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PAPR Reduction Using Companding on Cyclic Shift PTS

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ABSTRACT: Orthogonal Frequency Division Multiplexing (OFDM) is an attractive and promising technique in wireless communication. Peak-to-Average power ratio (PAPR) is a major drawback in the application of OFDM communication. A large amount of PAPR leads to loss of data integrity, which can reduce system efficiency. To avoid the occurrence of large peak power of signals various methods for the reduction of PAPR have been developed. Partial Transmit Sequence is one of the best method among various methods. In terms of PAPR reduction Cyclic Shift on PTS is better than conventional PTS. Here PTS and CSS corresponds to reduction of peak power. In this paper, to improve the reduction performance further a new scheme is proposed i.e. µ-law Companding is applied to cyclic shift PTS. Here Companding corresponds to the increase in average power. The simulation results show that the proposed method gives better PAPR reduction compared to previous methods.

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

I.INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has been widely adopted technique because of its high spectral efficiency and robustness to frequency selective fading channel[1].However, OFDM system suffers from high Peak-To-Average Power ratio (PAPR) of the transmit signal. PAPR is defined as Peak power to Average power of a signal. The reason for the high peaks is the modulation itself, When multiple sinusoids are added together to form the multicarrier signal, these peaks are generated. The high peak power of the transmit signal will cause signal distortion, which results in Bit Error Rate (BER) degradation, out-of band radiation, increase the complexity of the D/A converter and reduce the power efficiency of the transmitter's power amplifier. Different techniques had been proposed in the literature to deal with the high PAPR problem[2] for OFDM system, such as clipping, coding, nonlinear companding, Selected Mapping (SLM)[3] , Partial Transmit Sequences (PTS)[6] ,Interleaving, Tone Reservation (TR), Tone Injection (TI), and Active Constellation Extension(ACE). Each of these techniques has a various cost for Bit Error Rate (BER) and the reduced PAPR. Among all existing techniques, the PTS method is best scheme due to its good performance of PAPR reduction without any distortion of transmitted signals. In PTS scheme the input sequence is separated into number of different sub blocks and after that those all sub blocks are converted into them into time domain by using Inverse Fast Fourier Transform (IFFT).Then, the PAPR minimization is achieved through multiplying the time domain sequences with complex phase factors. Motivated by success in reducing PAPR by using PTS the improved technique Cyclic Shift on PTS [4][5] is introduced. Cyclic Shift PTS is better than PTS because at the receiver side PTS requires side information about the phase factors. Coming to Cyclic Shift PTS, in these scheme in place of multiplication with phase rotation factor cyclic shifting is done on time domain OFDM sequences by a Shift Value. The Shift Value sets selection [8] directly relates to the PAPR reduction. To select the SV sets so many factors are to be considered. Those are type of partition is used to divide the input and amount of correlation remains after dividing the input sequence. To know the amount of correlation Auto Correlation Function (ACF) has to be considered and based on the ACF the criterions are discussed for selection of Shift Values. As earlier said that PAPR reduction depend on peak power and average power. The above technique reduces only peak value. So to improve the reduction performance there is a need of increasing average power also. To achieve this µ-law companding[9] on Cyclic Shift is proposed in this paper. The reason is µ-law companding[10] technique is used to increase the average power by increasing the small signal power and unchanging the large peak signal power.

II.PROPOSED METHOD

A high-rate data stream is divided into N low-rate streams transmitted simultaneously by subcarriers in an OFDM system. Each of the subcarriers is independently modulated (complex data symbols) by using a typical modulation scheme such as quadrature amplitude modulation (QAM) or phase-shift keying (PSK). The inverse discrete Fourier transform (IDFT) generates transmitted OFDM signal. An OFDM signal in the discrete time domain of N subcarriers can be written as

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

where X(k) denotes the input symbols for k = 0, 1, … … , N − 1 and n is the index of discrete time.

