Reduction of PAPR using Modified PTS Technique Improvement: Simulation and Hardware Implementation

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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

(MSM) 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.

1. 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 [3]-[16] to reduce the PAPR of the OFDM signal. Among all schemes which are used to reduce PAPR, PTS and SLM techniques are 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, detailed study of 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 5 sections, in section 2 problems related to PAPR and C-PTS technique are discussed , whereas section 3 gives study of M-PTS scheme and in Section 4 Simulations results and Hardware results, Section 5 conclusion are discussed in detail.

2. C-PTS IN OFDM SYSTEM TO REDUCE PAPR

2.1 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.

2.2 C-PTS Scheme

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=$[\, X_1, X_2, \dots\dots\dots . X_N]^T$, 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 $X_l, l = 1, 2...$ M, such that

$$X=\sum_{l=1}^{M} X_l \tag{3}$$

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

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

Where b_l , $l = 1,2,\ldots\ldots,M$ is the weighting factor with phase factor $\phi_l = 0$ or π commonly.

After transforming to the time domain, the time domain vector becomes

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

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

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

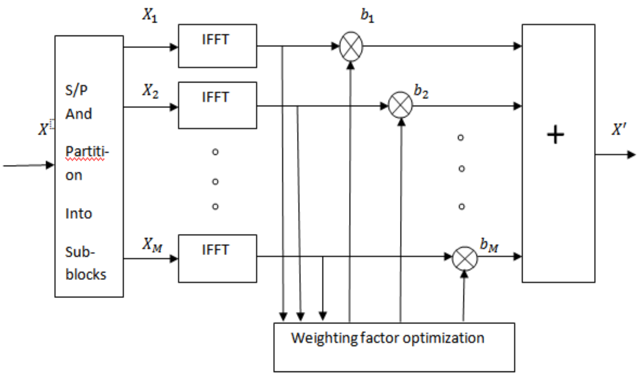

Fig 1 Block diagram of C-PTS technique

3. 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) 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.

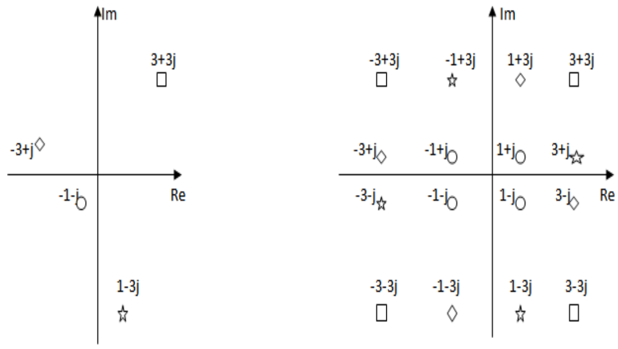

Fig 2 (a) Quaternary data (b) Mapping of quaternary data to 16-QAM constellation using 4 phase factors in M-PTS

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

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

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

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.

4. RESULT AND DISCUSSIONS

4.1 Matlab Simulation

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].

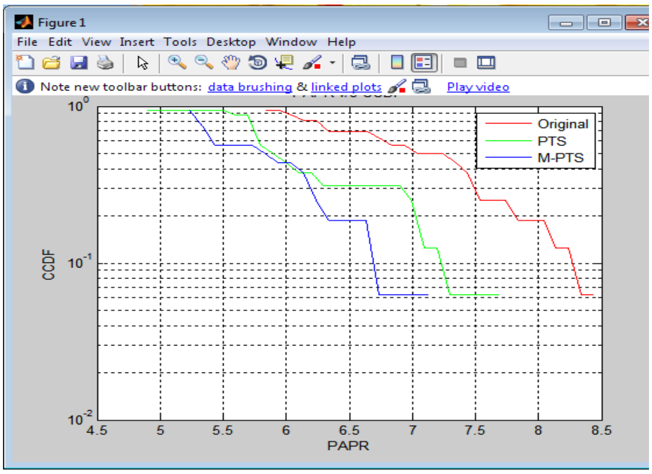

Fig 3 CCDF curve for original OFDM, C-PTS and M-PTS

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.

4.2 Hardware implementation

FPGA Implementation for PAPR reduction have implemented on a Virtex5 (XC5VLX110T) family FPGA using the Xilinx 13.4 ISE design tool suite and displayed results on chipscope-pro.

