A Cooperative Additional Hybrid and Clipping Technique for PAPR reduction in OFDM System

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Abstract— **OFDM is a multicarrier modulation technique used in the 4G wireless communication which provides numerous advantages such as High speed data transmission, high spectral efficiency, robustness to multipath fading etc. Despite of all these enormous advantages one of the major drawbacks associated with the OFDM system is the high Peak to Average Power ratio value. In this paper, we have proposed various algorithms such as Additional Hybrid technique, Alternate Additional Hybrid technique and Cooperative Additional Hybrid technique for finding the PAPR value in the OFDM system. After calculation of the PAPR values for the Alternate and Cooperative Additional Hybrid technique, we have applied the Clipping technique after IFFT in the Cooperative Additional Hybrid technique to suppress the excess peaks from the OFDM signal waveform thereby further reducing the PAPR value.**

Keywords— Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Additional Hybrid (AH) technique

I. INTRODUCTION

The day to day progressive discovery of increased multimedia wireless applications and devices have led to a strong demand for technology that can provide high speed data transmission and also utilize the available resources very efficiently. The technology that can fulfil all the demands for high data transmission and also utilize the available bandwidth resources effectively is the Orthogonal Frequency Division Multiplexing (OFDM) technology [1]. Research based on OFDM technology was first published by Robert W. Chang in the year 1966 [2].

OFDM is a multicarrier transmission system wherein a single higher rate data carrier is divided into a large number of parallel lower rate data carriers which are individually called as sub-carriers, thereby reducing the Inter symbol Interference (ISI) due to large symbol duration unlike the conventional Frequency Division Multiplexing (FDM) technology [3]. The sub-carriers in the OFDM signal are arranged in such a way that the sidebands of the individual sub-carrier overlap with each other and the corresponding output signal can be received without any adjacent carrier interference. Therefore, there is an efficient utilization of the bandwidth in the OFDM system. Due to all these merits, OFDM has been adopted as the standard choice for future high speed communication. It is also incorporated in the IEEE 802.11a and IEEE 802.11g for high speed data transmission. Various applications and standards in which OFDM has been incorporated is the Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) etc [4], [5]. However, one of the major drawback of the OFDM is the high PAPR which arises due to the IFFT operation. This high Peak to Average Power Ratio (PAPR) value causes the amplifier characteristics to shift in nonlinear region of operation, due to which OFDM system loses its Orthogonality leading to severe Inter carrier interference (ICI).

Based on the literature review of the research paper [6], several algorithms for reducing the PAPR value have been demonstrated. In this paper, we have worked on the concept of Additional Hybrid (AH) algorithm, and we are using a different approach for getting the simulation results. In these algorithms, we have carried out simulations by taking (V=4) as the number of sub-blocks. We have also modified the AH technique by reducing the computational complexity by considering only alternate number of sub-blocks for multiplication and this method is known as Alternate Additional Hybrid (alt-AH) technique. A Cooperative Additional Hybrid (Coop-AH) technique is also carried out where we use the property of circular permutation in order to further improve the PAPR performance we are using Coop-AH along with the Clipping technique.

The remaining paper is organized as follows. In Section II we have the description about the OFDM PAPR Problem. Section III describes the proposed techniques that we have used in our paper. Finally, Simulation results are given in Section IV, and Conclusions are drawn in Section V.

II. OFDM PAPR PROBLEM

For a discrete time domain signal x[n] PAPR is expressed as

$$\text{PAPR}\left(x[n]\right) = \frac{\max\limits_{0 \le n \le N-1} \left|x[n]\right|^2}{E\left[\left|x[n]\right|^2\right]} \tag{1}$$

where E [.] is the expectation operator. The PAPR calculation is done for every single OFDM symbol using the above formula [6]. The occurrence of IFFT pre-processing in the OFDM system is the main cause for increase in the PAPR value in the multicarrier OFDM system. This occurs because

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the data symbols of all the sub-carriers are random in nature and these symbols when added up coherently will produce a very high peak signal value with respect to the mean value. PAPR of the OFDM system is characterized by the Complementary Cumulative Distribution Function (ccdf) [7]. The ccdf plot displays the exact information of PAPR in terms of the percentage change in the OFDM signal. PAPR in the ccdf plot is measured when the probability of OFDM signal goes beyond the specified PAPR threshold level set within the OFDM system and is given by [1]

$$CCDF\left[PAPR\left(x^{n}(t)\right)\right] = \text{prob}\left[PAPR\left(x^{n}(t)>\delta\right)\right] \tag{2}$$

where $PAPR\left(x^{n}(t)\right)$ is the PAPR of the nth OFDM symbol and δ is some threshold taken for reference for finding the PAPR value.

