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Extended CSS Scheme For Reduction of PAPR in OFDM Systems

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is an efficient transmission technique for high data rate communication systems. The major problem of OFDM system is high Peak to Average Power Ratio(PAPR) which reduces the efficiency of the system and increases the system complexity. A Partial Transmit Sequence(PTS) scheme is one of the most effective solution for the purpose of PAPR reduction. A Cyclic Shifted Sequences(CSSs) scheme is developed from the PTS scheme to improve the PAPR reduction performance. In this paper, a new scheme is proposed i.e. µ-law Companding on Cyclic Shift Sequence scheme in order to achieve better PAPR reduction than previous methods. Here CSS scheme comes under the category of multiple signaling and probabilistic techniques which are used to reduce peak power, in the same way µ-law Companding comes under Signal distortion techniques which are used to increase average signal power. The simulation results show that the combination of these two methods gives better reduction performance compared to single methods(PTS or CSS).

Keywords: Cyclic Shifted Sequences (CSS), Orthogonal Frequency Division Multiplexing (OFDM), Partial Transmit Sequence (PTS), Peak-to-Average Power Ratio (PAPR), µ-law Companding.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is most widely used technique in many wireless communication systems such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), Wireless Local Area Network(WLAN)s, and Wireless Metropolitan Area Network(WMAN)s because of its orthogonality nature. Despite of its advantages, one of the major drawbacks in OFDM is the large PAPR value of the transmitted signals. This problem comes from the nature of the modulation used in OFDM i.e. multi carrier modulation, where multiple sub-carriers are added together to form the signal to be transmitted. Literature provides several schemes to reduce PAPR such as Partial Transmit Sequence(PTS) [1] ,Tone Injection(TI),Tone Reservation(TR) and Selective Mapping(SLM) [2]. In all the schemes PTS is the best scheme from the PAPR reduction point of view. In the PTS scheme, the input symbol sequence is divided into a number of different input symbol subsequences then Inverse Fast Fourier transform (IFFT) is applied to each input symbol subsequence and the resulting OFDM signal subsequences are added after being multiplied by a set of rotation factors. Next the PAPR is calculated for each output sequence and then the OFDM signal sequence with the minimum PAPR is selected to transmit. However, the complexity of the scheme increases when number of sub blocks increases. To reduce this complexity while maintaining better PAPR reduction, a new method is introduced based on PTS scheme i.e.CSS scheme. In Cyclic Shifted Sequences (CSS) scheme, where input signal subsequences are cyclically shifted instead of multiplication with rotation factor [3],[4]. The CSS scheme is better than the PTS scheme in two ways. First, its PAPR reduction performance is better than the PTS scheme's and in CSS scheme it is possible to recover the transmitted OFDM signal sequence without side information using some additional techniques at the receiver [7],[8]. The reduction performance of CSS scheme is entirely depend on selection of Shift Value(SV) sets [9]. The SV sets are selected based on type of partition is used to divide the input symbol sequence. In this paper the criterions which are used for the selection of good SV sets are discussed to achieve better reduction performance in CSS. To improve the reduction performance further, a new scheme is proposed based on combination of two different types of PAPR reduction techniques i.e. multiple signaling and probabilistic techniques(CSS) and signal distortion techniques(Companding)[10]. In the μ-law Companding, the compressor characteristic is piecewise, made up of a linear segment for low level inputs and a logarithmic segmemt for high level inputs. Instead of reducing the high peaks like Clipping, Companding scheme increase the value of small signals in order to bring them in the same level with the high peaks. Because of increased level of the small signals, average power of the signal will be increased. This paper is organized as follows. Section2 explains formulas for OFDM and PAPR. Section3 explains about PAPR reduction types. Section4 explains about proposed scheme.Section5 gives simulation results and finally Section6 gives conclusion.

II. OFDM and PAPR

2.1. Orthogonal Frequency Division Multiplexing (OFDM)

In OFDM, the input data is divided into several parallel streams. These parallel streams modulate different subcarriers. An OFDM signal sequence in time domain is generated by IFFT as

$$x(n) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X(k)\, e^{\frac{j2\pi kn}{N}} \quad \text{......................(1)}$$

Where N is the number of subcarriers, X = {X(0), X(1), . . . , X(N−1)} is an input symbol sequence in frequency domain and x ={x(0), x(1), . . . , x(N − 1)} is an OFDM signal sequence in time domain.

