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An Efficient Method for PAPR Reduction of OFDM Signal with Low Complexity

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Abstract- *Owing to the high spectral efficiency and the immunity to multipath channels, orthogonal frequency-division multiplexing (OFDM) is a promising technique for high-rate data transmission. But the high Peak-to-Average Power Ratio (PAPR) is one of the main obstacles to limit wide applications. In this paper, we propose a PAPR reduction method using Partial Transmit Sequence (PTS) Technique to lower the high PAPR of OFDM (orthogonal frequency division multiplexing) system. The merit of this proposed method is efficient PAPR reduction performance. In the paper, the PAPR reduction process is made more efficient by Low complexity reduced PAPR method using correlation property.*

Keywords – PAPR, PTS, OFDM.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is an attractive multicarrier technique for high-bit-rate transmission. In OFDM system, data is transmitted simultaneously through multiple frequency bands. It is robust to frequency selective fading and narrow band interference. So, OFDM has been adopted as wireless communication. However it is susceptible to high peak-to-average power due to an unstable envelope. This, in turn, leads to poor power efficiency. Furthermore, when it passes through nonlinear device such as HPA, high peak signals may be clipped. The distortions caused by this clipping effect will affect Orthogonality of sub-carriers [1]. In addition to this, large PAPR also demands ADCs (Analog-to-Digital Converters) with large dynamic range [2].

In order to reduce the PAPR of an OFDM signal, many techniques are proposed, which can be organized into three classes: signal distortion, block coding, and signal scrambling. The simplest class of techniques to reduce the PAPR is signal distortion, including clipping and peak windows [3]. To clip the signal, the peak amplitude is limited to some desired maximum level. It can give a good PAPR. But the BER performance becomes very worse due to many defected signals [4].Another method for PAPR reduction is based on the use of coding schemes, where the original data sequence is mapped onto a longer sequence with a lower PAPR in the corresponding OFDM signal. Basically, a coding scheme would involve a large look-up table and is more suitable for those OFDM systems with a small number of sub carriers [5]. Signal scrambling includes SLM, DSI and PTS techniques. SLM [6] may be classified into the phase control scheme to escape the high peak. One signal of the lowest PAPR is selected in a set of several signals containing the same information data. Both techniques require much system complexity and computational burden by using of many IFFT block. However, this is very flexible scheme and has an effective performance of the PAPR reduction without any signal distortion [8]. In DSI, each different dummy sequences are added into the same input data, and, after IFFT, the signal has a minimum PAPR is selected for output signal [7]. In PTS, an input data sequence is divided into a number of disjoint sub blocks, which are then weighted by a set of phase factors to create a set of candidate signals. Finally, the candidate with the lowest PAPR is chosen for transmission. This PTS scheme has a major drawback that it requires a very large number of computations to identify and select the optimum candidate signal that has a low PAPR from all the available combinations of candidate signals. This computational complexity has been reduced by implementing several modified techniques like iterative flipping, but all these techniques are implemented by reducing & eliminating the some of the candidate signals which has caused in the information loss.

This paper proposes a new PTS scheme to reduce the PAPR in OFDM systems with low & much reduced computational complexity. In this paper, we reduce the Computational Complexity in PTS scheme, by using the correlation property between the available candidate signals, instead of reducing the number of candidate signals and thus no information is being lost. This scheme achieves the PAPR reduction same as the conventional PTS scheme and reduces the computational complexity to a large extent. In section II, we introduce the concept of OFDM signal and overview of the PAPR problem. The conventional PTS scheme has been explained in the section III. The new PTS scheme to reduce the computational complexity has been implemented in section IV. Section V gives the computational analysis and focuses on the simulation results. The last section i.e. section VI concludes our paper.

