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Hardware implementation for reduction of PAPR by using modified PTS technique

Dr. Uday Wali[1], Prof. B. K. Shiragapur[2], Kalyani G. Fule[3] , Mahesh Tarlkar[4]

Professor, Dr. Uday Wali, Dept. of E&C , KLE College of Engg. & Tech.Belgaum Karnataka, India[1]
Asst. Professor, Dept. of E&Tc, Dr. D. Y. Patil School of Engg. , Lohagaon, Pune, India[2]
PG Student, Dept. of E&Tc, Dr.D. Y. Patil School of Engg. , Lohagaon, Pune, India[3]
PG Student, Dept. of E&Tc, Dr. D. Y. Patil School of Engg. , Lohagaon, Pune, India[4]

ABSTRACT: In this paper, the design and implementation of OFDM system along with Multi-Point Square Mapping combined with PTS (M-PTS) technique has received much attention in reducing the high peak to average power ratio (PAPR) of Orthogonal Frequency Division Multiplexing signals (OFDM). As compared to C-PTS technique, the proposed M-PTS technique needs not to submit side information but keeping almost the same performance of PAPR reduction as the C-PTS technique. A detailed Simulation of OFDM system is conducted and implemented using FPGA to validate the results.

KEYWORDS: Multi-point Square Mapping, (OFDM) Orthogonal Frequency Division Multiplexing, (M-PTS) Modified -PTS, (PTS) Partial Transmit Sequence, (C-PTS) Conventional PTS, (PAPR) Peak to average power ratio, (FPGA) Field Programmable Gate Array.

I.INTRODUCTION

Orthogonal frequency division multiplexing is being used for data transmission in a number of wireless communication systems, which includes digital audio broadcasting (DAB) and digital video broadcasting (DVB) SYSTEMS. OFDM is a multicarrier system, with various advantages over single carrier systems, such as ISI mitigation, robustness to multipath fading by the use of cyclic prefix, high bandwidth efficiency and low implementation complexity [1]. As a result, OFDM is a good choice for high data rate broadband communication.

However, one of the major drawbacks in the design of practical OFDM is high peak to average power ratio (PAPR), especially when the total number of subcarriers is large and all the subcarriers with same initial phase are added. In an OFDM transmitter, power amplification is performed by power amplifier (PA). If the OFDM signal has high fluctuations then PA should have very large linear range of operation and also leads to high complexity of analog to digital conversion, which makes it very expensive. A large PAPR introduces both in band distortion and out band distortion [2] which is undesirable.

Many schemes have been proposed in the literature to reduce the PAPR [3]-[17]. The PAPR reduction techniques are majorly divided into two categories.

[a] Distortion based techniques [3]-[7]
[b] Non-distortion techniques [8]-[17]

The schemes that introduce spectral re-growth belong to distortion based category. These techniques are the most straightforward PAPR reduction methods. The clipping is one of the simplest distortion based technique to reduce the PAPR of OFDM signal. It reduces the peak of the OFDM signal by clipping the signal to the desired level but it introduces both in-band distortion and out-bands radiation. To limit out-band radiation and PAPR iterative clipping and filtering scheme proposed in[3]-[4]. Companding is another popular distortion based scheme for PAPR reduction in OFDM system [5]. In µ-law companding scheme the peak value of the OFDM signal before and after companding remains same, which keeps peak power of the OFDM signal unchanged but the average power of the OFDM signal after companding increases and therefore the PAPR of the OFDM signal gets decreased. But due to increase in the average power of the OFDM signal the error performance of µ-law companding scheme degrades, which proposed in [6]. Exponential companding is another scheme which transform Rayleigh distributed magnitude of OFDM signal to a uniformly distributed OFDM signal using an exponential function and this scheme is known as 'Exponential Companding' scheme. Exponential Companding scheme can effectively reduce the PAPR of the OFDM signal but its BER performance also degrades with PAPR reduction[7]. Trapezoidal Companding is another efficient technique to reduce the PAPR of OFDM signal with low BER. All companding techniques distort the shape of the original OFDM signal and PAPR reduction capability is achieved at the cost of BER performance degradation.

