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PAPR Reduction Techniques by using combination of SLM and PTS Schemes for OFDM Systems

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Abstract **- Orthogonal Frequency Division Multiplexing(OFDM) is considered to be a promising technique for high data rate wireless communication. However, OFDM faces high Peak-to-Average Power Ratio (PAPR) problem that is a major drawback of multicarrier transmission system which leads to power inefficiency of HPA and DAC of the transmitter. This paper presents different PAPR reduction techniques with conventional hybrid SLM-PTS technique. In this paper, a new hybrid algorithm is proposed to obtain better PAPR reduction performance and reduce computational complexity compared with the conventional hybrid scheme. This proposed algorithm combines selected mapping (SLM) with partial transmit sequence (PTS) strategies, and further employs linear addition and exchange of various PTS sub-blocks to create more alternative OFDM signal sequences.**

Keywords: *OFDM, SLM, PTS, PAPR, HPA*

I. INTRODUCTION

In wireless communication systems, the orthogonal frequency division multiplexing (OFDM) technique is a widely popular and attractive scheme for high-data-rate transmission because it can cope with frequency-selective fading channel. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrow band sub channels experiences almost flat fading. Orthogonal frequency division multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications. [3] OFDM can provide large data rates with sufficient robustness to radio channel impairments. Many research centers in the world have specialized teams working in the optimization of OFDM systems. In an OFDM scheme, [4] a large number of orthogonal, overlapping, narrow band subcarriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the subcarriers is such that there is a very compact spectral utilization. With OFDM, it is possible to have overlapping sub channels in the frequency domain, thus increasing the transmission rate. The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects (a) Frequency selective fading. (b) Inter symbol interference (ISI). Orthogonal frequency division multiplexing (OFDM) technology is one of the most attractive candidates for fourth generation (4G) wireless communication. The basic block diagram of OFDM system is shown in figure 1.

The major problem one faces while implementing this system is the high peak – to – average power ratio of this system. A large PAPR increases the complexity of the analog – to – digital and digital – to – analog converter and reduces the efficiency of the radio – frequency (RF) power amplifier. This paper is organized as follows, in part 2 introductions about PAPR is given, part 3 explains about SLM and PTS techniques for PAPR reduction and part 4 gives new proposed method.

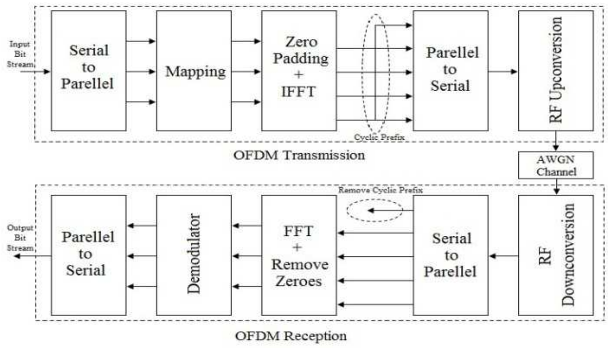

Figure 1: OFDM block diagram.

II. PAPR IN OFDM

OFDM signal exhibits a very high PAPR, which is due to the summation of sinc waves and non-constant envelope. Therefore, RF power amplifiers have to be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region causing signal distortion. This signal distortion introduces inter modulation among the subcarriers and out-of-band radiation. PAPR is a very important situation in the communication system because it has big effects on the transmitted signal. Low PAPR makes the transmit power amplifier works efficiently, on the other hand, the high PAPR makes the signal peaks move into the non-linear region of the RF power amplifier which reduces the efficiency of the RF power amplifier. In addition, high PAPR requires a high-resolution digital- to- analog converter (DAC) at the transmitter, high-resolution analog -to -digital converter (ADC) at the receiver and a linear signal. Any non-linearity in the signal will cause distortion such as inter-carrier interference (ICI) and inter symbol interference (ISI).