To define the PAPR of x(n) in Eq. (1) is the ratio of the maximum instantaneous power to the average power of the PAPR of the transmitted signal is given by

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

Figure 1 shows the block diagram of µ-law companding on Cyclic shift PTS. The process involve in this block diagram is discussed below

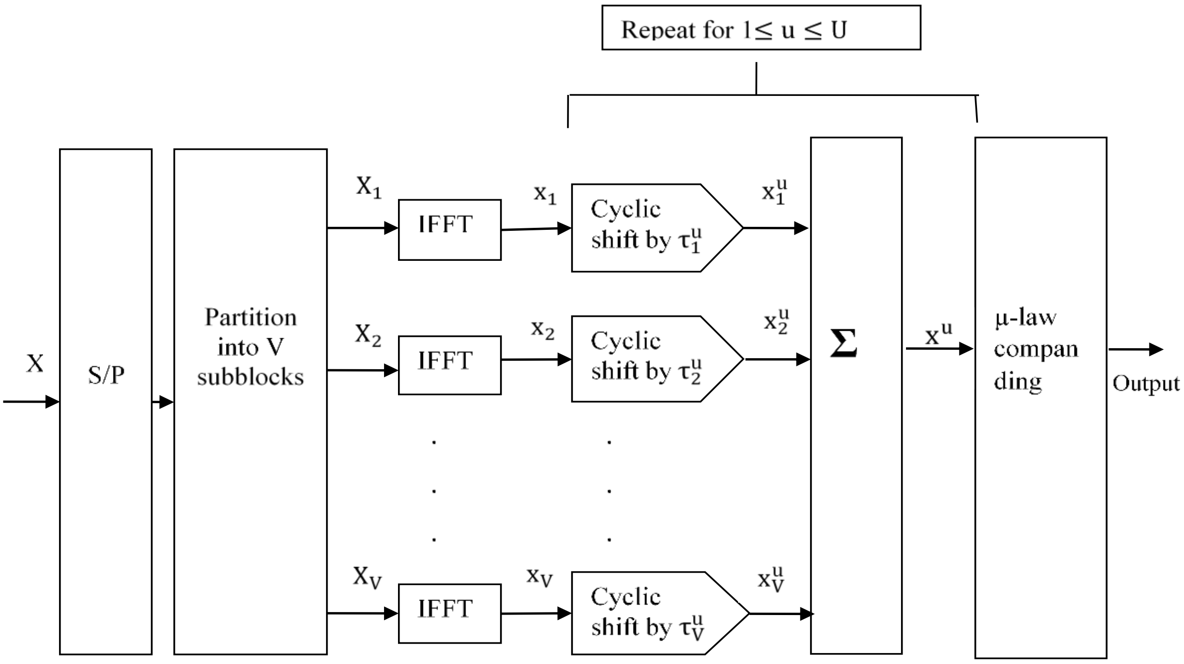

Figure 1. Block diagram of µ-law companding on Cyclic shift PTS

Step1
The input sequence X is divided into V number of sub blocks $X_1, X_2, \ldots, X_V$ by using certain partitioning method.

Partitioning methods
There are 3 types of partitioning methods
1 .Interleaved partition
2 .Adjacent partition
3 .Random partition

Interleaved Partition

In this partition the input subcarrier (N) into (L) subblocks for each one contains N/V contiguous subcarriers. The main idea of this operation breaks down the high correlation patterns of the input data frames on OFDM signal. Figure2 show the operation of interleaving partition scheme.

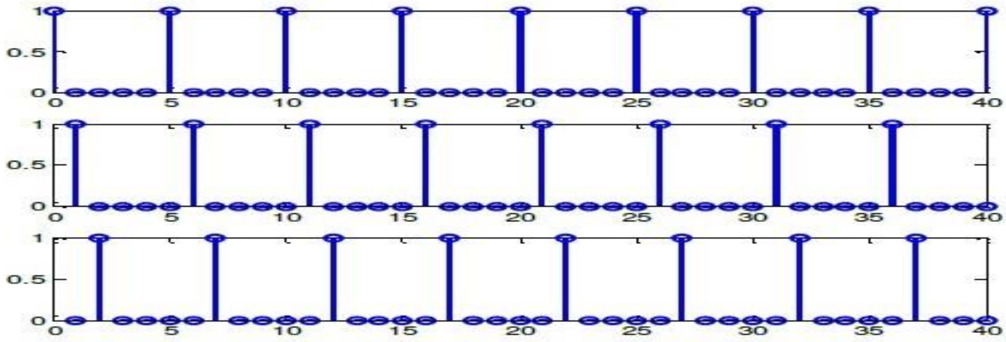

Figure2 Interleaved partition scheme

$$I_0 \;= [I_0^{(1)}0 \ldots .\, 0I_0^{(2)}0 \ldots \ldots 0I_0^{(V)}00 \ldots .\,] \tag{3}$$