Non-distortion PAPR reduction techniques do not distort the shape of the OFDM signal and therefore no spectral re-growth takes place. Coding techniques is one of the simplest non-distortion PAPR reduction techniques, which can be applied for reducing the PAPR of OFDM signal. But these type of schemes result in significant loss data rate in OFDM system. Two more distortion-less PAPR reduction techniques namely selective mapping [8, 11] and partial transmit sequence [9]-[17]. In SLM OFDM systems, as the number of alternative OFDM signal increases, the number of bits required to encode the side information also gets increased, which results in data rate loss. The PTS scheme is mentioned in below sections, among all techniques PTS technique is very attractive due to their good PAPR reduction without the restriction of the number of subcarriers. In C-PTS technique, if the number of sub-blocks or the number of phase factors in the phase set increases then it not only increases the computational complexity for selecting the optimum set of phase sequence but also increases the amount of SI to be conveyed to the receiver. The SI results in data rate loss in OFDM system.

In this paper, we studied a Multi-point square mapping method combined with C-PTS, which is named as M-PTS to avoid transmitting side information (SI) but giving the almost same results of reduction of PAPR as that of C-PTS.
The paper is organized into IV sections, in section II problems related to PAPR and C-PTS technique are discussed , whereas section III gives study of M-PTS scheme and in Section-IV Simulations results.

II. C-PTS IN OFDM SYSTEM TO REDUCE PAPR

A: PAPR in OFDM system

Presence of large number of independently modulated sub –carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio is termed as peak to average power ratio (PAPR). The major disadvantages of a high PAPR are – increased complexity in the analog to digital / digital to analog converter and reduction in efficiency of amplifiers.

Let the data blocks of length N be represented by a vector X=$[X_0, X_1, \dots\dots\dots, X_{N-1}]$. Duration of any symbol X_k in the set X is T and represents one of the sub-carriers $\{f_n, n = 0,1, \dots\dots, N-1\}$ set. As the N sub –carriers chosen to transmit the signal are orthogonal to each other, so we can have $f_n = n\Delta f$, where $n\Delta f = \frac{1}{NT}$ and NT is the duration of the OFDM data block X. the complex data block for the OFDM signal to be transmitted is given by

$$x(t)=\frac{1}{\sqrt{N}}\sum_{N=0}^{N-1} X_n . e^{j2\pi n\Delta f t}, 0 \le t \le NT, \quad (1)$$

The PAPR of the transmitted signal is defined as

$$PAPR=\frac{\max|x(t)|^2 \; 0\le t<NT}{\frac{1}{NT}\int_0^{NT} |x(t)|^2 dt} \quad (2)$$

Reducing the *max*|*x(t)*| is the principle goal of PAPR reduction techniques. Since, discrete –time signals are deal with in most systems, many PAPR techniques are implemented to deal with amplitudes of various samples of *x(t)*. Due to symbol spaced output in the first equation we find some of peaks missing which can be compensated by oversampling the equation by some factor to give the true PAPR value.

B: C-PTS scheme

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In the PTS approach, the input data block is partitioned into disjoint sub-blocks. Each sub-block is multiplied by a weighting factor, which is obtained by the optimization algorithm to minimize the PAPR value. We define the data-block as a vector $X=[X_1, X_2, \ldots \ldots \ldots . X_N]^T$, where N denotes the number of sub-carriers in the OFDM frame. Then, X is partitioned into M disjoint sub-blocks represented by the vector $X_l, l = 1, 2\ldots$ M, such that

$$X=\sum_{l=1}^{M} X_l \quad (3)$$

Here, it is assumed that the clusters X_l consist of a set of sub-blocks and are of equal size. Then, a weighted sum combination of the M sub-blocks which are written as

$$X' = \sum_{l=1}^{M} b_l X_l, \quad b_l=e^{j\phi_1} \quad (4)$$

Where b_l , $l = 1,2,\ldots\ldots\ldots,M$ is the weighting factor with phase factor $\phi_l = 0$ or π commonly.
After transforming to the time domain, the time domain vector becomes

$$x = IFFT\{ \sum_{l=1}^{M} b_l .\ X_l\} = \sum_{l=1}^{M} b_l .IFFT\{x_l\} \quad (5)$$

