this scheme can be extended as

$$b = \begin{bmatrix} b_{1,1} & \ldots\ldots & b_{1,N} \\ \vdots & \vdots & \vdots \\ b_{P,1} & \ldots\ldots & b_{P,N} \end{bmatrix}_{(P\,X\,N)} \quad (12)$$

Where P>V and is the number of iterations that should be set in accordance with the number of iterations of the PTS.
The value of P can be calculated as follows:

$$P = DW^{V-1} \quad (13)$$

where D=1,2,…D_N. *D* is the coefficient that can be specified based on the PAPR reduction and complexity and D_N is the amount that is specified by the user. The value of *P* depends on the number of sub blocks *V* if the number of allowed phase factor is assumed to be constant. There is a tradeoff for choosing the value of *D*, the higher *D* leads to higher PAPR reduction but at the expense of higher complexity; while lower *D* gives smaller PAPR reduction but with less complexity.

4.3 Computational Complexity

The total complexity of the PTS is given by,

$$C_{PTS} = \frac{3VN}{2\log N} + 2VIN \quad (14)$$

Where I=W^{V-1} and I is the number of iterations required for searching the optimum phase factor. The total complexity of the PTS with New Phase Sequence is given by,

$$C_{NewPTS} = \frac{3VN}{4VN\log N} + PVN \quad (15)$$

where P is the number of iterations and V is the number of sub blocks. It can be observed that the complexity equations consist of two parts; the first part is actually the complexity of the IFFT itself and the second part is the complexity of the searching algorithm [2],[11].

4.4 Low Complexity PTS with Clipping

In this method, the OFDM symbols are divided in to number of sub blocks and the signals corresponding to IFFT of each sub block is clipped. This method provide better PAPR reduction than the PTS scheme with new phase sequence but the clipping introduces slight distortion in the signal.

As the PTS with new phase sequence offers less complexity than conventional PTS, it is considered as the low complexity PTS throughout this paper.

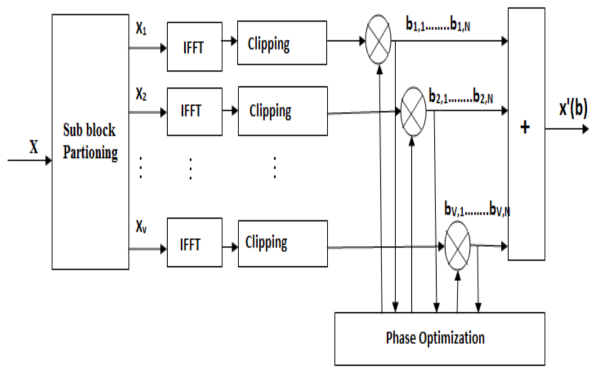

Fig -4: Block Diagram of Low complexity PTS with clipping

Here, the OFDM sequence is divided in to several (V) sub blocks as in PTS and new phase sequence applied to PTS schemes. In this method separate clipping is done on each block. The peak clipping can be performed only on time domain signal. Hence clipping is introduced in the new phase sequence applied to PTS scheme after the IFFT operation in each block.

The advantages of this scheme are:

- Low complexity: As clipping is a PAPR reduction technique which is simple in implementation, the introduction of clipping to a low complexity PTS scheme does not increase the complexity of the system.
- Better PAPR reduction: The combined effect of clipping and PTS with new phase sequence scheme reduces PAPR considerably.
- Enhancement of power efficiency and therefore less power consumption and more battery life.

But the clipping technique introduces distortion in the signal [12],[13]. However peak clipping of signal below a particular threshold can maintain the BER in the tolerable range. Therefore the system can be used only where the OFDM system can tolerate slight reduction in performance, ie less power consumption and more battery life are the major concern.

5. SIMULATION RESULTS & OBSERVATIONS

The simulation is performed with 64 sub band OFDM symbols. PAPR reduction of OFDM with QPSK and BPSK mapping and the computational complexity of PTS scheme with different number of sub blocks in [2] are examined. Over sampling factor selected for the various PAPR reduction simulations is, L=4.

As the clipping technique causes distortion of the signal, the clipping technique has to be implemented such that it does not degrade the performance of the OFDM system below the tolerable range. The threshold value set for peak clipping depends on the OFDM system and the input signal. The clipping at an amplitude of 0.2 strictly depends on the OFDM system and input signal used in this work. The test is achieved on 10000 OFDM symbols and the following results are obtained.

Table -1: Computational Complexity of PTS Scheme for Different Number of Sub Blocks

Number of Sub Blocks	***Number of Sub carriers***	***Complexity***
2	256	1.0702e+03
4	256	3.2860e+04
8	256	1.6777e+07

From Table -1it is clear that as the number of sub blocks increases the complexity increases as in [2].

