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Peak-To-Average Power Ratio (PAPR) Reduction in Ofdm Systems Using Dummy Signal Hybrid Slm-Pts Technique

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ABSTRACT
OFDM is a promising technique for the present generation communication systems where high data rate and fading channels are of major concern. However still some challenging issues remain unresolved in the design of OFDM systems. One of the major problem is high PAPR. The high PAPR of transmitted systems reduces the system efficiency and hence increases the cost of Radio Frequency(RF) Power Amplifier and also degrades the BER. In this paper, a Dummy Signal Hybrid (DH) SLM-PTS scheme is proposed to obtain the better PAPR reduction performance with reduced computational complexity. The simulation results are examined with other hybrid schemes and found that DH scheme provides better PAPR reduction performance compared to other hybrid schemes but at the cost of computational speed, because each time it compares the PAPR of the signal with threshold value and generates dummy signal accordingly with reduced PAPR.
Keywords- CCDF, OFDM, PAPR, PTS, SLM.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a promising solution for high data rate transmission because it has high spectral efficiency and is robust against Frequency Selective Fading channels. Hence is the most preferred multicarrier modulation technique for the future generation mobile communications systems [1]. However, some drawbacks are still unresolved in the design of OFDM system. A major drawback of OFDM is the high Peak-to-Average-Power-Ratio (PAPR) of transmitted signal. When the signals of all the sub-carriers are added constructively, the peak power can be the number of sub-carriers times the average power. When a high PAPR OFDM signal passes through a nonlinear device, it may cause in-band distortion and undesired spectral spreading. Thus, handling occasional large peaks leads to low power efficiency. Therefore, how to find a solution to reduce high PAPR effectively is one of the most important implementation issues in OFDM communications. [2][3]

To deal with this problem, many PAPR reduction schemes have been proposed, such as block Coding, Clipping, Companding transform schemes, Selective Mapping (SLM) and Partial Transmit Sequence (PTS)[4]. Among all the above techniques SLM-PTS are most widely used techniques.

1.1. Selected mapping (SLM) And Partial Transmit Sequence (PTS) Techniques

In SLM technique, 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.[5][6]

In PTS technique, each input data block is partitioned into a number of disjoint sub-blocks, and then the inverse FFT of all the sub-blocks are optimally combined to form a low PAPR OFDM signal transmission.[5][6]

Based on the preceding survey results, a novel hybrid SLM-PTS methods was proposed combining SLM and PTS methods and based on it, other Hybrid methods such as, AH, SH, MH were introduced. In this paper a new Hybrid Scheme DH was proposed and compared it's performance with other hybrid schemes.

II. SYSTEM DESCRIPTION

2.1. OFDM System Model

A discrete-time OFDM model with N sub-carriers is considered. With the linearity property of the N narrow sub-carriers, the discrete-time OFDM signal can be written as:

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

where, n= 0,1,.....,N-1. For simplicity we can have x=IFFT(X), where $X = [X(0), \ldots\ldots, X(N-1)]^T$.

2.2. PAPR And Complementary Cumulative Distributive Function

PAPR of a signal can be defined as:

$$\mathrm{PAPR} = \frac{\max_{0 \le n \le N-1} |x(n)|^2}{E\{|x(n)|^2\}} \qquad (2)$$

where E{.} denotes expectation operator.

As, PAPR is a random variable, an adequate statistics is needed to characterize it. The CCDF is one of the most regularly used parameters, which is used to measure efficiency of any PAPR techniques [7]. CCDF is used to measure the PAPR of certain data block exceeds the given threshold $PAPR_0$, that is the CCDF of PAPR can be written as:

$$\mathrm{CCDF}(\mathrm{PAPR}_0) = \mathrm{PR}(\mathrm{PAPR} > \mathrm{PAPR}_0) \qquad (3)$$

In general, for OFDM systems with Gaussian time domain samples, the CCDF of PAPR can be written as:

$$\Pr(\mathrm{PAPR} > \mathrm{PAPR}_0) = (1 - e^{-\mathrm{PAPR}\,0})^N \qquad (4)$$