The PAPR can be minimized by exhaustive search for appropriate combination of each block and its corresponding phase factors. With the optimized weighing factor $\bar{b}_l$, the optimized transmitted bit vector $\bar{X}$ can be generated as

$$\bar{X}=\sum_{l=1}^{M} \bar{b}_l X_l \quad (6)$$

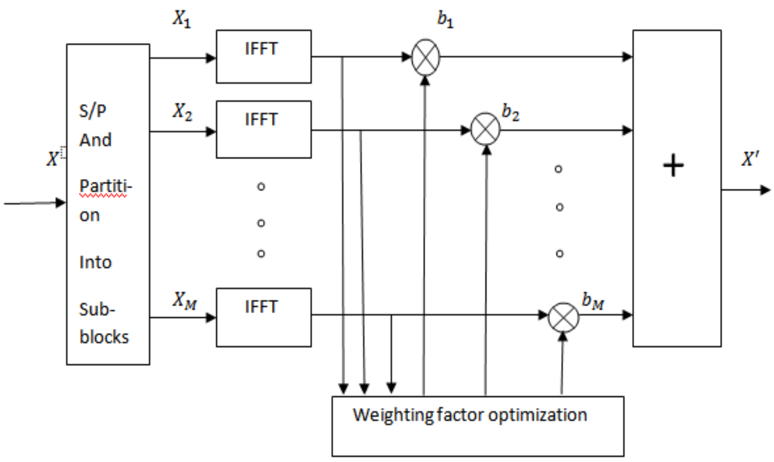

Fig 1 Block diagram of C-PTS technique

Where $x_l = IFFT\{X_l\}$ is called conventional partial transmit sequence(C-PTS). Fig 1 shows the well-known structure of PTS technique used in OFDM system.

III. PROPOSED M-PTS FOR PAPR REDUCTION

In this section, a multi-point square mapping based PTS technique has been reviewed to reduce PAPR. In this method, receiver does not require any SI to retrieve the original OFDM signal. In this scheme, the bit stream is first converted into quaternary data points (0, 1, 2 and 3) which are lying in four different quadrants and then obtained quaternary data points are initially mapped to four different points of 16-QAM constellation as per Table 1. As seen from Fig 2(a) the initially mapped constellation points lie in four different quadrants and cover all 16 points of 16-QAM constellation after multiplication with 4 phase factors (1,j,-1,-j). In Fig 2(b) the constellation points generated from (3+3j, -3+j, -1-j, 1-3j)

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after multiplication with phase factors (1,j,-1,-j) , are denoted by the same style of marker. All data points of 16-QAM constellation are divided into four different groups. Each of these groups has four constellation points lying in four different quadrants. Each of these groups corresponds to one quaternary data point. The complete mapping scheme used in M-PTS is given in Table 1. After performing quaternary to 16-QAM mapping, conventional PTS scheme is used to reduce the PAPR of the OFDM signal.