$$I_1 \;= [0I_1^{(1)}\,0 \ldots .\, 00I_1^{(2)}\,0 \ldots \ldots 000I_1^{(V)}0 \ldots .0] \tag{4}$$

$$I_L \;= [00 \ldots ..\, I_L^{(1)}\,0 \ldots .00I_L^{(2)}\,0 \ldots \ldots 0I_L^{(V)}\,] \tag{5}$$

Adjacent partition

Adjacent partition is a simple method to implement the partition process, and its performance is better than the interleaving partition scheme. An adjacent partition scheme divides the sequence into (L) sub-block vectors similar to the interleaving partition scheme but each sub-block contains N/V of the consecutive subcarriers.

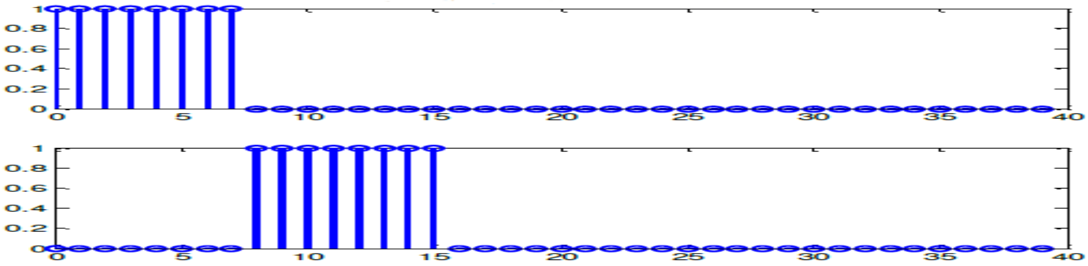

Figure 3 Adjacent partition

$$A_0 = [A_0^{(1)} A_0^{(2)} A_0^{(3)} 000 \ldots \ldots \ldots \ldots ..0] \tag{6}$$

$$A_1 = [0000 \ldots .0, A_1^{(1)} A_1^{(2)} A_1^{(3)} 000 \ldots \ldots \ldots ..0] \tag{7}$$

$$A_V = [0000 \ldots .0,000 \ldots .00, A_0^{(1)} A_0^{(2)} A_0^{(3)}] \tag{8}$$

Random partition

Pseudo-random partition has the best PAPR reduction performance compare with interleaving and adjacent partition schemes. Each subcarrier can be randomly distributed on any position of the sub-block (L).

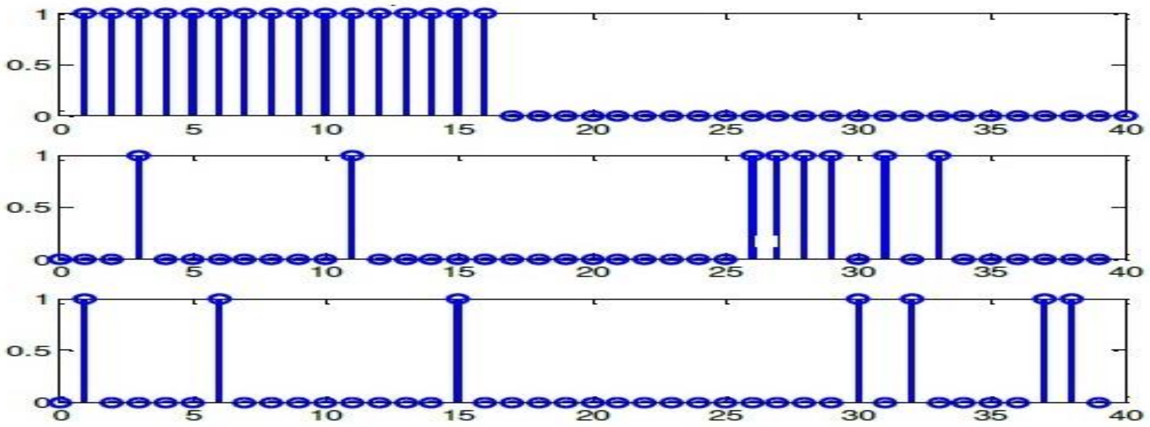

Figure 4 Random partition scheme

$$P_0 = [P_0^{(1)}\, 0 \ldots .000 P_0^{(V)}\, 0 \ldots \ldots 0 P_0^{(2)}\, 00 \ldots .0] \tag{9}$$