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

III. PAPR REDUCTION TECHNIQUES

A) Selective Level Mapping (SLM):

In the SLM technique [9] ,the transmitter generates a set of sufficiently different candidate data blocks, all representing the same information as the original data block, and selects the most favorable for transmission . A block diagram of the SLM technique is shown in Fig.2. Each data block is multiplied by U different phase sequences, each of length N, $B^{(u)} = [b_0, b_1, b_{N-1}]$, $u = 1, 2,...U$, resulting in U modified data blocks. To include the unmodified data block in the set of modified data blocks, we set b_1 as the all-one vector of length N. After applying SLM to X, the multicarrier signal becomes among the modified data blocks $X^{(u)}$, $u = 1, 2, U$, the one with the lowest PAPR is selected for transmission. Information about the selected phase sequence should be transmitted to the receiver as side information. At the receiver, the reverse operation is performed to recover the original data block. For implementation, the SLM technique needs U IFFT operations, and the number of required side information bits is $log_2 U$ for each data block. This approach is applicable with all types of modulation and any number of subcarriers. The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase sequences. Figure 2 shows the PAPR reduction using SLM method. Figure 3 shows the flowchart:

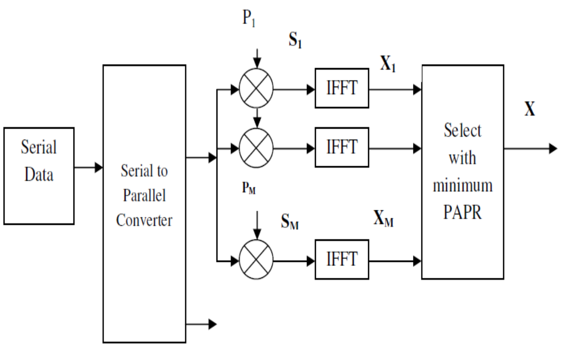

Figure 2:- PAPR reduction using SLM method.

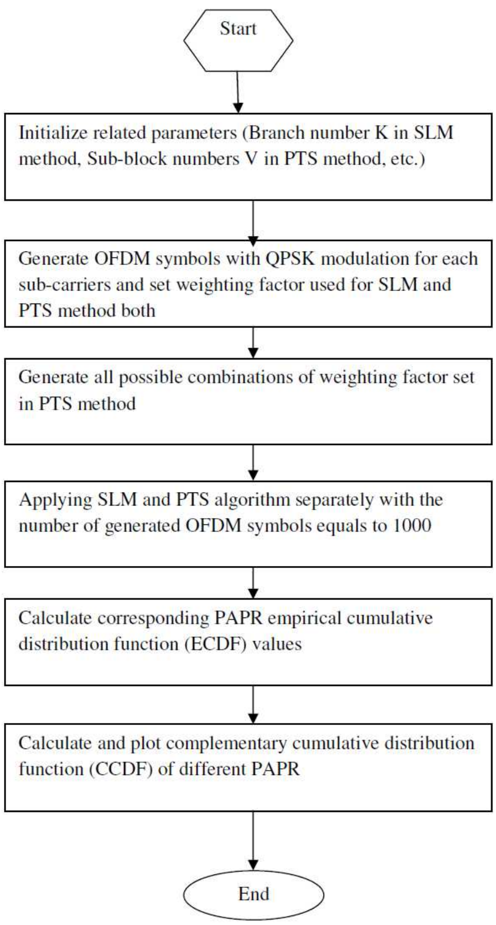

Figure 3: Flowchart for SLM method.