2.2. Peak-to-Average Power Ratio (PAPR)

The PAPR of the OFDM signal sequence *x* is defined as the ratio of maximum instantaneous power to average power.

$$PAPR = \frac{P_{max}}{P_{avg}} = \frac{\max_{0 \le n < N}|x(n)|^2}{E[|x(n)|^2]} \quad \text{.................... (2)}$$

III. PAPR REDUCTION TYPES

PAPR reduction techniques can be classified into three main categories

3.1. Signal distortion Techniques

Signal distortion techniques reduce the PAPR by distorting the transmitted OFDM signal before it passes through the Power Amplifier. Clipping and Filtering, Peak Windowing, Companding techniques are the signal distortion techniques.

3.1.1. Companding Techniques

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The Compading method consists of a compressor and an expander. The compressor is a simple logarithm computation block can be applied at the transmitter end after IFFT in OFDM system . The inverse system of a compressor is called expander.Expansion is applied at the receiver end prior to the FFT process. μ-law Companding[11] is one of the methods to reduce PAPR of OFDM signal by increasing the average power of the signal with less circuit complexity. The samples of the OFDM signal may have higher peaks and lower peaks, which give less average power the signal, and leads to high PAPR. Here μ-law Companding enlarges the small signals power and leaves unchanged the higher peak signals power. This leads to increase in the average power of the signal. The μ-law Companding is given by

$$y = \frac{V \log\left(1+\mu\frac{|x|}{V}\right)}{\log(1+\mu)}\,\mathrm{sgn}(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where μ is the Companding parameter which controls the amount of compression, x is the input signal and V is the maximum value of x.

For normalized input signal $|x| \leq 1$, the characteristic becomes

$$y = \frac{\log(1+\mu|x|)}{\log(1+\mu)}\,\mathrm{sgn}(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

3.2. Multiple Signaling and Probabilistic Techniques

This method either generate multiple permutation of the OFDM signal and transmit the one with minimum PAPR or to modify the OFDM signal by introducing phase shifts, adding peak reduction carrier or changing constellation points. Major techniques under this category are Selective Mapping(SLM) and Partial Transmit Sequence(PTS).The Computational complexity is more in SLM compared to PTS.

3.3. Coding Techniques

In these techniques, reduction in PAPR is achieved by adding some error detection and correction codes such as linear block codes and turbo codes to the original data.

IV. PROPOSED SCHEME

Figure1 shows the block diagram of Proposed Scheme. It involves the combination of CSS scheme and Companding technique. First CSS scheme [4][5] is applied and the result then added to Companding circuit.

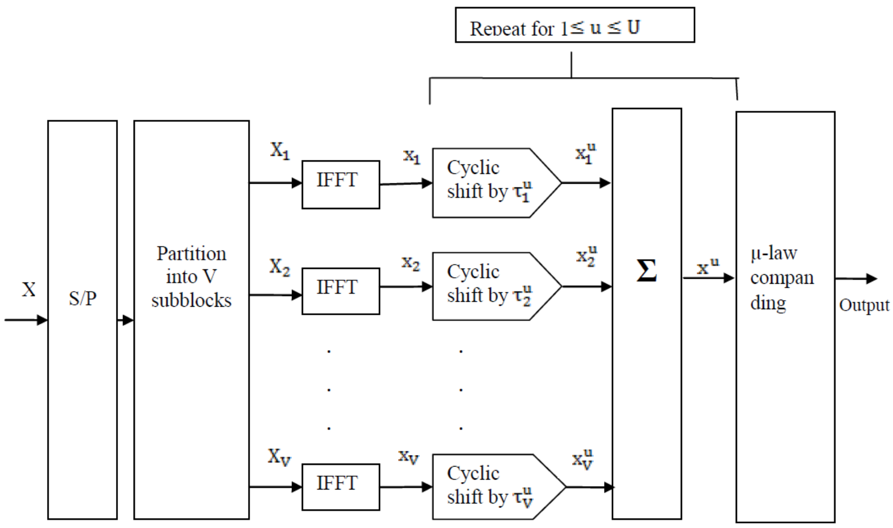

Fig1. Block diagram of Proposed scheme

In the CSS scheme [9] the input X is divided into V sub blocks $X_1, X_2, \ldots, X_V$ by using certain partition method (Random, Adjacent or interleaved).Then IFFT converts the V sub blocks in frequency domain to the V OFDM signal subsequences in time domain $x_1, x_2, \ldots, x_V$, where $x_v=\{x_v(0), x_v(1), \ldots, x_v(N-1)\}$, $1 \le v \le V$. Next, the V OFDM signal subsequences are cyclically shifted and combined together to make the u-th ($1 \le u \le U$) alternative OFDM signal sequence as

$$x^u = \sum_{v=1}^{V} x_v^u \quad \ldots\ldots(5)$$

Where x_v^u denotes the left cyclic shift of x_v by some integer τ_v^u ($1 \le v \le V$) i.e.