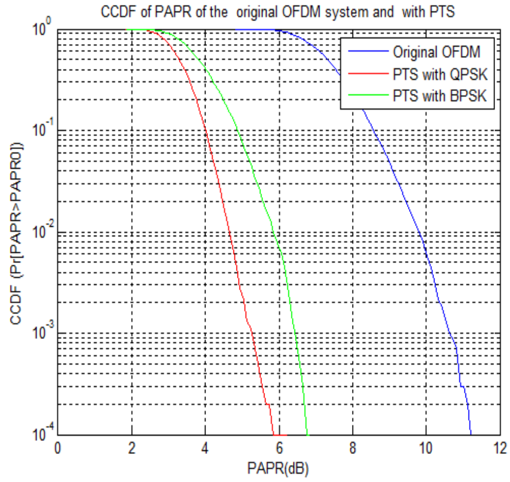

Fig -5: PAPR reduction of PTS Scheme with BPSK and QPSK modulation

Fig. 5 shows the PAPR of original OFDM system, the PAPR of OFDM system which has undergone the Partial Transmit Sequence Scheme with QPSK and BPSK modulation. The PAPR of original OFDM system lies near to 11dB whereas the PAPR of PTS system with QPSK modulation lies near to 6 dB and the PAPR of PTS system with BPSK modulation lies near to 7 dB. From Fig. 5 it is clear that PTS method provides a better PAPR reduction performance with QPSK mapping than with BPSK mapping. Based on the simulation results obtained in Fig. 5 and TABLE I, the QPSK mapping and number of sub blocks, V=4 are used in the rest of the simulations.

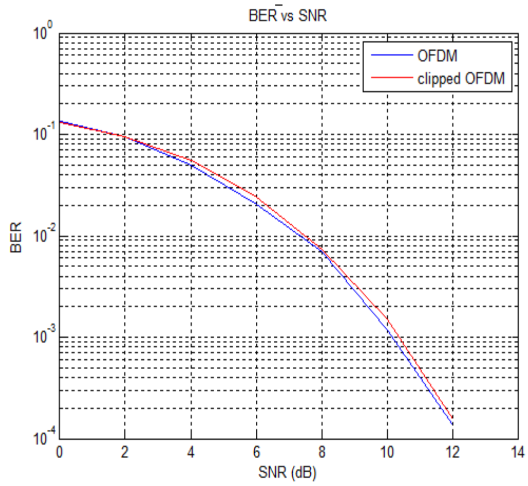

Fig -6: BER Vs SNR of OFDM system with and without clipping of peak of OFDM signal.

Fig. 6 shows the BER Vs SNR plot of OFDM system with and without clipping of the OFDM signal peak. From the figure it can be observed that the BER is slightly increased for the OFDM system when the peak of the OFDM signal is clipped, ie the clipping at amplitude of 0.2 introduced slight distortion in the OFDM signal. However as this value of clipping threshold introduces only slight performance degradation this value can be used for clipping of in the input signal in the OFDM system for PAPR reduction.

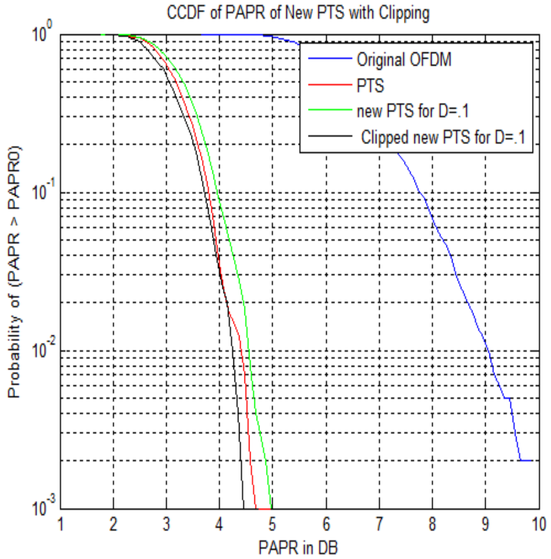

Fig -7: PAPR Reduction of PTS scheme, New phase sequence applied to PTS Scheme and PTS Scheme with both New Phase Sequence and clipping

Fig.7 shows the PAPR of original OFDM system, the PAPR of OFDM system which has undergone the Partial Transmit Sequence Scheme, PTS with New Phase sequence scheme and PTS Scheme with both New Phase Sequence and clipping. It can be observed that the PAPR reduction of the PTS Scheme with both New Phase Sequence and clipping scheme offers better PAPR reduction than the Partial Transmit Sequence Scheme and the PTS with New Phase sequence scheme at the expense of slight reduction in system performance.