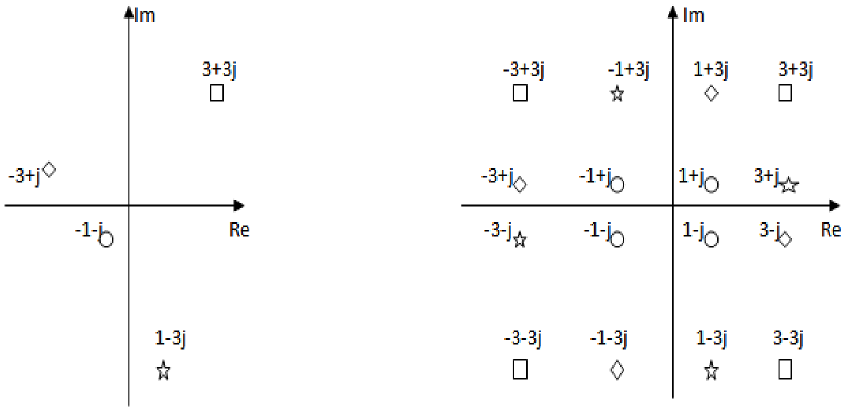

Fig 2 (a) Quaternary data (b) Mapping of quaternary data to 16-QAM constellation using 4 phase factors in M-PTS

Quaternary data	Initially Mapped Quaternary data points to 16 QAM constellation	Constellation points after multiplication with phase factors in p				
		1	j	-1	-j	Group Number
0	3+3j	3+3j	-3+3j	-3-3j	3-3j	G_1
1	-3+j	-3+j	-1-3j	3-j	1+3j	G_2
2	-1-j	-1-j	1-j	1+j	-1+j	G_3
3	1-3j	1-3j	3+j	-1+3j	-3-j	G_4

Table 1 Mapping of Quaternary data points to 16-QAM Constellation

Demodulated Constellation Symbols belonging to Group	De-mapped Constellation Point	Recovery Quaternary data
G_1	3+3j	0
G_2	-3+j	1
G_3	-1-j	2
G_4	1-3j	3

Table 2 De-mapping of 16-QAM Constellation Symbols to quaternary Data Points

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A de-mapping scheme shown in Table 2 is used to recover the quaternary data points. According to Table 2, if any of the data points is decoded as {3+3j, -3+3j, -3-3j, 3-3j} , {-3+j, -1-3j, 3-j, 1+3j}, {-1-j, 1-j, 1+j, -1+j} or {1-3j, 3+j, -1+3j, -3-j}, then is de-mapped to quaternary data 0,1,2 or 3 respectively. Decoding does not require any information about the phase factors thus the major constraints of PTS technique; means the need of SI is completely eliminated.

IV. SIMULATION RESULTS

In this section, simulations have been conducted in MATLAB to evaluate the ability of the PAPR reduction using M-PTS , in which random OFDM symbols are generated with the number of sub-carriers *N=128* . For comparisons, we have shown the simulation results of the CCDF curve for Original OFDM, C-PTS and M-PTS scheme in fig 3. For both M-PTS and C-PTS, we divide all the sub-carriers into M= 4 sub-blocks, and phase rotation factors are chosen from the set P = [1, j, -1, -j].