$$x_v^u=\{x_v(\tau_v^u), x_v(\tau_v^u+1), \ldots\ldots x_v(N-1), x_v(0), \ldots\ldots x_v(\tau_v^u-1)\} \quad \ldots\ldots(6)$$

The output of adder is applied to the µ-law Companding[11] circuit. Let us consider x^u is considered as variable S then output is

$$\text{Output} = \frac{\log(1+\mu|S|)}{\log(1+\mu)}\operatorname{sgn}(S) \quad \ldots\ldots(7)$$

Finally, the OFDM signal sequence with minimum PAPR is obtained. The cyclic shift operation does not destroy the orthogonality between the input symbols because, cyclic shifting in time domain is equal to multiplying a corresponding linear phase vector in frequency domain. For the u-th alternative OFDM signal sequence the SV set is considered as $\bar{\tau}^u=\{\tau_1^u, \tau_2^u \ldots\ldots \tau_V^u\}$. Similarly U SV sets ($\bar{\tau}^1, \bar{\tau}^2, \bar{\tau}^3, \ldots\ldots \bar{\tau}^U$) are constructed to implement the CSS scheme for testing U alternative OFDM signal sequences. Same as PTS scheme, the CSS scheme can also use three partition methods, those are Random, Adjacent, and Interleaved partition methods. Among three of them the Random partition method gives the best PAPR reduction performance while the Interleaved partition method gives the worst PAPR reduction performance but it needs lowest computational complexity. The Adjacent partition method requires high computational complexity as the Random partition needs, but it gives worst PAPR reduction performance than the Random partition. For the careful selection of τ value three criterions are used for three different partition schemes.

4.1. For Random Partition

4.1.1. Criterion1: Suppose that we have U SV sets; For every (i, j) pair out of the U SV sets (i ≠ j), the pair should satisfy the condition that the relative distances $\tau_v^i - \tau_v^j \bmod N$ are distinct from each other for all v's.

4.2. For Interleaved Partition

4.2.1. Criterion 2 : Suppose that we have U SV sets; For every (i, j) pair out of the U SV sets (i ≠ j), the pair should satisfy the condition that the relative distances $\tau_v^i - \tau_v^j \bmod N/V$ are distinct from each other for all v's.

4.3. For Adjacent Partition

4.3.1. Criterion 3: Suppose that we have U SV sets; For every (i, j) pair out of the U SV sets (i ≠ j), the pair should satisfy the condition that the relative distances $\tau_v^i - \tau_v^j \bmod N$ are distinct from each other for all v's . Furthermore, the mutual differences of the V relative distances ($\tau_1^i - \tau_1^j$, $\tau_2^i - \tau_2^j$, ……………$\tau_V^i - \tau_V^j \bmod N$) should be as close to N/2 as possible.

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V. SIMULATION RESULTS

Figure 2 shows that CSS scheme using Random partition will give better performance than other two methods .In this both Random and Interleaved partition methods are applied to PTS and CSS schemes.