$$P_1 = [00 P_1^{(V)}\, 0 \ldots . 0 P_1^{(2)}\, 0 \ldots \ldots 000 P_1^{(1)} 0 \ldots .0] \tag{10}$$

$$P_L = [00000 \ldots .. P_L^{(1)}\, 00 \ldots .00 P_L^{(V)}\, 00 \ldots \ldots 0 P_L^{(2)}\, 000] \tag{11}$$

Step 2

Then IFFT converts V sub blocks in frequency domain to the V OFDM signal subsequences in time domain $x_1, x_2, \ldots, x_V$, where $x_v=\{x_v(0), x_v(1), \ldots, x_v(N-1)\}$, $1 \le v \le V$.

Step 3

The time domain OFDM signals are then cyclically shifted by using Shift Value (an integer) and added together to make alternative OFDM signal as

$$x^u = \sum_{v=1}^{V} x_v^u \tag{12}$$

The above equation is for only one u alternative signal in the same way total U alternate signals are generated 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.

$$x_v^u = \{x_v(\tau_v^u), x_v(\tau_v^u + 1), \ldots \ldots \ldots x_v(N-1), x_v(0), \ldots \ldots \ldots x_v(\tau_v^u - 1)\} \tag{13}$$

Here τ_v^u is a shift value and for u^th^ alternate signal the SV set is defined as $\bar{\tau}^u = \{\tau_1^u, \tau_{2,}^u \ldots\ldots\ldots\ldots \tau_V^u\}$ similarly the SV sets for total U alternative signals are $(\bar{\tau}^1, \bar{\tau}^2, \bar{\tau}^3, \ldots\ldots\ldots \bar{\tau}^U)$.

To select one SV set there are total N^V cases. That is $\bar{\tau}^u = \{\tau_1^u, \tau_2^u \ldots\ldots\ldots\ldots \tau_V^u\}$ can be varied from $\{0,0,\ldots\ldots\ldots 0\}$ to $\{N-1, N-1, \ldots\ldots\ldots\ldots N-1\}$.selection of only U SV sets from N^V can be done by using some criterions which can guarantee the PAPR reduction performance of the Cyclic shift PTS scheme without any risk.

To select SV sets the first assumption is that the components in the alternate OFDM signal sequences are mutually orthogonal That is, $x_v(0), x_v(1), \ldots, x_v(N-1)$ are mutually independent for all v. If U = 2 and V = 4, we can select two SV sets, $\bar{\tau}^1 = \{0,0,0,0\}$ and $\bar{\tau}^2 = \{0,0,0,1\}$.In this case, the PAPR reduction performance becomes not good because two alternative OFDM signal sequences (x^1 and x^2) generated by using these two SV sets may have high dependency each other. Instead, it is better to select two SV sets such as $\bar{\tau}^1$={0,0,0,0} and $\bar{\tau}^2$={0,1,2,3} which leads to increasing statistically independency between two alternative OFDM signal sequences ($x^1$and x^2). That is, in order to generate two alternative OFDM signal sequence within dependency, the relative distances $\tau_v^1 - \tau_v^2$ for all v's have to be distinct from each other. When U > 2, this has to be guaranteed for all possible SV set pairs out of U SV sets. Now by using this Criterion 1 is derived.

Criterion1: Suppose if U SV sets are considered then for every (i, j) pair out of the U SV sets ($i \neq j$), the pair should satisfy the condition that the relative distances $\tau_v^i - \tau_v^j$mod N are distinct from each other for all v's.
The Criterion 1 is valid when the components in all alternative OFDM signal subsequences are mutually independent. However, actually the OFDM signal subsequence components are not mutually independent. So to know the amount of correlation between components ACF is considered.