III. PAPR REDUCTION USING HYBRID SLM-PTS TECHNIQUES

3.1. Conventional Hybrid Scheme

Conventional Hybrid scheme (CH) is the PAPR reduction technique, where SLM AND PTS schemes are combined. In this method the original OFDM symbol is multiplied with U phase rotation sequences, and then each of the new OFDM symbol is partitioned into V pair wise disjoint sub-blocks. These OFDM sub-blocks values are calculated by each optimization of PTS blocks. In general, for simplicity V is considered to be 2. Each signal $\hat{x}^{(u)}$, where u=1,......U, with lowest PAPR is selected by each optimization block [8]. They can be written as:

$$\left\{\hat{b}_1^{(u)}, \hat{b}_2^{(u)}\right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{\operatorname{argmin}} \left\{\sum_{V=1}^{2} b_V^{(u)} x_V^{(u)}\right\} \qquad (5)$$

$$\hat{x}^{(u)} = \sum_{V=1}^{2} b_V^{(u)} x_V^{(u)} \qquad (6)$$

where, $1 \le u \le U$. By the selection block, the relative low PAPR can be obtained from those lowest PAPR values of each PTS block. The CCDF of the CH scheme can be written as:

$$\mathrm{CCDF}_{CH} = \left(\Pr(\mathrm{PAPR}_{PTS} > \mathrm{PAPR}_0)\right)^U \qquad (7)$$

In order to recover the transmitted data information, the receiver must have the knowledge of side information. Therefore the required side information bits can be written as:

$$N_{CH} = \log_2 U + (V-1)\log_2 W \qquad (8)$$

where, w is the number of allowed phase rotation factors. In the above equation the first and the second term represents the SLM and PTS required side information bits.

3.2. Additional hybrid scheme

PAPR reduction is improved in CH scheme, by generating a large number of alternative OFDM signal sequences without increasing the number of IFFT to avoid high computational complexity. Here a new additional hybrid (AH) scheme by combining the modified SLM scheme with CH scheme. The system performance is not compromised.[8]

Clearly, the first U signal $\hat{x}^{(u)}$, where $u = 1, \ldots., U$, are the same as the signal in the CH scheme. Furthermore, the alternative OFDM signal sequence are generated by the linear combination of the sub-block signal from different PTS blocks after IFFT operation. Using the linear property of Fourier transform, the linear combination of these sequence can be obtained by:

$$x_v^{(u)} = c^{(i)} x_v^{(i)} + c^{(k)} x_v^{(k)} \qquad (9)$$

Where $U + 1 \le u \le U^2, 1 \le i, k \le U, 1 \le v \le 2$, and $c^{(i)}$ and $c^{(k)}$are some coefficient to be chosen later. That is to say, if we have OFDM signal sequence $x_v^{(i)}$ and $x_v^{(k)}$, alternative OFDM signal sequence is 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 sequence $P^{(i)}$ and $P^{(k)}$ has unit magnitude. Basically the element of the sequence $X_v^{(i)}$ and $X_v^{(k)}$ have unit magnitude if the following condition are satisfied:

- $c^{(i)} = \pm(1/\sqrt{2})$ and $c^{(k)} = \pm(1/\sqrt{2})j$ and
- Each element of $P^{(i)}$ and $P^{(k)}$ takes the value in ± 1.

Since $\left|c^{(i)}\right| = \left|c^{(k)}\right|^2 = 1/2$, the average power of $x_v^{(u)}$ is equal to one half of the sum of average power of $x_v^{(i)}$ and $x_v^{(k)}$..From U binary phase rotation sequences, we can obtain $2\binom{U}{2}$ excessive pair sub-block sequences thus, there are total U^2 excessive pair sub-blocks sequence for AH schemes. Then the alternative OFDM signal of lowest PAPR in AH scheme can be written as:

$$\left\{b_1^{(u)}, b_2^{(u)}\right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{argmin} \left\{b_1^{(u)} x_1^{(u)} + b_1^{(u)} x_2^{(u)}\right\} \qquad (10)$$

$$\hat{x}^{(u)} = \hat{b}_1^{(u)} x_1^{(u)} + \hat{b}_1^{(u)} x_2^{(u)} \qquad (11)$$

Where $U + 1 \le u \le U^2$.

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

$$N_{AH} = \log_2 U^2 + (V-1)\log_2 W \qquad (12)$$

3.3. Switching hybrid scheme

Instead of generating alternative OFDM sequence with linear combination , a new switching hybrid (SH) scheme by combining the switching technique with the CH scheme.[8] The system performance is desirable that the number of IFFT is reduced but the PAPR reduction performance is not compromised.