After modelsim simulation, Hardware implementation has been done using chip scope, and for same input. During the compilation and synthesis process, the ISE tool chain generates a report showing device utilization. Once the system was implemented in Verilog HDL this report was used to determine the overall size and structure of the FPGA device required to implement this technique. The behavioural test of this M-PTS transmitter has been tested as mentioned earlier using the ISE tool chain as shown in Figure 5. This behavioral test has been done using Modelsim simulator, in this modelsim input is din (1100) and output is as shown in fig.5 and dout=fffc in hex the output of the chip scope is as shown in fig 4.

In the same way as shown in fig 4 and fig 5 the results of Basic OFDM and C-PTS is obtained. Compare the Basic OFDM, C-PTS and M-PTS results.

Fig 6 depicts the performance of the PAPR reduction of M-PTS and C-PTS techniques are compared with OFDM system, When QAM is employed. As shown in Fig 6, PAPR = 11.2dB for C-PTS technique, and PAPR= 11dB for the proposed M-PTS technique, whereas PAPR=15dB for Original OFDM. The PAPR reduction of 3.8dB for C-PTS as compared to Original OFDM and 4dB in case of M-PTS which is a most significant part for the reduction of PAPR.

From fig 6 it shows that the proposed scheme is practically implemented. It is feasible and cost effective in real time application.

5. 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. Hardware implementation shows that proposed scheme is feasible practical and real time. Above the table body