ACF of OFDM signal subsequences

Let $S_v$be the discrete power spectrum of the v^{th} OFDM signal subsequence x_v ,thenS_v= {p(0), p(1), . . . , p(N - 1) where $p(k)=E[|X_v(k)|^2]$, and p(k) can have the value of zero or one. If interleaved partition is used then S_1={10101010} and S_2 = {01010101} when N= 8 and V = 2.The ACF is the Inverse Discrete Transform(IDFT) of S_v.

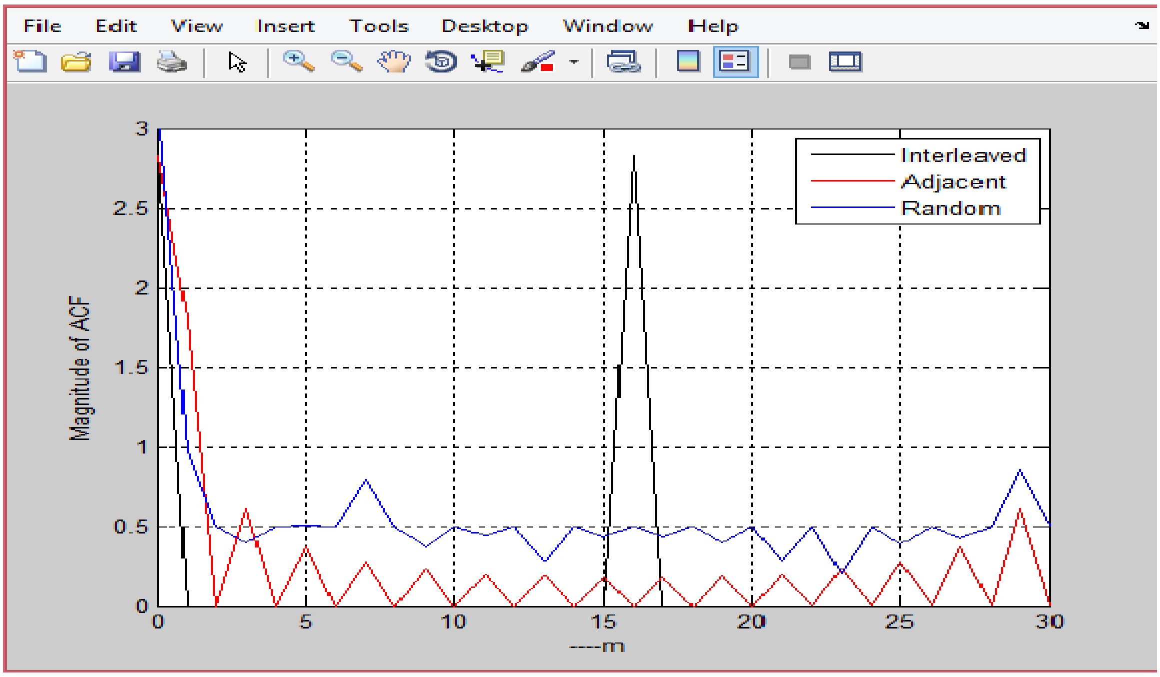

Figure 5 Magnitude of ACF for different partitions

Here only the magnitude of the ACF is considered because the high peak of the OFDM signal sequence is closely related to the magnitude of components. Figure5 shows the ACF among OFDM signal sequences when different partitions are used. So based on this information the SV sets selection is derived for three partition cases as per the amount of correlation. For Figure6 the values are S_1={1010…..1010}for an interleaved partition;S_1={11……1100……00} for an adjacent random partition.; S_1={10010110011111000110101110100000} for a random partition; N=32 and V=2.

For Random Partition:

In this case, the shape of the ACF is similar to a delta function. Therefore, the Criterion 1 Can be valid criterion.

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For Interleaved Partition

In this case, the shape of the ACF is the impulse train. Then cyclic shift by N/V cannot make the OFDM signal subsequence much different. Therefore, Criterion 1 has to be slightly modified as follows.

Criterion 2: Suppose if U SV sets are considered then for every (i, j) pair out of the U SV sets (i ≠j), the pair should satisfy the condition that the relative distances τ_v^i -τ_v^jmod N/V are distinct from each other for all v's.