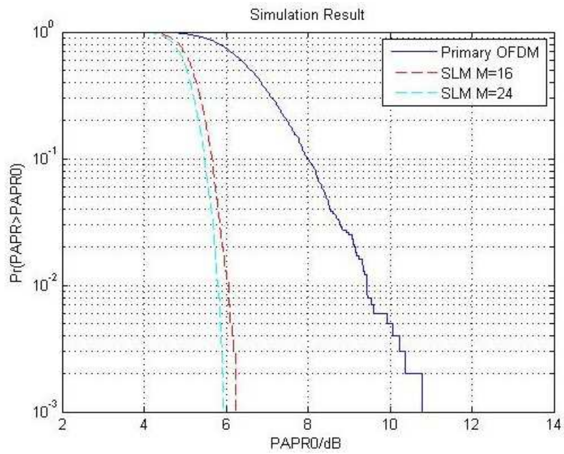

Figure 4: CCDF of PAPR with Different set of phase vectors (Elapsed time is 1.268421seconds).

B) Partial Transmit Sequence (PTS):

PTS method is a distortion less phase optimization scheme provides reduction of PAPR with a small amount of redundancy [7]. The input data is divided into number of disjoint sub blocks and they are weighted by a set of phase factors to create a set of candidate signals [6]. Finally the candidate signal with the lowest PAPR with the help of threshold is chosen for transmission. N denote the number of subcarriers used for parallel information transmission and X_k $(0 \leq k \leq N\text{-}1)$ represent the k^{th} complex modulated symbol in a block of information symbols. The objective is to optimally combine the V sub blocks to obtain the time domain OFDM signals with the lowest PAPR. Without any loss of performance, one can set $b_1=1$ and observe that there are $(V\text{-}1)$ sub blocks to be optimized. Consequently, to achieve the optimal phase factor for each input data sequence (assume that there are W phase vectors in the phase set), W_{v-1} combinations should be checked in order to obtain the minimum PAPR. Therefore, [1] the search complexity for an optimum set of the phase factors increases exponentially with the number of sub blocks.

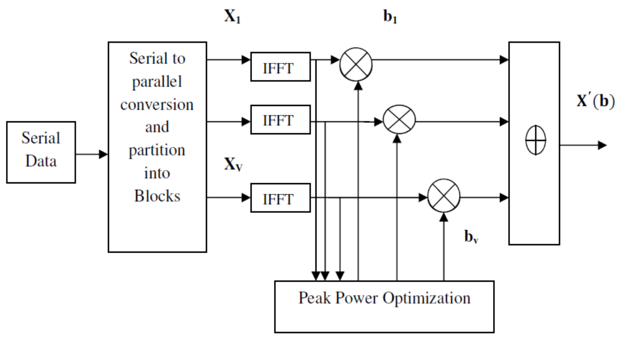

Figure 5: PAPR reduction using PTS technique.

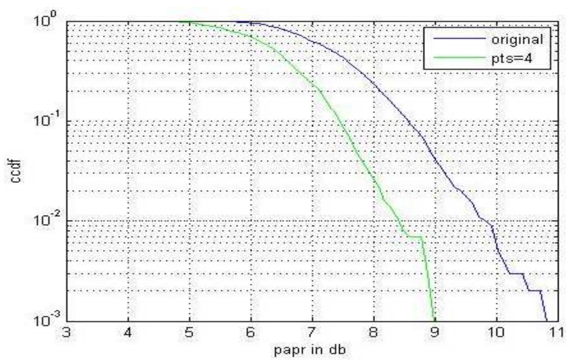

Figure 6: CCDF of PAPR for PTS technique.

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C) Earlier SLM-PTS Combined Method:

The block diagram of the earlier SLM-PTS combine method (so called CH method) is shown in Fig. 7. The original OFDM symbol is multiplied with the U phase rotation sequences, and then each of the new OFDM symbols is partitioned into V pair wise disjoint sub-blocks [1]. Those OFDM sub-block values are calculated by each optimization of PTS blocks. For simplicity and without loss of generality, $V = 2$ is always considered here. Each signal $x^{(u)}$, where $u = 1, . . . , U$, with the lowest PAPR is selected by each optimization block. They can be written as