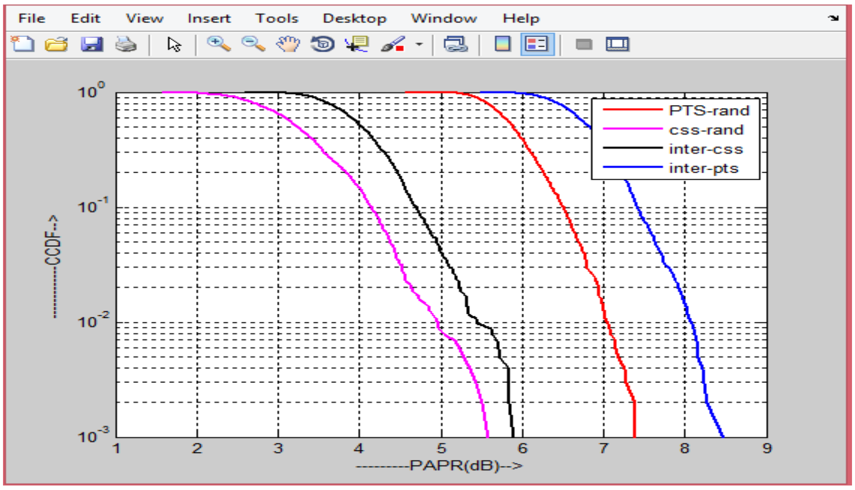

Figure 2. Comparison of the PAPR reduction performance between the conventional PTS scheme and the CSS scheme when N = 128 and U = 64.

To verify the 3 criterions for three different partition methods in this two U SV sets are constructed one is with satisfying criterion and the other is without satisfying criterion

5.1. For Random Partition

The SV sets $\bar{\tau}^1$ = {0, 0, 0, 0} , $\bar{\tau}^2$= {0, 8, 16, 24}, $\bar{\tau}^3$= {0, 16, 32, 48}, and $\bar{\tau}^4$ = {0, 24, 48, 72} are satisfies *Criterion 1*. On the other hand, the SV sets $\bar{\tau}^1$ = {0, 0, 0, 0}, $\bar{\tau}^2$= {0, 4, 8, 12}, $\bar{\tau}^3$ = {0, 16, 20, 24}, and $\bar{\tau}^4$ = {0, 28, 32, 36} are not satisfies *Criterion1*.

5.2. For Interleaved Partition

The SV sets $\bar{\tau}^1$ = {0, 0, 0, 0}, $\bar{\tau}^2$ = {0, 1, 2, 3}, $\bar{\tau}^3$= {0, 2, 4, 6}, and $\bar{\tau}^4$ = {0, 3, 6, 9} are satisfies *Criterion2*. On the other hand, the SV sets $\bar{\tau}^1$= {0, 0, 0, 0},$\bar{\tau}^2$= {0, 8, 16, 24}, $\bar{\tau}^3$= {0, 16, 32, 48}, and $\bar{\tau}^4$ = {0, 24, 48, 72} are not satisfies *Criterion 2.*

5.3. For Adjacent Partition

The SV sets $\bar{\tau}^1$ = {0, 0, 0, 0}, $\bar{\tau}^2$ = {0, 44, 73, 95}, $\bar{\tau}^3$= {0, 9, 35, 84}, and $\bar{\tau}^4$ = {0, 25, 45, 110} are satisfies *Criterion3*. On the other hand, the SV sets $\bar{\tau}^1$ = {0, 0, 0, 0}, $\bar{\tau}^2$ = {0, 1, 2, 3}, $\bar{\tau}^3$= {0, 2, 4, 6}, and $\bar{\tau}^4$= {0, 3, 6, 9} are not satisfies *Criterion3.*

Figure 3 shows one of the example that how the criterion satisfied SV sets will give better PAPR than randomly generated SV sets that means the SV sets which are not satisfying criterions. For this graph Interleaved partition method is used and parameter values are N=32, U=4 and V=4.