II. OFDM AND DISTRIBUTION OF THE PAPR

Let us denote the collection of all data symbols X[k], k = 0, 1, …, N – 1, as a vector $X = [X_0, X_1, ..., X_{N-1}]^T$ that will be termed a data block. The complex base band representation of a multicarrier signal consisting of N sub carriers is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X[k] e^{j2\pi\Delta f k t / T}, t \in [0, T] \quad (1)$$

Where $j = \sqrt{-1}$ Δf is the sub carrier spacing, and NT denotes the useful data block period. In OFDM the sub carriers are chosen to be orthogonal (i.e. $\Delta f = 1/NT$). The PAPR of the transmit signal is defined as

$$PAPR = \frac{\max |x|^2}{E\left[|x|^2\right]} \quad (2)$$

In particular, a base band OFDM signal with N sub channels has $PAPR_{max} = 10\log_{10} N$. From the central limit theorem, it follows that for large values of N, the real and imaginary values of x(t) become Gaussian distributed. Therefore the amplitude of the OFDM signal has a Rayleigh distribution, with a cumulative distribution given by $F(z) = (1 - e^{-z})$ .The probability that the PAPR is below some threshold level can be written as $P(PAPR \leq z) = (1-e^{-z})^N$. In fact, the complementary cumulative distribution function of PAPR of an OFDM is usually used, and can be expressed as $P(PAPR > z) = 1 - (1 - e^{-z})^N$.

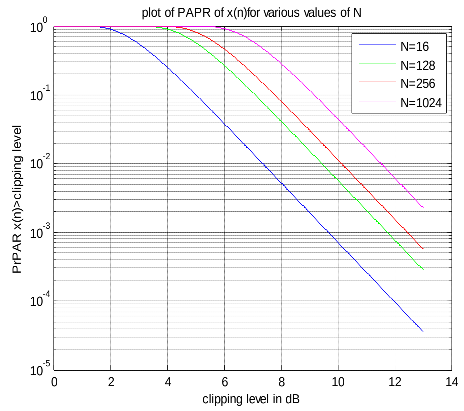

Fig 1. Plot of CCDF of PAPR for various values of N

The CCDFs are usually compared in a graph such as Fig. 1, which shows the CCDFs of the PAPR of an OFDM signal with 256 and 1024 sub carriers (*N* =16,128, 256,1024) for quaternary phase shift keying (QPSK) modulation. The horizontal and vertical axes represent the threshold for the PAPR and the probability that the PAPR of a data block exceeds the threshold, respectively. It is shown that the unmodified OFDM signal has a PAPR that exceeds 10 dB for less than 1 percent of the data blocks for N = 256. With a certain PAPR value, the occurrence probability of OFDM signals which exceed this value augment, as the number N increases.

III. A CONVENTIONAL PTS

In the PTS technique, an input data block of N symbols is partitioned into disjoint sub blocks. The sub carriers in each sub block are weighted by a phase factor for that sub block. The phase factors are selected such that the PAPR of the signal is minimized.

Figure 2 shows the block diagram of the PTS technique. In the PTS technique [9,10] input data block X is partitioned into V disjoint sub blocks $\mathbf{X}_v = [X_{v,0}, X_{v,1}, …, X_{v,N-1}]$, v = 1, 2, …, V.

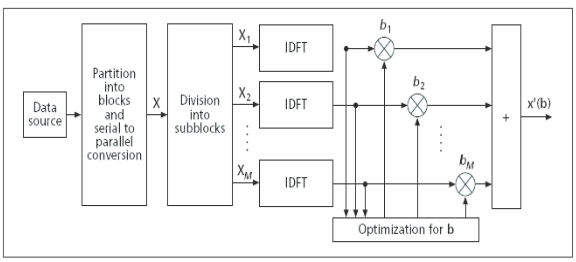

Fig2. A block diagram of the PTS technique

The sub blocks are combined to minimize the PAPR in the time domain. The set of phase factors is denoted as a vector b = $[b_1, b_2, \ldots, b_v]$. The time domain signal after combining is given b

$$x'(b)=\sum b(v).x(v) \qquad 0\leq v\leq V \qquad (3)$$

$$x'(b) = [x'_0(b), x'_1(b). \ldots x'_{N-1}(b)] \qquad (4)$$

The objective is to find the set of phase factors that minimizes the PAPR. Minimization of PAPR is related to the minimization of max [x' (b)].