$$\left\{\hat{b}_1^{(u)}, \hat{b}_2^{(u)}\right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{\arg\min}\left\{\sum_{v=1}^{2} b_v^{(u)} X_v^{(u)}\right\} \qquad (1)$$

$$\hat{X}^{(U)} = \sum_{v=1}^{2} b_v^{(u)} X_v^{(u)} \qquad (2)$$

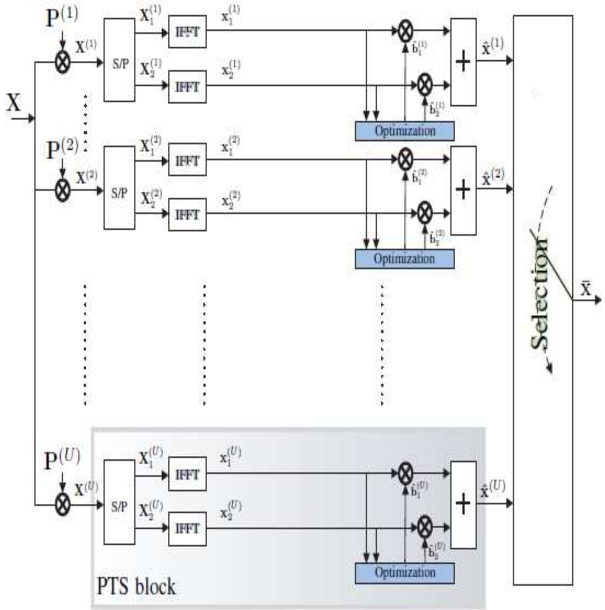

Figure 7: SLM-PTS combine method.

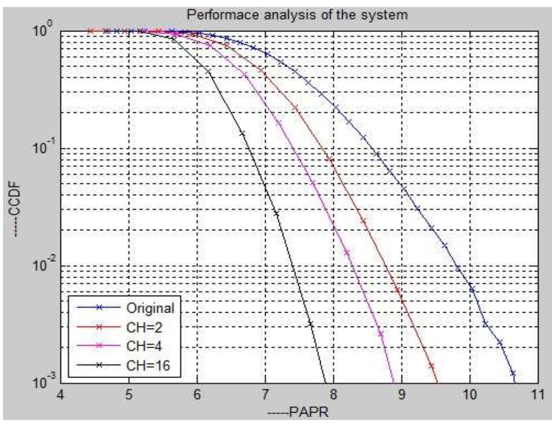

Figure 8 : CH method simulation.

D) Extended Hybrid Scheme:

In order to improve the PAPR reduction performance in CH scheme, we have to generate a large number of alternative OFDM signal sequences without increasing the number of IFFT to avoid high computational complexity [1]. Here, a new extended hybrid (AH) scheme by combining the modified SLM scheme with CH scheme.

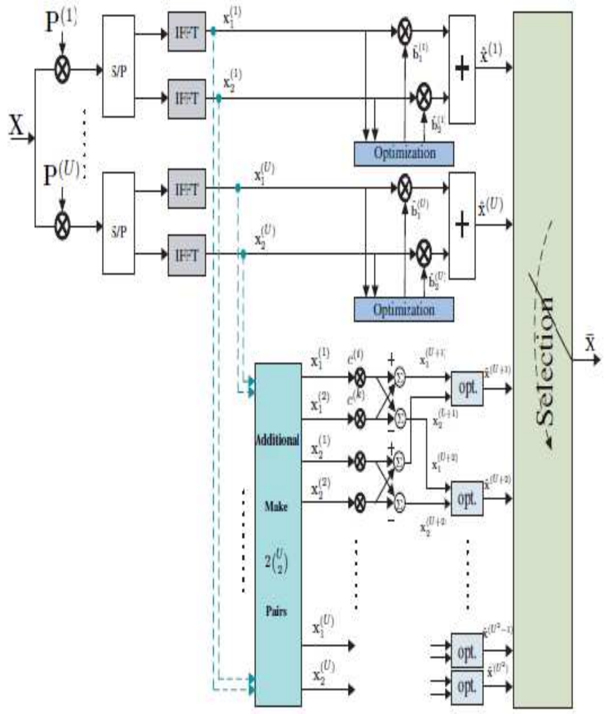

Figure 9: AH method.