For Adjacent Partition

In this case, the shape of the ACF is similar to a sinc function. Then cyclic shift by a small integer cannot make the OFDM signal subsequence much different. Instead, cyclic shift by an integer close to N/2 can make the OFDM signal subsequence much different. Therefore, the constraint that the relative distances have to be distinct from each other in Criterion 1 should be changed into a stronger constraint as follows.

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

Step4

Finally by using all the above factors the one with minimum PAPR is obtained. To reduce its PAPR further the output of adder is applied to μ-law companding circuit. . μ-law Companding is one of the methods to reduce PAPR of OFDM signal by increasing the average power of the signal with less circuit complexity. In the μ-law Companding, the compressor characteristic is piecewise, made up of a linear segment for low level inputs and a logarithmic segment for high level inputs.if x^u is considered as variable S then output is

$$\text{Output} = \frac{\log(1+\mu|S|}{\log(1+\mu)}\text{sgn}(S) \qquad (14)$$

Where μ is the Companding parameter which controls the amount of compression.

III. RESULTS

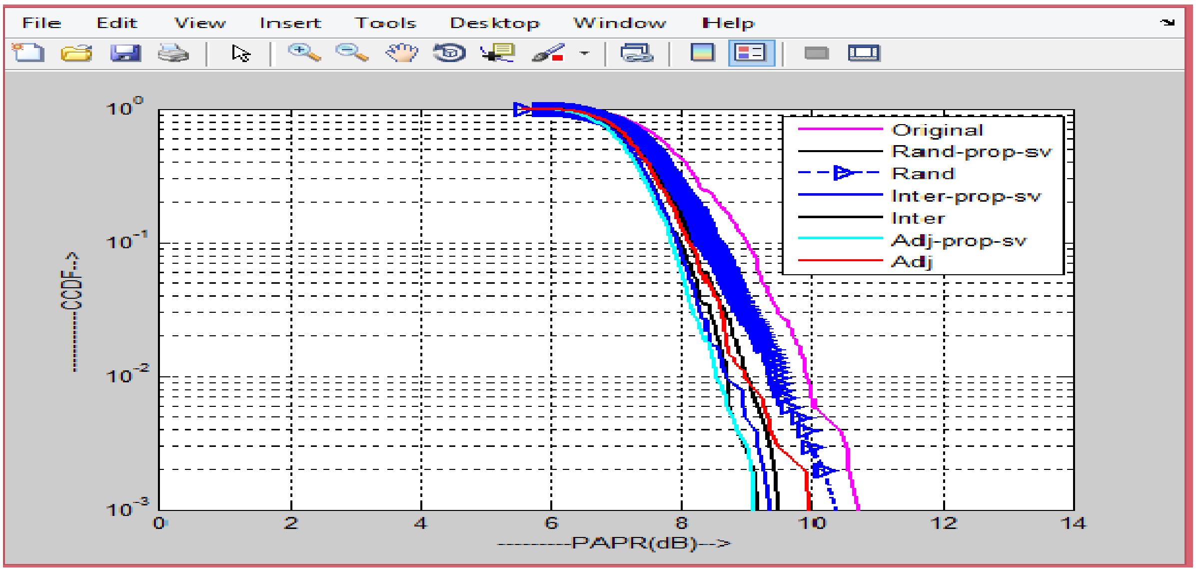

Figure 6.Comparison of the PAPR reduction performance of the CSS scheme for three partition cases, which are random, interleaved, and adjacent partition cases when N= 128, U= 4, and V= 4 according to the used SV sets.

Figure 6 shows the need of selection of SV sets and explains that how the Shift Value set shows impact on PAPR reduction. In this the SV sets which are generated according to criterion are shows better performance than not satisfying criterion SV sets.