III. PROPOSED HYBRID METHODS

A. Additional Hybrid (AH) Technique

This technique is basically the combination of modified Selective Mapping (SLM) along with the Partial Transmit Sequence (PTS) and is implemented with a view to improve the PAPR reduction performance [6]. In this technique, a large number of alternative OFDM signal sequences are created while keeping the number of IFFT operations constant in order to avoid the high computational complexity. The block diagram of the Additional Hybrid (AH) technique is shown in the Fig. 1. In this technique the original OFDM symbols are first multiplied by $P^{(u)}$ where u = 1,.,*U*. Here '*U'* denotes the phase rotation sequence. After multiplication of phase rotation sequences with the OFDM symbols, the product obtained is $\hat{X}^{(u)}$ which are distributed parallelly depending upon the value of the disjoint sub-block which is *V*=4 in this sequence. These OFDM sub-block sequences are converted in time domain by the process of IFFT. The signal obtained after the IFFT process are then subjected to multiplication with the phase rotation factors. This step of multiplication with the phase rotation factors is called as the optimization process wherein the lowest PAPR value among the disjoint sub-block sequences is calculated by the formula given in eqn. (1). After this step, we have alternate OFDM signal sequences generated which are replicated for each sub-block after the IFFT by V^2 (here *V*=4) and are carried downwards as shown in Fig.1. The linear combination of the OFDM signal with the additional sequence is given by

$$x_v^{(u)} = c^{(i,k)} x_v^{(i,k)} \tag{3}$$

where $U+1 \le u \le U^2$, $1 \le i, k \le U$, $1 \le v \le 4$ the co-efficient $c^{(i,k)}$ is chosen at later step. Suppose for instance we have OFDM signal sequences $x_v^{(i)}$ and $x_v^{(k)}$, the other OFDM sequences denoted by eqn. (3) can be obtained without performing IFFT operation. The value selected for $c^{(i)} = \pm\left(\frac{1}{\sqrt{2}}\right)$ and $c^{(k)} = \pm\left(\frac{1}{\sqrt{2}}\right)j$ and either of the value of $c^{(i,k)}$ can be selected at a time depending upon the number of elements of the phase rotation sequences. $P^{(i)}$ and $P^{(k)}$ takes value in ± 1. The average power obtained by $x_v^{(u)}$ is equal to the half of the sum of the average power of $x_v^{(i)}$ and $x_v^{(k)}$ because $\left|c^{(i)}\right|^2 = \left|c^{(k)}\right|^2 = \frac{1}{2}$. Thus, from *U* binary phase sequences, we obtain $2\binom{U}{2}$ excessive pair sub-block sequence, thus total U^2 pair sub-blocks sequence is obtained for AH technique. Therefore, in the AH technique the OFDM having the lowest PAPR is given by [6],

$$\left\{\hat{b}_1^{(u)},\hat{b}_2^{(u)},\hat{b}_3^{(u)},\hat{b}_4^{(u)}\right\} = \underset{\left\{b_1^{(u)},\, b_2^{(u)},\, b_3^{(u)},\, b_4^{(u)}\right\}}{\min\arg} \left\{b_1^{(u)}x_1^{(u)} + b_2^{(u)}x_2^{(u)} + b_3^{(u)}x_3^{(u)} + b_4^{(u)}x_4^{(u)}\right\}$$

$$\hat{x}^{(u)} = \hat{b}_1^{(u)}x_1^{(u)} + \hat{b}_2^{(u)}x_2^{(u)} + \hat{b}_3^{(u)}x_3^{(u)} + \hat{b}_4^{(u)}x_4^{(u)}$$

where $1 \le u \le U$.

