Two Set Phase Factor Optimization of PTS Technique for PAPR Reduction in OFDM System

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Abstract: PAPR reduction is the main problem in OFDM technique. When multiple subcarriers are multiplexed in OFDM, sometimes the instantaneous power exceeds certain threshold limit that distorts the output because the output is out of the linear range of power amplifier. PAPR can be successfully reduced by using PTS (Partial Transmit Sequence) technique. Therefore in our proposed work, we modified PTS method by placing multiple set of phase factor. Two different set of phase factors has been taken which are multiplied by OFDM signal and results in low PAPR output signal. Simulation result of this paper shows better PAPR reduction than original PTS technique as shown in the results. The work is done in Matlab software.

Keywords: CCDF (Complementary Cumulative Distribution Function), IFFT (Inverse Fast Fourier Transform), OFDM (Orthogonal Frequency division Multiplexing), PAPR (Peak-to-Average Power Ratio), PTS (Partial Transmit Sequence).

1. INTRODUCTION

OFDM is a special form of the frequency-division multiplexing (FDM) multicarrier modulation technique. The main advantage of OFDM is that it is highly capable of ignoring inter-symbol interference but it is also have a big problem that is PAPR. High value of PAPR results in non-linearity in high power amplifier and hence the performance of the OFDM system is degraded [1].There are number of PAPR reduction techniques. The efficiency of any PAPR Reduction technique is measured through Cumulative Distribution (CDF) [2]. To overcome this problem an amplifier with high dynamic range can be used but it will cause high cost to the system. This problem can be rectified by using technique like partial transmit sequence (PTS) in OFDM system [3].

The transmission of high PAPR signal through non-linear power amplifier results in spectral broadening increasing the dynamic range of the Digital to Analog converters and there by increases the cost of the system [4]. OFDM has drawn significant interests over past decade for its robustness against the multipath fading channels. OFDM is an effective high-speed data transmission scheme without using very expensive equalizers and it has been proposed as the air interface for broadband wireless applications such as wireless local area networks (WLANs) [5].

PTS technique is very popular in decreasing PAPR among other available techniques. In the proposed work, in place of single set of phase vector, two different set of phase vectors has been taken which results in further reduction in PSNR.

2. PAPR

The output of the OFDM system is actually a superposition of multiple sub-carriers and therefore sometimes instantaneous power output might increase to such a great level that it crosses mean power of the system. Then it is required to implement very high-power amplifiers to perform successful transmission. These kind of high power amplifiers are very costly as well as have very low efficiency. For the high peak power, it will not come in the limits of the linear power amplifier and this result in non-linear distortion which vary the superposition of the signal spectrum which output in degradation of overall performance. PAPR is defined frequently in terms of its complementary cumulative distribution function (CCDF). Researchers have been proposed a lots techniques for PAPR reduction like clipping method, coding method, Partial transmit sequence (PTS), selective mapping (SLM) method etc [6].

A better way to characterize the PAPR is to use CCDF of PAPR. The CCDF is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold. The CDF of the amplitude of a signal sample is given by the CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques [6].
In simple terms PAPR can be defined as,

$$PAPR = \frac{\text{Maximum power of a signal}}{\text{Average power of a signal}} \quad (1)$$

PAPR can be defined in dB [4],

$$\text{PAPR (in dB)} = 10\log 10\left(\frac{\text{Maximum power of a signal}}{\text{Average power of a signal}}\right) \quad (2)$$

PAPR signifies dynamic range of orthogonal frequency division multiplexed signal, it can be expressed as a ratio of maximum peak power to average power during a symbol period.

3. PARTIAL TRANSMISSION SEQUENCE (PTS)

PTS technique was proposed by the Muller and Hubber in 1997. Fig.1 shows the PTS scheme. The first step is to partition the main data stream into multiple sub sequences. Then every symbol is applied with IFFT. The resulting signals are then multiplied by rotating vectors. After that these sub sequences are summed up. Now PAPR of respective sequence is obtained and lowest PAPR signal selected for transmission [3].

Partial transmit sequence is very effective method for reduction of PAPR in the OFDM system. It is a two-step process. In first step, original OFDM single is divided into a number of sub-blocks. In second step, the output of first step is combined with phase rotated sub-blocks which gives a number of outputs, out of those outputs the one with minimum PAPR is selected for transmission. Another way to express Partial transmit sequence method is by multiplying the original OFDM signal with a number of phase sequences [8].

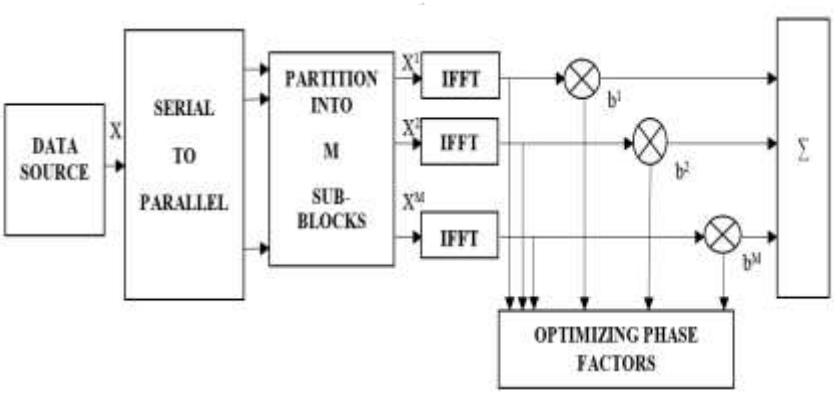

Fig. 1: Block diagram of PTS technique [6]