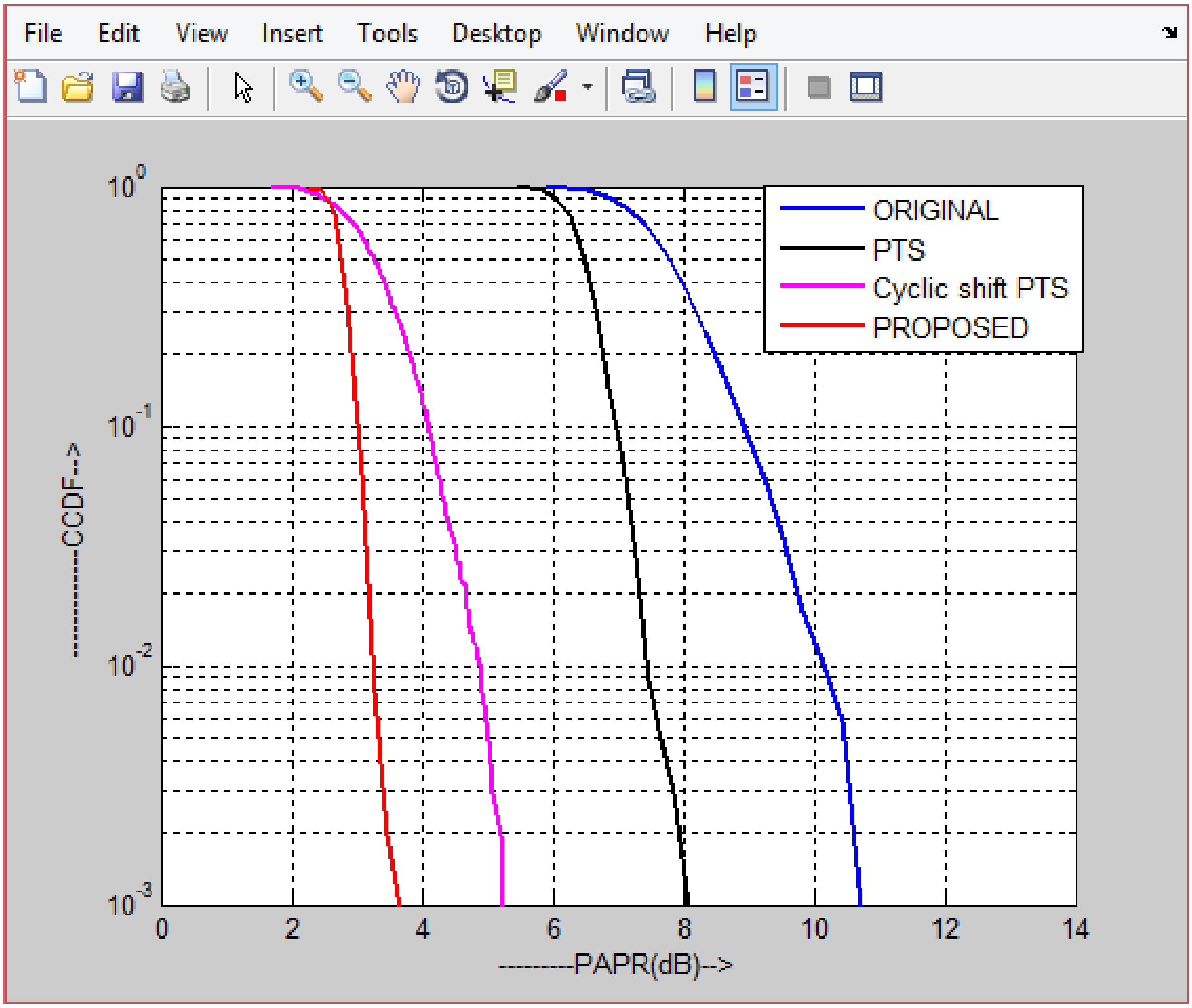

Figure 7. Comparison of PAPR values for different reduction methods

Figure 7 shows the comparison between PTS, Cyclic shift PTS and µ-law companding on cyclic shift PTS. The simulation results clearly shows that the PAPR is reduced 10.6 dB from 4 dB.

IV.CONCLUSION

In this paper a new technique is proposed for PAPR reduction, which combines two classic PAPR reduction methods the cyclic shift PTS and the Companding method. The Companding technique use µ-law with suitable values of µ. The simulations results prove that the performance of proposed method is better than the performance which can be obtained using only one of the two composing methods applied separately. This work can be extended by replace µ-law companding with other PAPR reduction techniques.

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