By the switching block, we can use original U pairs $\left\{x_1^{(u)}, x_2^{(u)}\right\}$ to generate excessive $2\binom{U}{2}$ pairs of OFDM sequences without increasing the number of IFFT units. Thus, there are total U^2 pairs $\{x_1^{(u)}, x_2^{(u)}, \ldots, x_1^{(u^2)}, x_2^{(u^2)}\}$ are operated by each optimization unit. Obviously, the first U signals $\hat{x}(u)$, 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 $\hat{x}(u)$ can be written as:

$$\left\{b_1^{(u)}, b_2^{(u)}\right\} = \underset{\left\{b_1^{(u)}, b_2^{(u)}\right\}}{argmin} \left\{b_1^{(u)} x_1^{(i)} + b_1^{(u)} x_2^{(k)}\right\} \quad (13)$$

$$\hat{x}^{(u)} = \hat{b}_1^{(u)} x_1^{(i)} + \hat{b}_2^{(u)} x_2^{(k)} \quad (14)$$

where U + 1 ≤ u ≤ U2, 1 ≤ i, k ≤ U and i ≠ k. In(14), $x_v^{(i)}$ and $x_v^{(k)}$, i ≠ k come from different PTS blocks, which are generated by different phase rotation sequences, so that $P^{(i)}$and $P^{(k)}$, where $1 \leq i, k \leq U, i \neq k$, can obtain differently alternative OFDM sequences with the minimum PAPR. Noteworthy, the number of required side information bits can be written as:

$$N_{SH} = \log_2 U^2 + (V-1)\log_2 W \quad (15)$$

3.4. Modified hybrid scheme

In order to further improve the PAPR reduction performance without increasing the number of IFFT, the modified hybrid (MH) algorithm is proposed by combining AH and SH schemes to generate more and more alternative OFDM sequences [8]. Those $\left\{x_1^{(u)}, x_2^{(u)}\right\}$ pairs, where$1 \leq u \leq U$, are the signal inputs of the additional block and switching block respectively and simultaneously.

Using the linear property of Fourier transform, the linear combination of U phase rotation sequences can obtain excessive $2\binom{U}{2}$ alternative OFDM sequences. After optimization blocks, those overall lowest PAPR $\hat{x}^{(u)}$ can be written as the same as (11). Using the switching technique among PTS blocks, the signals of U phase rotation sequences can obtain excessive $2\binom{U}{2}$ alternative OFDM sequences.

In the MH scheme, if V = 2 and U phase rotation sequences are considered, the original signals $x_v^{(u)}$ can generate excessive $2\binom{U}{2}$ pairs of sequences respectively and simultaneously by either additional block or switching block. Therefore, there are total $2U^2 - U$ OFDM sequences with the lowest PAPR in the MH scheme. In order to recover the transmitted data information, the number of required side information bits can be obtained by:

$$N_{MH} = \log_2(2U^2 - U) + (V-1)\log_2 W \quad (16)$$

IV. DUMMY SIGNAL HYBRID SCHEME

In this method, first the original OFDM symbol is multiplied with the U phase rotation sequences and then the complex valued dummy signals are generated and added to the vector of data sub-carriers[9]. The new vector is then constructed from K-data and L-dummy subcarriers in the frequency domain. L can be any number less than k. The new vector s is given by:

$$S = [X_k, W_l] \quad (17)$$

Where $X_k = [X_{k,0}, X_{k,1} \ldots \ldots .., X_{k,N-L-1}]$, k = 1,2,.......K is the data subcarrier vector and $W_l = [W_{l,0}, W_{l,1} \ldots \ldots .., W_{l,L-1}]$, l = 1,2,.......L is the dummy signals vector.

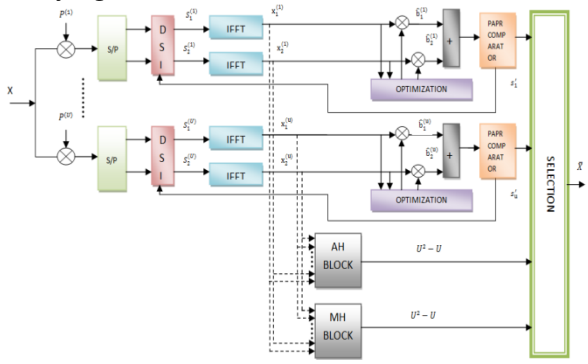

figure 1: block diagram of dummy signal hybrid scheme

Now, this new OFDM vector is partitioned into V pair disjoint sub-blocks. Those OFDM sub-blocks values are calculated by each optimization of PTS blocks. After the generation of the optimum OFDM signal, the PAPR is checked with the acceptable threshold that is predefined before. If the PAPR value is less than the threshold, the original OFDM signal will be transmitted otherwise the dummy signal is again generated with the feedback as shown in Fig.1 This process is one iteration. The number of iterations can be increased to achieved the desired PAPR .