Thus, we have to select the OFDM signal sequence $\bar{X}$ such that it has the minimum PAPR among the values of $\hat{x}^{(u)}$ signal sequences after each optimization operation.

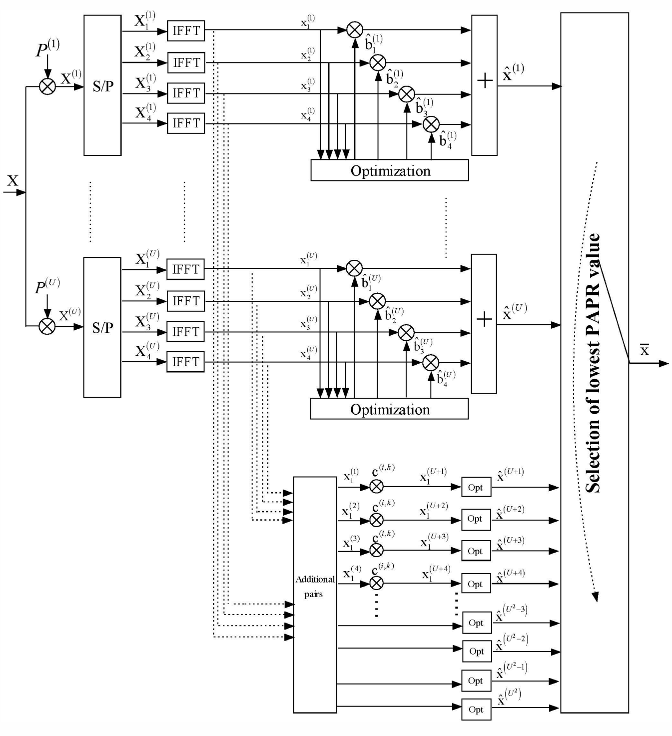

Fig. 1. Block diagram of Additional Hybrid technique

B. Alternate Additional Hybrid Technique (alt-AH)

In this Alternate Additional Hybrid technique (alt-AH), the concept of optimization of AH algorithm takes place. In this algorithm, weighting co-efficients are multiplied by the disjoint sub-block sequences only for the half of the sub-block sequences [8], [9] as shown in Fig. 2. For example, the first sub-block is kept as it is and the second sub-block sequence is multiplied by phase rotation factor then again, the next sub-block i.e. third sub-block will be kept as it is and then the fourth sub-block is again multiplied by particular phase rotation factor. This repetitive multiplication of phase rotation factor is done for every alternate sub-block. Finally, after all the multiplication sequences there will be 50% sub-block sequences which will be multiplied by phase rotation factors and 50% sub-block sequences will be non-multiplied by phase rotation factors. Due to this, there is a tremendous reduction in the computational complexity.

C. Cooperative Additional Hybrid (Coop-AH) Technique & Clipping Technique

In order to implement Cooperative Additional Hybrid (Coop-AH) technique, which is based on the Alternate Additional Hybrid technique, every alternate sub-block is first multiplied by phase rotation factors so that total 50% of the sub-block are kept as it and rest 50% of the sub-block sequence is multiplied by the phase rotation factor for the purpose of phase optimization. By doing this, the computational complexity of the system is reduced. So, in order to increase the number of candidate sequences, spatial sub-block circular permutation technique is employed for all the even sub-blocks wherein the sequence of the even sub-block is modified merely by circular permutation [8]. After the Coop AH technique, Clipping is also applied to get a better PAPR value by suppressing the unwanted peaks. As we all know clipping is one of the simplest PAPR reduction technique, we have employed this technique to reduce the PAPR value in the transmitter section of the OFDM section. In this technique, we have limited the signal to some threshold value or a predetermined clipping level. In this paper the clipping threshold level taken is 90% of the peak value which ultimately leads to cancellation of the upper 10% of the unwanted signal. We know that these unwanted clipping can pose some problems in the PAPR value keeping that in mind we have reduced the signal peak clipping to only 10% and thereby allowing all the 90% of the OFDM signal to pass through the system.

IV. SIMULATION RESULTS

All the simulations are performed in MATLAB software. The threshold level for comparing the PAPR values for all the reduction techniques used in this paper is considered to be at 50% probability in the ccdf plot. We begin by investigating the PAPR for OFDM signal based on the block diagram shown in the Fig.1. The common simulation parameters for all the reduction techniques are mentioned in the Table I. given below.