The system performance is desirable that the number of IFFT is reduced but the PAPR reduction performance is not compromised. The block diagram of AH scheme is shown in Fig. 9. Clearly, the first U signals $x^{(u)}$, where $u = 1, . . . , U$, are the same as the signals (1) in the CH scheme [1]. Furthermore, the alternative OFDM signal sequences are generated by the linear combination of the sub-block signals from different PTS blocks after IFFT operation. Using the linear property of Fourier transform, the linear combination of these sequences can be obtained by

$$X_v^{(u)} = c^{(i)} X_v^{(i)} + c^{(k)} X_v^{(k)} \qquad (3)$$

where $U+1 \le u \le U^2$, $1 \le i, k \le U$, $1 \le v \le 2$, $c^{(i)}$ and $c^{(k)}$ are some coefficients to be chosen later. That is to say, if we have OFDM signal sequences $X_v^{(i)}$ and $X_v^{(k)}$, the other alternative OFDM signal sequences in (4) can be obtained without performing IFFT operation. Now, we would investigate how to make each element of $X_v^{(i)}$ and $X_v^{(k)}$ to have unit magnitude under the condition that each element of the phase sequences $P^{(i)}$ and $P^{(k)}$ has unit magnitude. Basically, the elements of the sequence $X_v^{(i)}$ and $X_v^{(k)}$, have unit magnitude if the following conditions are satisfied:-

$$c^{(i)} \pm \frac{1}{\sqrt{2}} \quad and \quad c^{(k)} \pm \frac{1}{\sqrt{2}} j \qquad (4)$$

Each element of $P(i)$ and $P(k)$ takes the value in (4).Since $|c^{(i)}|^2 = |c^{(k)}|^2 = 1/2$, the average power of $x^{(u)}$ is equal to one half of the sum of average power of $x^{(i)}$ and $x^{(k)}$. From U binary phase rotation sequences, we can obtain $2\ {}^{n}C_r$ excessive pair sub-blocks sequences, thus, there are total U^2 pair sub-blocks sequence for AH scheme. Then, the alternative OFDM signal of lowest PAPR in AH scheme can be written as

$$\left\{\hat{b}_1^{(u)}, \hat{b}_2^{(u)}\right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{\arg\min}\left\{b_1^{(u)} X_1^{(u)} + b_2^{(u)} X_2^{(u)}\right\} \qquad (5)$$

$$\hat{X}^{(U)} = \left\{ \hat{b}_1^{(u)} X_1^{(u)} + \hat{b}_2^{(u)} X_2^{(u)} \right\} \qquad (6)$$

We have to select and transmit the resulting OFDM signal sequence, which has the minimum PAPR among the whole OFDM signal sequences of overall lowest PAPR $x^{\wedge(u)}$ sequences, which are composed by $\{x_1^{(u)}, \ldots, x_v^{(u)}\}$ after each optimization operation. The number of required side information bits for transmitter can be written as

$$N_{AH} = \log_2 u^2 + (V-1)\log_2 w \qquad (7)$$

E) Switching Hybrid Scheme:

Instead of generating alternative OFDM sequences with linear combination, a new switching hybrid (SH) scheme by combining the switching technique with the CH scheme is used. The system performance is desirable that the number of IFFT is reduced but the PAPR reduction performance is not compromised. The block diagram of SH scheme is shown in