In general, the selection of the phase factors is limited to a set with a finite number of elements to reduce the search complexity. The set of allowed phase factors is written as P = {0, 1, …, W – 1}, where W is the number of allowed phase factors. So, we should perform an exhaustive search for V phase factors. Hence, W^V sets of phase factors are searched to find the optimum set of phase factors. The search complexity increases exponentially with the number of sub blocks V. PTS needs V IDFT operations for each data block. The amount of PAPR reduction depends on the number of sub blocks V and the number of allowed phase factors W. Thus, this conventional PTS scheme requires a large computations to get an optimal candidates signal with low PAPR.

IV. A PROPOSED REDUCED COMPLEXITY PTS SCHEME

Here, we propose a new PTS scheme which reduces the computational complexity without reducing the number of candidate signals. In all available combinations there may be certain pairs which may have the same relations. Thus, we use the correlation property among these phase factors in each subset, such that the computational complexity is reduced.

To start with our proposed method, let us first define the phase factors in a phase set. Let us denote the number of phase factors as W. If we take W=2, then it indicates that there are two phase factors, one is in-phase & other is out-of-phase factor with phase factor set as {1,-1}. In same way, if we take W=4, then the phase factors set consists of {1,-1,j,-j} which indicates real & imaginary, in-phase & out-of-phase factors.

Now, knowing these phase factors, we can create a fundamental combination known as Prototype Vectors. We derive all the other vectors from this prototype vector. For example, if W=2 & M=2, then the prototype vectors are {1,1} & {1, j}. Because of using the correlation property, all the vectors derived from same prototype vector differ each other by a sign change only.

Based on these phase factor, number of subblocks of the PTS, by knowing all the vectors, we can write the candidate signals. Hence by using the correlation property and knowing all the vectors, we can write the first candidate signal derived from first prototype vector as

$$x_{1,1} = x_1 + x_2 + \ldots + x_M \qquad (5)$$

Now, we can derive the second candidate signal from first candidate signal by using the sign change property as

$$x_{1,2} = x_{1,1} - sign(b_{1,1,m}) \cdot 2x_m \qquad (6)$$

Where $b_{i,k,m}$ represents the kth phase weighting vector based on the ith prototype vector and is applied to the mth subblock of the PTS OFDM transmitted signal and $sign(A)$ indicates the sign of A.

Similarly, we can write the i+1th candidate signal derived from this first prototype vector as

$$x_{1,i+1} = x_{1,i} - sign(b_{1,i,m}) \cdot 2x_m \qquad (7)$$

Now, we can derive the first candidate signal that of the 2nd prototype vector denoted by $s_{2,1}$ from $s_{1,prev}$ as given by

$$x_{2,1} = x_{1,prev} + b_{1,prev,m}(A_{2,m} - 1) \cdot x_m \qquad (8)$$

Where $prev = 2^M - 1$ indicates the previous prototype vector, and A_i is the value which denote the change of the real & imaginary phase factors in the various prototype vectors.

So in general, we can write the i+1th candidate signal derived from the second prototype vector as

$$x_{2,i+1} = x_{2,i} - sign(b_{2,i,m}) \cdot 2x_m \qquad (9)$$

Combining all the above equations from 5 to 9, we can summarize the general equations to get the candidate signals as given below

$$x_{i+1,1} = x_{i,prev} + b_{i,prev,m}(A_{i+1,m} - 1) \cdot x_m \qquad (10)$$

And

$$x_{k+1,i+1} = x_{k+1,i} - b_{k+1,i,m} \cdot 2x_m \qquad (11)$$

With all the above equations, we get the all possible candidate signals with reduced computational complexity. From these candidate signals, we choose the one with minimum PAPR for transmission.