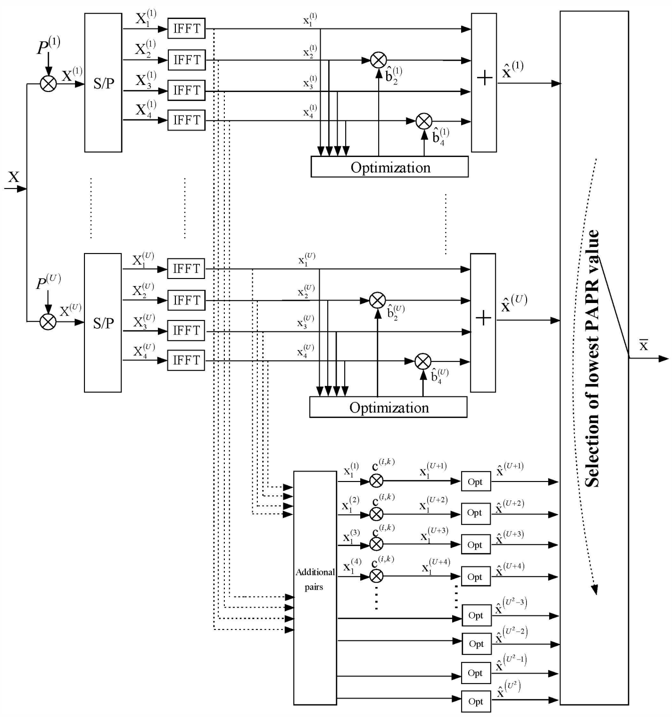

Fig. 2. Block diagram of Alternate Additional Hybrid technique

TABLE I
Simulation Parameters

Simulation Parameters	Values
No. of OFDM symbols	5678
No. of sub-carriers	64
Modulation Technique	QPSK
Oversampling factor	4
No. of sub-blocking used	V= 4
Phase rotation factors	$b^v \in \{\pm 1, \ \pm j\}$
Phase rotation sequences	$P^u \in \{\pm 1\}$

A. Performance of Additional Hybrid (AH), Alternate AH, Cooperative AH technique

In this section, we investigate the PAPR of Additional Hybrid technique and Alternate Additional Hybrid reduction technique based on the block diagram shown in the Fig. 1 and Fig. 2 respectively. The simulation parameters are shown in Table I.

As seen from the ccdf plot of Fig. 3. the average PAPR value of the original OFDM signal i.e. at 50% probability is measured to be 7.271 dB. After applying the Additional Hybrid technique, the PAPR of the signal with U=2 and U=4 phase rotation sequences is 6.925 dB and 6.569 dB respectively. This shows that as we increase the number of phase rotation sequence, the OFDM signal shows an improvement in the PAPR value. Further reduction in the PAPR value can be obtained by applying the Alternate Additional Hybrid reduction technique which gives PAPR value of 6.254 dB and 5.875 dB for U=2 and U=4 phase rotation sequence respectively. Finally, upon application of Cooperative Additional Hybrid reduction technique, the PAPR value obtained for the signal is approximately 5.747 and 5.360 for U=2 and U=4 phase rotation sequence respectively as shown in Table II.

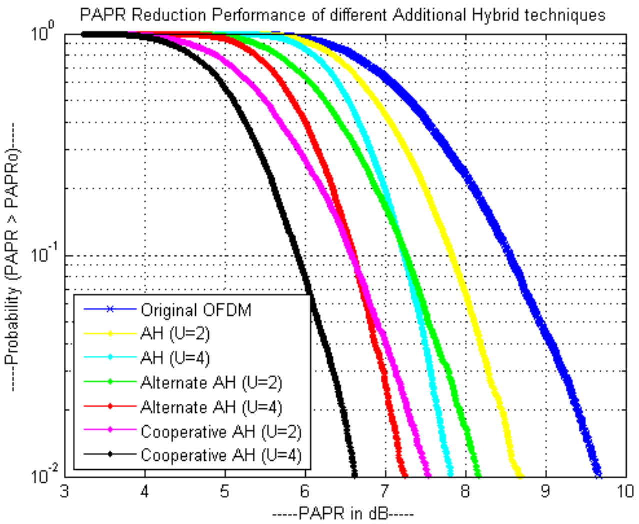

Fig. 3. The PAPR reduction performance of Additional Hybrid (AH), Alternate AH, Cooperative AH technique.