$$\bar{X} = argmin\left\{\sum_{V=1}^{2} s'_{\{U\}}\right\} \quad (18)$$

$$S'_{\{U\}} = \sum_{V=1}^{2} x_V^{(U)} . \hat{b}_V^{(U)} \quad (19)$$

In the DH scheme, if V = 2 and U phase rotation sequences are considered, the original signals $x_v^{(u)}$ can generate excessive $2\binom{U}{2}$ pairs of sequences respectively and simultaneously by either additional block or switching block. Therefore, there are total $2U^2 - U$ OFDM sequences with the lowest PAPR in the DH scheme. In order to recover the transmitted data information, the number of required side information bits can be obtained by:

$$N_{DH} = \log_2(2U^2 - U) + (V-1)\log_2 W \quad (20)$$

V. COMPARATIVE SIMULATION RESULTS

Table 1: Simulation Parameters

Simulation parameters	Specifications
Number of OFDM symbols	5000
Number of subcarriers	64
Number of sub blocks	V = 2
Phase Rotation Factors	$b^{(v)} \in \{\pm 1, \pm j\}$
Phase Rotation Sequences	$P^{(U)} \in \{\pm 1\}$
Modulation Scheme	QPSK

Table 2: Side Information And Performance Comparison For Various Papr Reduction Schemes

Schemes	$PAPR_0(10^{-3})$	Side Information
Original	11.04	-
CH	8.03	$N_{CH} = log_2 U + (V-1) log_2 W$
AH	8.01	$N_{AH} = \log_2 U^2 + (V-1)\log_2 W$
SH	8.01	$N_{SH} = \log_2 U^2 + (V-1)\log_2 W$
MH	7.02	$N_{MH} = \log_2(2U^2 - U) + (V-1)\log_2 W$
DH	6.02	$N_{DH} = \log_2(2U^2 - U) + (V-1)\log_2 W$

Table I specifies the system parameters for comparative simulations. Fig. 2,3,4,5,6 shows the PAPR reduction performance with CH, AH, SH, MH and DH for various values of 'U'. It can be observed that as the number of 'U' increases from U=2,4,16,..., the PAPR reduction performance becomes better and also it could be observed that AH, SH, MH and DH shows better PAPR reduction performance compared to the CH scheme for the same value of 'U'. In table II, PAPR reduction performance and side information of various schemes is discussed.

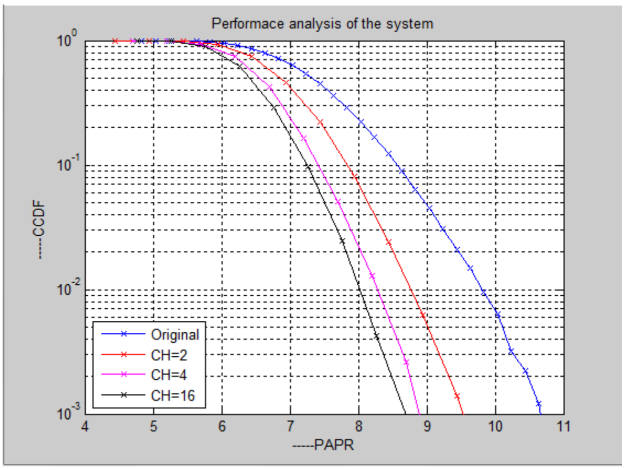

figure 2: the papr reduction performance of conventional hybrid scheme for ofdm systems.