Now, let us see the above reduced computational complexity PTS algorithm considering an example. Let us do the partial transmission of sequences by taking 3 sub blocks i.e. M=3 and let us consider 4 phase factors set i.e. W=4.

Rewriting the equations 10 & 11 using M=3 & W=4 to get the candidate signals, we can write

$$x_{1,i+1} = x_{1,i} - sign(b_{1,i,m}) \cdot 2x_m \qquad (12)$$

$$x_{2,1} = x_{1,4} + sign(b_{1,4,3})(A_{2,3} - 1)x_3 \qquad (13)$$

$$x_{2,i+1} = x_{2,i} - sign(b_{2,i,m}) \cdot 2x_m \qquad (14)$$

$$x_{3,1} = x_{2,4} + sign(b_{2,4,2})(A_{3,2} - 1) \cdot x_2 \qquad (15)$$

and similarly we can write the equations so on till we get the last candidate signal i.e. $X_{4,4}$. So, by using the equations from 16 to 19, we can write the candidate signals as follows

$$x_{1,1} = x_1 + x_2 + x_3 \qquad (15)$$

$$x_{1,2} = x_1 - x_2 + x_3 \qquad (16)$$

$$x_{1,3} = x_1 - x_2 - x_3 \qquad (17)$$

$$x_{1,4} = x_1 + x_2 - x_3 \qquad (18)$$

$$x_{2,1} = x_1 + x_2 - jx_3 \qquad (19)$$

$$x_{2,3} = x_1 - x_2 + jx_3 \qquad (20)$$

$$x_{2,4} = x_1 + x_2 + jx_3 \qquad (21)$$

$$x_{3,1} = x_1 + jx_2 + jx_3 \qquad (22)$$

$$x_{3,2} = x_1 - jx_2 + jx_3 \qquad (23)$$

$$x_{3,3} = x_1 - jx_2 - jx_3 \qquad (24)$$

$$x_{3,4} = x_1 + jx_2 - jx_3 \qquad (25)$$

$$x_{4,1} = x_1 + jx_2 - x_3 \qquad (26)$$

$$x_{4,2} = x_1 - jx_2 - x_3 \qquad (27)$$

$$x_{4,3} = x_1 - jx_2 + x_3 \qquad (28)$$

$$x_{4,4} = x_1 + jx_2 + x_3 \qquad (29)$$

Here, note that, due to the correlation property the computational complexity has been reduced to a large extant. Now, from these available candidate signals, we transmit the one with minimum PAPR.

V. Computational Complexity Analysis

In the previous section, we have seen how we had reduced the computational complexity of the proposed system. Here in this section, we analyze the computational complexity reduction by defining the term Computational Complexity Reduction Ratio (CCRR) of the proposed PTS scheme comparing with that of the conventional PTS scheme. The CCRR is given by

$$CCRR = \left(1 - \frac{Proposed \quad PTS \quad complexity}{Conventional \quad PTS \quad Complexity}\right) \times 100\,\%$$

(30)

From equation 6 it is clear that the number of multiplications required by the proposed PTS is given by

$$\alpha_{mul} = N \cdot [(\frac{W}{2})^{M-1} - 1] \qquad (31)$$

And the number of multiplications required by the conventional PTS is given by

$$\beta_{mul} = N.[C^1_{M-1}\left(\frac{W}{2} - 1\right) + 2C^2_{M-1}\left(\frac{W}{2} - 1\right)^2 + \ldots + (M-1)C^{M-1}_{M-1}\left(\frac{W}{2} - 1\right)^{M-1}] \cdot 2^{M-1} \qquad (32)$$

Similarly, From equation 11, we can say that the number of additions required by the proposed PTS scheme has reduced to N because it is only necessary to calculate the x_m Hence, the ratio of the addition complexity of proposed scheme to that of conventional PTS scheme is $\frac{1}{M-1}$.