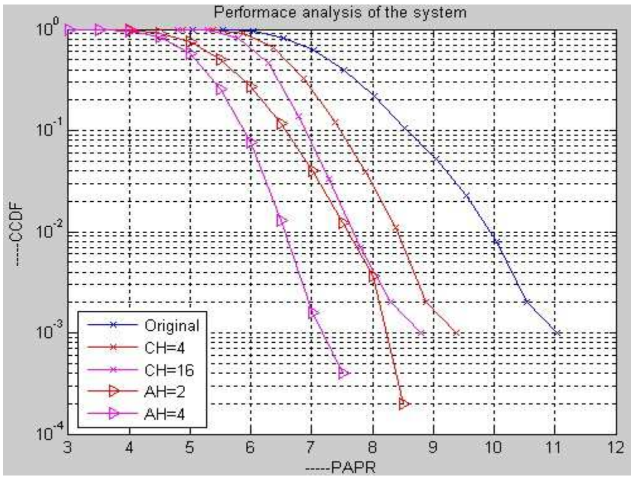

Figure 10: Simulation results of AH method.

Fig. (11). By the switching block, we can use original U pairs $\{x_1^{(u)}, x_2^{(u)}\}$ to generate excessive $2^U{}_2$ pairs of OFDM sequences without increasing the number of IFFT units. Thus, there are total U^2 pairs $\{X_1^{(u)}, X_2^{(u)}, X_3^{(u)}, X_4^{(u)},..\}$ are operated by each optimization unit. Obviously, the first U signals , $x^{\wedge(u)}$, where $u=1,\ldots.U$ are the same as the signals in the CH scheme. After the optimization blocks, the other alternative OFDM sequences with lowest PAPR $x^{\wedge(u)}$ can be written as

$$\left\{ \hat{b}_1^{(u)}, \hat{b}_2^{(u)} \right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{\arg\min} \left\{ b_1^{(u)} X_1^{(i)} + b_2^{(u)} X_2^{(k)} \right\} \qquad (8)$$

$$\hat{X}^{(u)} = \hat{b}_1^{(u)} X_1^{(i)} + \hat{b}_2^{(u)} X_2^{(k)} \qquad (9)$$

where $U+1 \le u \le U^2$, $1 \le i, k \le U$. In (9) $X_v^{(i)}$ and $X_v^{(k)}$ for $i \ne k$ come from different PTS blocks, which are generated by different phase rotation sequences, so that $P(i)$ and $P(k)$, where can obtain differently alternative OFDM sequences with the minimum PAPR. Noteworthy, the number of required side information bits can be written as

$$N_{SH} = \log_2 U^2 + (V-1)\log_2 W \qquad (10)$$

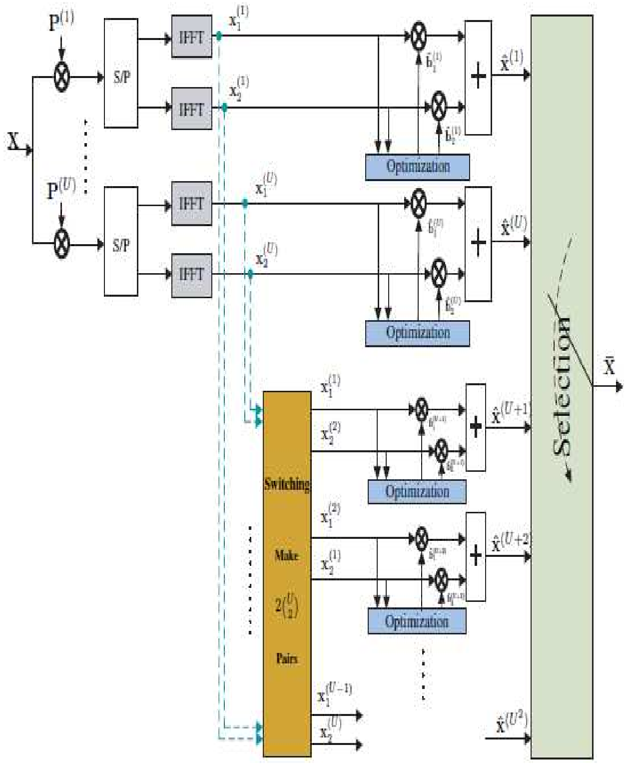

Figure 11: SH method.