TABLE II
Performance Comparison of Additional Hybrid (AH), Alternate AH, Cooperative AH technique.

Parameters	$PAPR_o\left(\frac{10^0}{2}\right)$
Original OFDM	7.271 dB
AH (U=2)	6.925 dB
AH (U=4)	6.569 dB
Alternate AH (U=2)	6.254 dB
Alternate AH (U=4)	5.875 dB
Cooperative AH (U=2)	5.747 dB
Cooperative AH (U=4)	5.360 dB

B. Performance of Additional Hybrid (AH), Alternate AH, Cooperative AH technique along with Clipping technique

Here we investigate the PAPR based on the block diagram shown in the Fig. 2. The simulation parameters are shown in the Table I. From the simulation results obtained from ccdf plot in Fig. 4. we have taken the Additional Hybrid, Alternate AH and Cooperative AH technique for (U=4) number of phase rotation sequences only. In the figure, we have also added the Clipping technique after the IFFT process in the Alternate Additional Hybrid technique for reducing the PAPR value. The PAPR value of the signal after applying the Clipping threshold level for 90% of the OFDM signal waveform, the signal waveform which exceeds 90%, ie. The upper 10% of the OFDM signal will be clipped off due to the threshold level from the OFDM signal waveform. In order to have smooth transmission we have taken the clipping percentage for the signal to be clipped at 90% so that maximum signal is passed without any distortion. The PAPR of the combined Cooperative Additional Hybrid along with Clipping technique is found to be the lowest as shown in Table III.

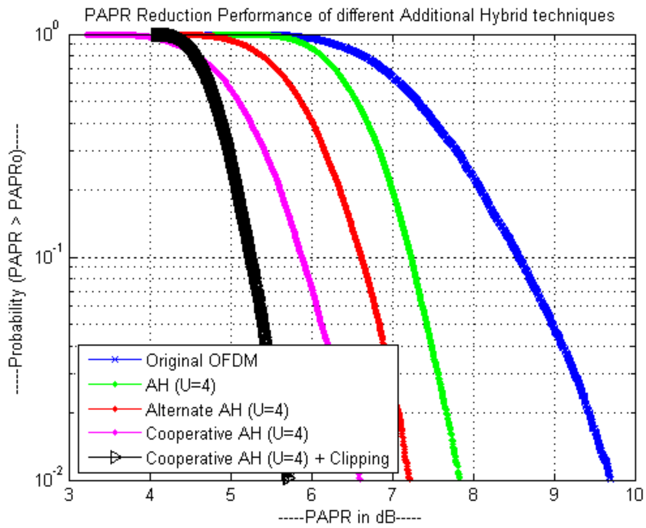

Fig.4. The PAPR reduction performance of Additional Hybrid (AH), Alternate AH, Cooperative AH technique along with Clipping technique

TABLE III.
Performance Comparison of Additional Hybrid (AH), Alternate AH, Cooperative AH technique along with Clipping technique for (U=4).

Parameters	$PAPR_o\left(\frac{10^0}{2}\right)$
Original OFDM signal	7.290 dB
AH (U=4)	6.570 dB
Alternate AH (U=4)	5.872 dB
Cooperative AH (U=4)	5.342 dB
Cooperative AH (U=4) + Clipping	4.823 dB

V. CONCLUSION

As per the results obtained from the simulation of the different Additional Hybrid (AH) techniques and Clipping technique, we can conclude that as the number of phase rotation sequence increases in the Alternate and Cooperative Additional Hybrid reduction techniques, PAPR reduction performance becomes much better and reduces considerably. Further reduction in the PAPR have been achieved when we have applied the Clipping technique by setting a threshold value or the threshold clipping level above which the unwanted peaks are suppressed and cancelled out effectively without causing a distortion in the OFDM signal.

Therefore, a combination of Cooperative Hybrid and Clipping technique possesses the best output as compared to only Additional Hybrid technique.

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