Now, if we take, M=6, then we get Addition CCRR as 80% and Multiplication

CCRR as 98% with the proposed PTS scheme compared to the conventional PTS scheme. With this, we can say that the proposed PTS scheme can reduce the computational complexity to a very extant when compared to the conventional PTS scheme.

VI. Simulation Results

In this proposed PTS scheme, we have not reduced the number of candidate signals as in other cases, but we have used the correlation property in order to reduce the computational complexity. In this regard we can prove this by observing the Complementary Cumulative Distribution Function CCDF.

Here, as we have used the correlation property instead of reducing the number of candidate signals, we achieve the PAPR reduction as same as in the case of conventional PTS scheme. The results have been simulated in the MATLAB.

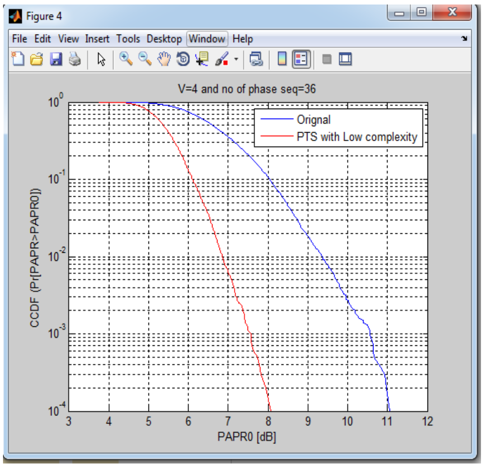

Fig 2. CCDF of PAPR

VII.CONCLUSION

Hence our Proposed PTS scheme not only reduces the computational complexity but also achieves the same PAPR reduction as that of the conventional system.

VIII. ACKNOWLEDGMENT

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REFERENCES

[1] R. W. Chang and R. A. Gibby, "A Theoretical Study of Performance of an Orthogonal Multiplexing Data Transmission Scheme," *IEEE Trans. On Commun.*, vol. 16, no. 4, pp. 529-540, Aug. 1968

[2] MULLER, s., BAUML, R., FISCHER, R., and HUBER. J.: *'OFDM with reduced peak-to-average power ratio by multiple signal representation'*. To appear in Annuls of Telecommunications, Special issue on multirate digital signal processing in telecommunication applications

[3] Xiaodong Li and Leonard J. Cimini. "Effects of clipping and Filtering on the Performance of OFDM". *IEEE*,1997, pp.1634-1638

[4] X. Li and L. J. Cimini, Jr., "Effect of Clipping and filtering on the Performance of OFDM," *Elect. Letter*, vol. 2, no. 5, pp. 131-133, May 1998.

[5] J. A. Davis and J. Jedwab, "Peak-to-mean power control in OFDM, Golay complementary sequences and Reed-Muller codes," *IEEE Trans. Inform. Theory*, vol. 45, no. 11, pp. 2397–2417, Nov. 1999.

[6] P. Van Eetvelt, G. Wade, and M. Tomlinson, "Peak to Average Power Reduction for OFDM Schemes by Selective Scrambling," *Elect. Letter*, vol. 32, no. 21, pp. 1963-1964,Oct. 1996

[7] Heung-Gyoon Ryu, Jae-Eun Lee, and Jin-Soo Park, "Dummy sequence insertion (DSI) for PAPR reduction in the OFDM communication system," *IEEE Transactions on Consumer Electronics*, vol. 50, pp.89-94, Feb. 2004.

[8] R.W. Bauml, et al., "Reducing the Peak-to-average Power Ratio of Multicarrier Modulation by Selected Mapping", *Electronics Letters*, Vol.32, No.22,1996,pp.2056-2057.

[9] T.Chalapathi and Madhu Babu, " A Low Complexity Algorithm for PTS based PAPR Reduction Scheme in OFDM Systems,"IJERT,Vol. 1,No 3,May 2013.

[10] S. H. Müller and J. B. Huber, "A Novel Peak Power Reduction Scheme for OFDM," *Proc. IEEE PIMRC '97*, Helsinki, Finland, Sept. 1997, pp. 1090–94.