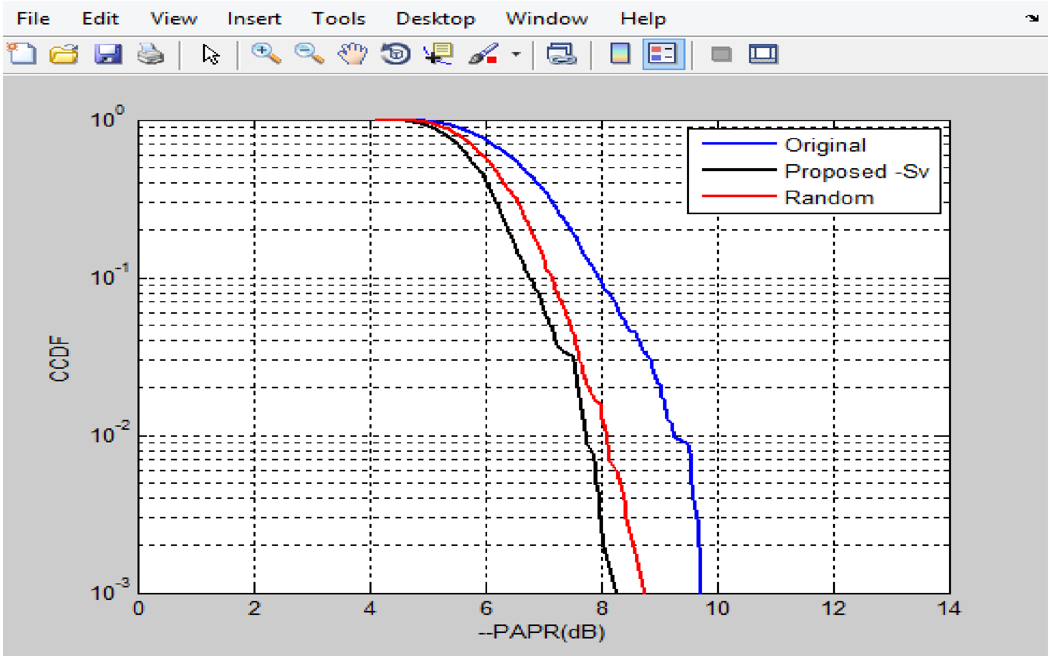

Figure3.The optimality of the proposed SV sets when N = 32, U = 4, interleaved partition, and V = 4

From the Figure 4 we observed that original OFDM signal has PAPR value nearly 10.6dB by using PTS scheme the PAPR is reduced to 8 dB and by using modified version of PTS i.e. CSS the PAPR reduced to 5 dB. Now the combination of PTS and µ-law Companding (Proposed method) reduces PAPR to 3dB and proves that this proposed method is better than other two methods.

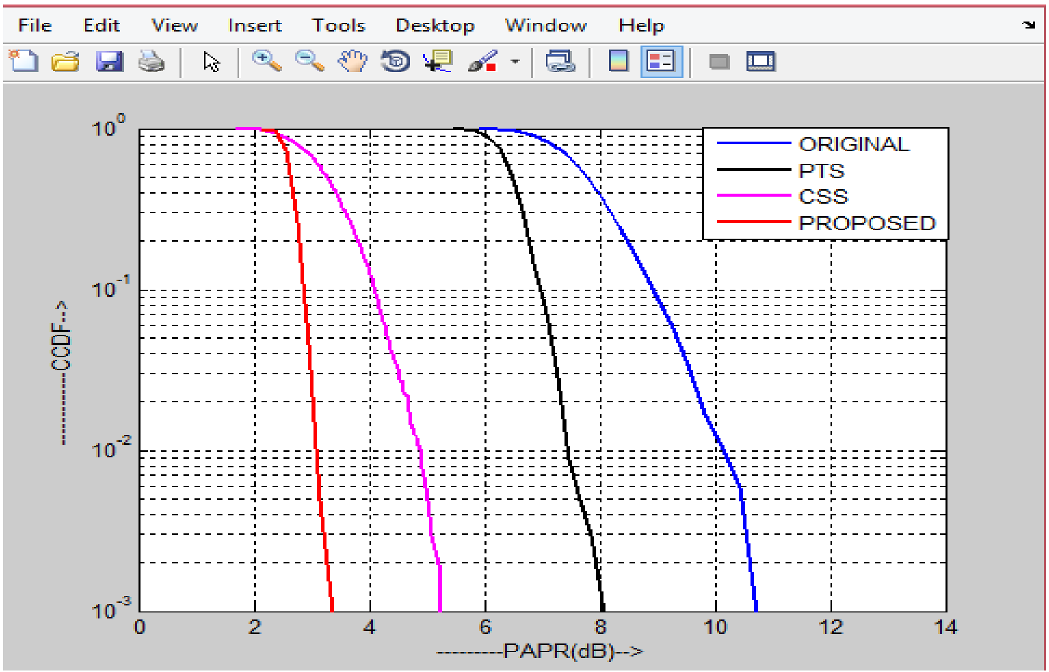

Figure4. Comparison of PAPR values of Proposed method with previous methods

VI. CONCLUSION AND FUTURE WORK

A new PAPR reduction scheme by combining PTS and µ-law Companding has been proposed in this paper. The CSS scheme is evolved from the PTS scheme. The criterions to select good SV sets are used for the optimal PAPR reduction performance of CSS scheme. Companding is also one of effective method in terms of PAPR reduction because of its low complexity. By combining two effective methods the proposed method shows better reduction performance compared to previous methods. This work can be extended by replacing µ-law Companding with other PAPR reduction methods.

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