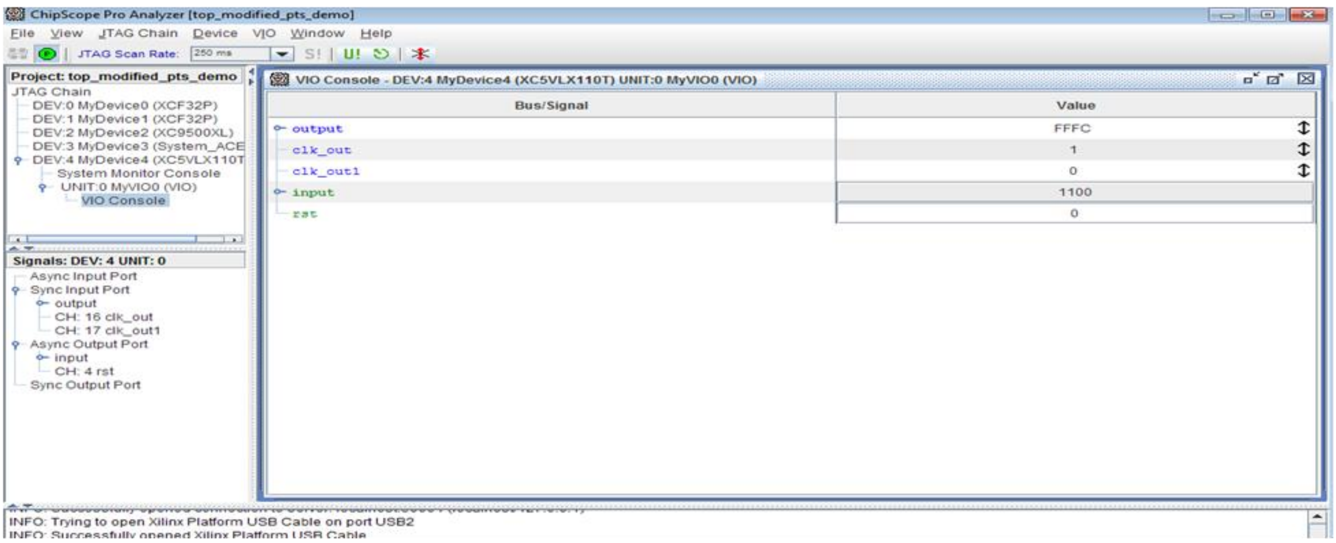

Fig 4 Hardware implementation results of M-PTS using Chipscope-pro

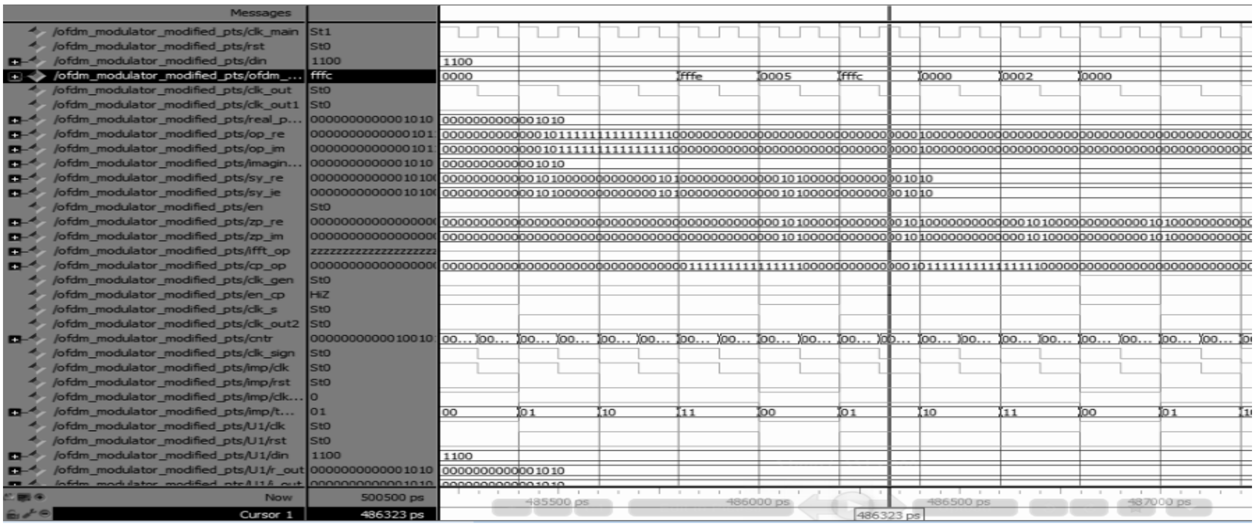

Fig 5. Simulation result of M-PTS using modelsim

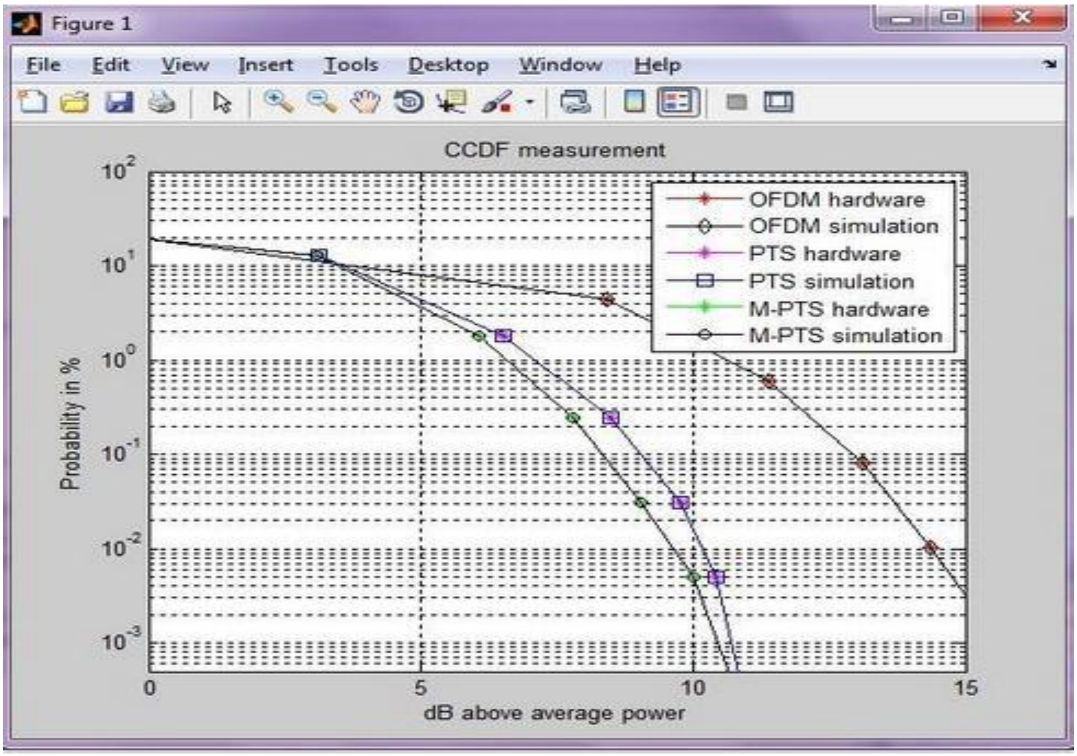

Fig 6 CCDF plots of the hardware implementation of the proposed PAPR reduction technique (for QAM modulation process)

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