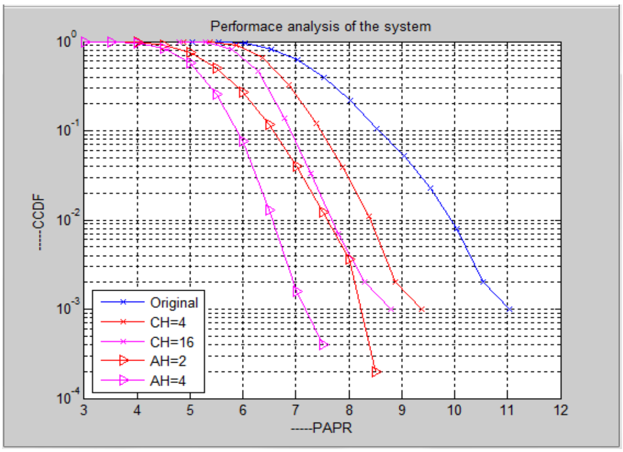

figure 3: the papr reduction performance of additional hybrid scheme for ofdm systems.

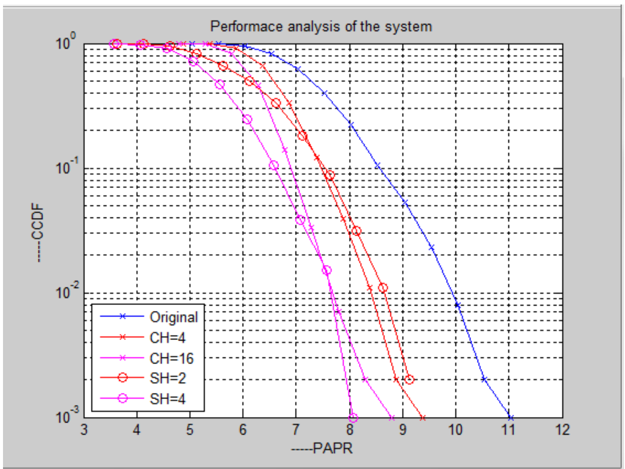

figure 4: the papr reduction performance of switching hybrid scheme for ofdm systems.

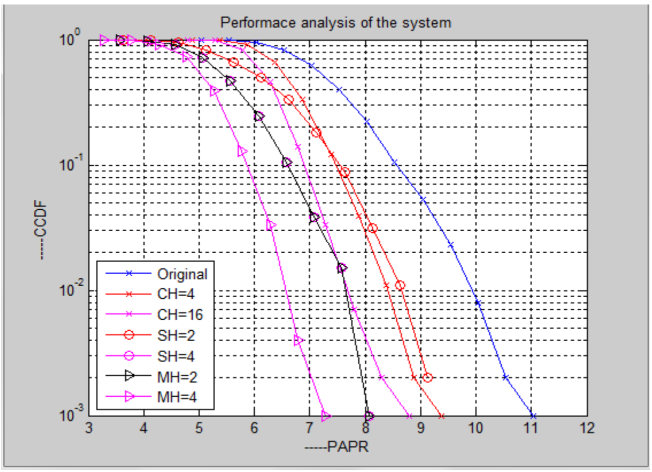

figure 5: the papr reduction performance of modified hybrid scheme for ofdm systems.

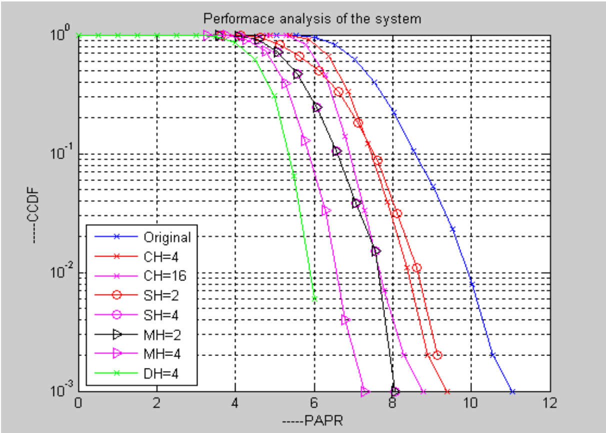

figure 6: the papr reduction performance of dummy signal hybrid scheme for ofdm systems.

VI. CONCLUSION

From the simulation results it could be conclude that, CH scheme provides better PAPR reduction performance with the number of 'U' increases at the cost of computational complexity with the increase of the number of IFFT. The other hybrid schemes AH,SH, MH and DH provides better PAPR reduction performance compared to CH with same number of IFFT. Finally, from the results it could be conclude that DH is the most promising hybrid scheme for better PAPR reduction performance, compared to other hybrid schemes but at the cost of speed. The processing speed of the system is reduced as it repeats the process of inserting the dummy signal and hence increasing the number of iterations to reduce the PAPR of the signal less than $PAPR_0$ (threshold).

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