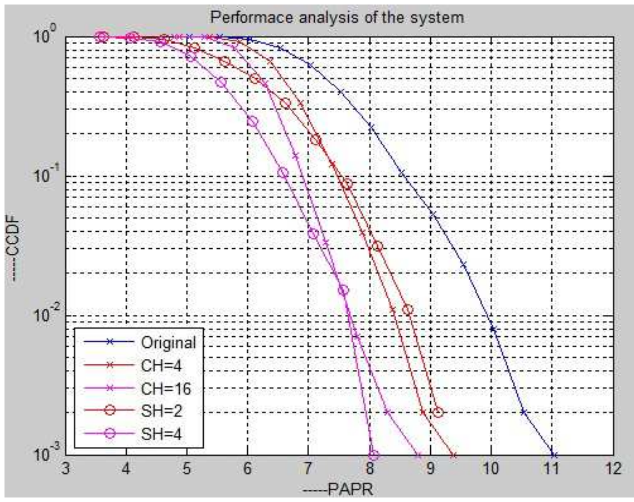

Figure 12: Simulation results of SH method.

F) Proposed hybrid Method:

In order to further improve PAPR reduction performance without increasing the number of IFFT operations, the new hybrid algorithm is proposed which uses both SLM and PTS schemes. Further both additional hybrid and conventional hybrid methods are used to generate more no. of alternative OFDM sequences. So without increasing the no. of IFFT operations, new set of values are produced to reduce computation complexity. Here by using additional hybrid scheme a new set of sequences is produced and again by using switching technique another set is produced. Both set are multiplied by different set of phase vectors and among all these one with minimum PAPR is selected. This proposed method improves PAPR performance to great extent as compared to earlier methods. The simulation result of proposed combined method is show in Fig. (13)

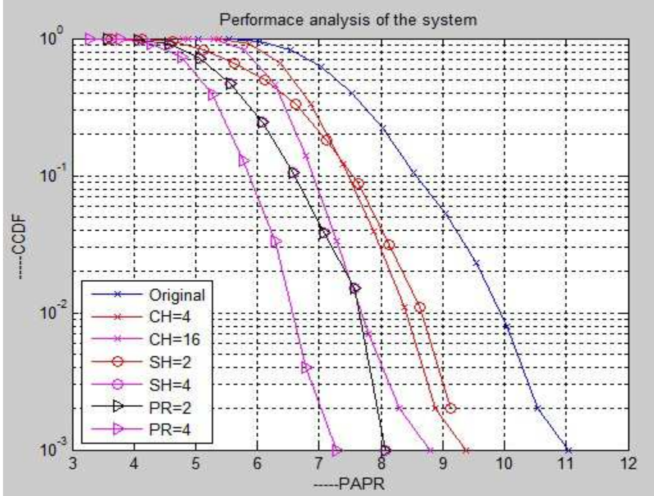

Figure 13: Simulation result of proposed method.

IV. CONCLUSION

In order to reduce PAPR many techniques like coding, phase rotation and clipping are used. Two different PAPR reduction methods e.g. partial transmits sequence (PTS) and selective mapping (SLM) are also used to reduce PAPR. Although SLM scheme is one of the effective methods to reduce PAPR of OFDM signals, the sequences are pseudo-random which will decrease the method effectiveness. In this paper, proposed hybrid algorithm obtained a better PAPR reduction performance and reduces computational complexity compared with the conventional hybrid scheme. In general, the PAPR reduction performance becomes better as the number of *U* increases in CH scheme, but the CH scheme has high computational complexity because of the increase of the number of IFFT. The AH scheme gives better performance but as compared to SH it has more computational complexity. So the new method is proposed which utilizes features of both the techniques and reduces PAPR to great extent.

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