CONCLUSIONS AND FUTURE WORKS

The major difficulty one faces in the practical implementation of the Orthogonal Frequency Division Multiplexing is its high PAPR. To transmit signals with large PAPR, expensive wide range power amplifiers are required. One of the effective methods of PAPR reduction is Partial Transmit Sequence scheme. The complexity of this scheme can be reduced by the application of a new phase sequence but the PAPR reduction is slightly reduced. A scheme comprising of the PTS with both the new phase sequence and the clipping has been introduced in this paper. As clipping of peak of signal is simple in implementation, it does not increase the complexity of the system and a better PAPR reduction can be achieved. The BER Vs SNR of the OFDM system with and without clipping of peak signal is examined. By applying the scheme the PAPR is reduced further. There exist a trade off for choosing the threshold for clipping, greater the clipping greater will be the distortion but better PAPR reduction , while lower clipping gives low distortion of the signal and lower the PAPR reduction achieved. Since clipping causes degradation in the system performance, this scheme can be used where less power consumption and more battery life are our primary concern.

The filtering of a clipped signal reduces the distortion introduced due to clipping. Hence by introducing the clipping in the proposed scheme is expected to reduce the signal distortion due to clipping and provide better PAPR reduction. This can be a scope of future work as it enhances the system performance.

REFERENCES

[1]. Md. Ibrahim Abdullah, Md. Zulfiker Mahmud, Md. Shamim Hossain, Md. Nurul Islam(2011):'Comparative Study of PAPR Reduction Techniques in OFDM' Vol. 1, No. 8, ARPN Journal of Systems and Software,263-269.

[2]. Pooria Varahram, Borhanuddin Mohd Ali(2011): 'Partial Transmit Sequence Scheme with New Phase Sequence for PAPR Reduction in OFDM Systems',IEEE Transactions on Consumer Electronics, Vol. 57, No. 2,366-371

[3]. Suverna Sengar, Partha Pratim Bhattacharya(2012): 'Performance Improvement In OFDM System By PAPR Reduction', Signal & Image Processing : An International Journal (SIPIJ) Vol.3, No.2,157-169.

[4]. V. Vijayarangan, Dr. (Mrs) R. Sukanesh(2005): 'An Overview Of Techniques For Reducing Peak To Average Power Ratio And Its Selection Criteria For Orthogonal Frequency Division Multiplexing Radio Systems',Journal Of Theoretical And Applied Information Technology,25-36.

[5]. Gagandeep Kaur, Rajbir Kaur(2012): 'Comparative study of SLM and PTS techniques for PAPR Reduction of an MC-CDMA system', International Journal of Engineering Research and Applications Vol. 2, Issue 4,779-784.

[6]. P. Tu, X. Huang, E. Dutkiewicz(2007): 'Peak-to-Average Power Ratio Performance of Interleaved Spread Spectrum OFDM Signals',Research online.

[7]. Umer Ijas Butt(2008): 'A Study on Tone Reservation technique for Peak to Average Power Ratio reduction in OFDM systems',M.Tech paper,University of Manchester.

[8]. Davis, J.A. and J. Jedwab(1999): 'Peak-to-mean power control in OFDM, Golay complementary sequences, and Reed-Muller codes', IEEE Trans. Inform. Theory, Vol. 45, 2397–2417.

[9]. H. G Ryu., and K. J Youn(2002): 'A new PAPR reduction scheme: SPW (subblock phase weighting)', IEEE Trans. on Consumer Electronics, vol. 48, no. 1, pp. 81 – 89.

[10]. R. J. Baxley and T Zhou(2007): 'Comparing slected mapping and partial transmit sequence for PAPR reduction', IEEE Trans. Broadcast, vol. 53, no. 4, pp.797-803.

[11]. S. G. Kang, J. G. Kim, and E. K. Joo(1999): 'A novel subblock partition scheme for partial transmit sequence OFDM', IEEE Trans. Broadcast, vol. 45, no. 3, pp. 333–338.

[12]. H. G Ryu., and K. J Youn(2002): 'A new PAPR reduction scheme: SPW (subblock phase weighting)', IEEE Trans. on Consumer Electronics, vol. 48, no. 1, pp. 81 – 89.

[13]. Ochiai, H. and K. Imai(2001): ' On the Distribution of the Peak-to-Average Power Ratio in OFDM Signals', IEEE Transactions on Communications, 49 (2): 282-289.