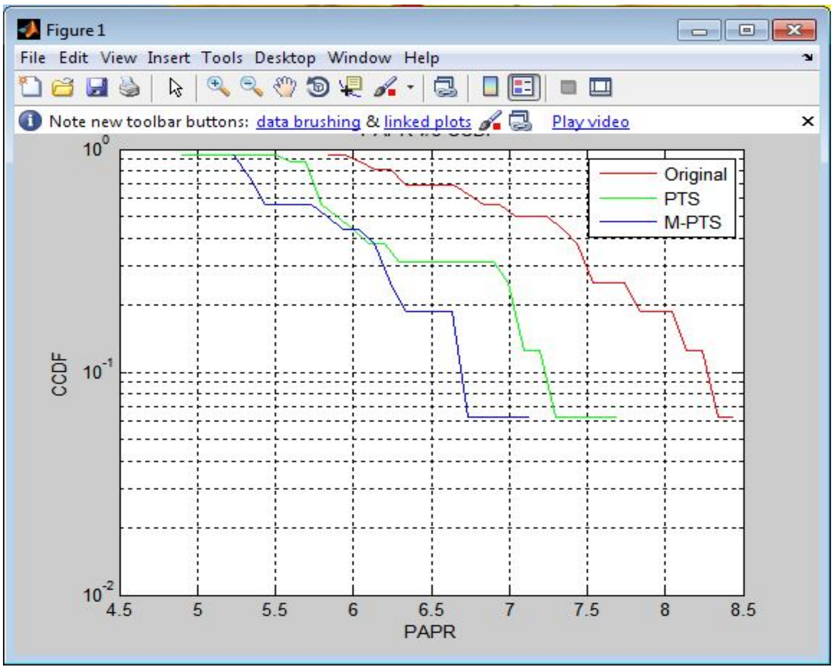

Fig 3 CCDF curve for original OFDM, C-PTS and M-PTS

Fig 3 depicts the performance of the PAPR reduction of M-PTS and C-PTS techniques are compared with OFDM system. When QAM is employed and *N=128* . As shown in Fig 3, PAPR = 7.5dB for C-PTS technique, and PAPR= 7dB for the proposed M-PTS technique, whereas PAPR=8.5dB for Original OFDM. The PAPR reduction of 1dB for C-PTS as compared to Original OFDM and 1.5dB in case of M-PTS which is a most significant part for the reduction of PAPR.

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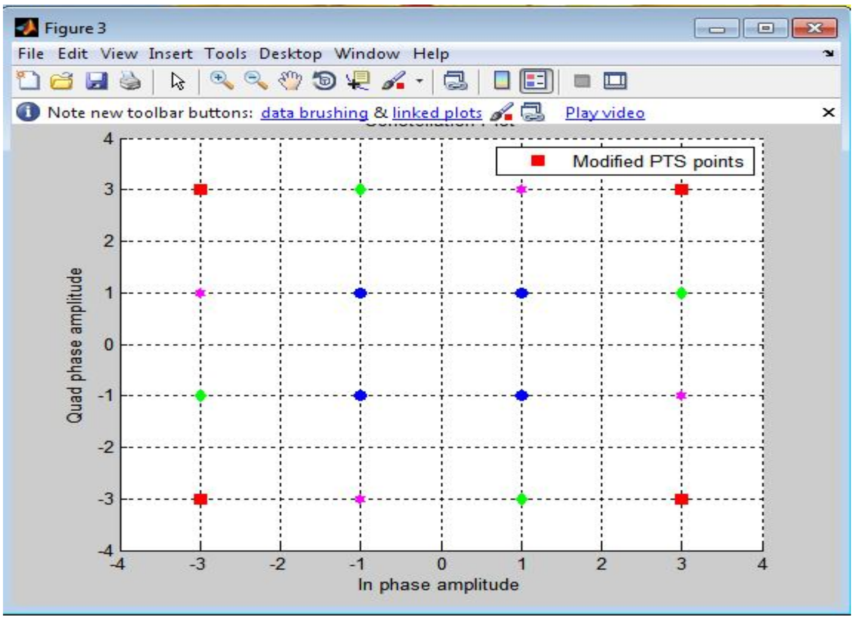

Fig 4 Constellation Points of M-PTS.

Figure 4 describes the constellation points of M-PTS scheme after simulation, which is describe in Section III.

V. CONCLUSION

In this paper, we first reviewed a technique, called as Multi-Point Square Mapping. Then, we describe how to combine Multi-Point Square Mapping and the C-PTS, named as M-PTS, to reduce the PAPR in OFDM systems. The M-PTS scheme could offer good PAPR reduction, which is almost the same as that of C-PTS technique. However, the proposed M-PTS technique needs not to submit side information (SI). Therefore, the proposed M-PTS technique has better bandwidth efficiency compared with the C-PTS technique.

VI.FUTURE WORK

The paper deals with reduction of PAPR in OFDM. I am going to implement this M-PTS in VERTEX V by using System generator. Comparison of results will do by using MATLAB as well as VERTEX V. Validation of results using speech and image signal.

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