In this scheme, at first stage the input data (X) is divided into sub-blocks (M). In each sub block there is a weighing factor (phase factor) for corresponding subcarrier. The phase factors are selected in such a way that the resultant signal becomes of having least PAPR. The disjoint sub-blocks generated by dividing input data is

$$X^m=[X_0^m, X_1^m, X_2^m \ldots\ldots X_{N-1}^m]; \quad m=1, 2\ldots M \qquad (3)$$

All the sub-carriers position which is presented in other sub-blocks must be zero so that the sum of all the sub blocks constitutes the original signal, i.e.

$$x=\sum_{m=1}^{M} X^m \qquad (4)$$

The set of phase factors denoted as Vector b = [b1; b2…….; bM] are introduced. A phase factor is multiplied to each sub block and then summed up. It can be given as [3]

$$X' = \sum_{m=1}^{M} \mathrm{IFFT}(b^m.\bar{X}^m) = \sum_{m=1}^{M} b^m.\mathrm{IFFT}(\bar{X}^m) = \sum_{m=1}^{M} b^m.x^m \qquad (5)$$

$$b^m \subseteq \ominus, \ominus=[e^{j\theta 1}, e^{j\theta 2}, \ldots\ldots\ldots e^{j\theta v}] \qquad (6)$$

Here x (m) is the PTS Sequence while collection of phase factors are denoted by ⊖. The purpose here is to determine the phase factor which gives the output signal with minimum PAPR. Note that with the increase in the number of sub blocks the search complexity increases exponentially. The PTS algorithm is described as firstly, disjoint sub-blocks are created by dividing OFDM sub-carriers and then IFFT of each sub-block is taken to generate the OFDM signals and at last Using optimizing algorithm weighting factors are generated and combined with the output signals.

4. PROPOSED WORK

In our proposed work, the output of IFFT is passed through two different sets of phase vectors as shown in equation 7 & 8.

P1= [1, -1, j, -j] (7)

P2= [1+j, -1+j, 1-j, -1-j] (8)

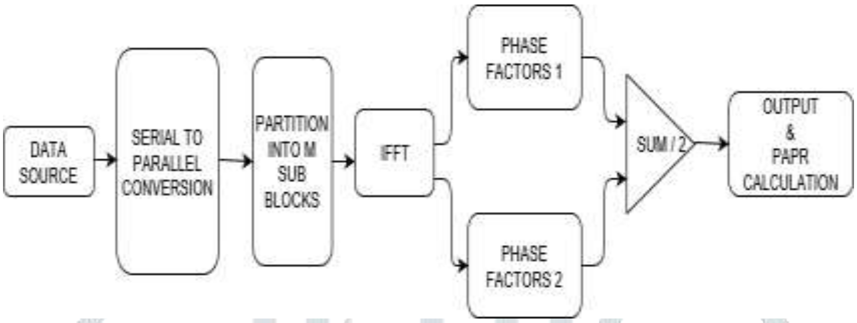

Fig. 2: Block diagram of Proposed PTS technique

After optimizing the IFFT output from set of phase vector 1 and same IFFT output form set of phase vector 2, the output of two blocks are sum up. The output of sum block is taken for PAPR calculation.

5. SIMULATION & RESULTS

TABLE 1: CCDF data for without PTS

	CCDF Without using PTS (ORIGINAL OFDM)	
S.No.	Cx	Cy
1	4.821	0.999
2	4.921	0.999
3	5.021	0.999
4	5.121	0.999
5	5.221	0.998
6	5.321	0.997
7	5.421	0.995
8	5.521	0.992
9	5.621	0.988
10	5.721	0.981
11	5.821	0.974
12	5.921	0.966
13	6.021	0.954
14	6.121	0.939
15	6.221	0.917
16	6.321	0.885
17	6.421	0.855
18	6.521	0.818
19	6.621	0.785
20	6.721	0.750
21	6.821	0.709
22	6.921	0.661
23	7.021	0.617

24	7.121	0.590
25	7.221	0.539
26	7.321	0.506
27	7.421	0.461
28	7.521	0.419
29	7.621	0.376
30	7.721	0.340
31	7.821	0.299
32	7.921	0.264
33	8.021	0.226
34	8.121	0.199
35	8.221	0.172
36	8.321	0.1460
37	8.421	0.124
38	8.521	0.106
39	8.621	0.0900
40	8.721	0.0800
41	8.821	0.0660
42	8.921	0.0500
43	9.021	0.0390
44	9.121	0.0340
45	9.221	0.0270
46	9.321	0.0220
47	9.421	0.0200
48	9.521	0.0170
49	9.621	0.0150
50	9.721	0.0110
51	9.821	0.0100
52	9.921	0.0090
53	10.021	0.0050
54	10.121	0.0040
55	10.221	0.0030
56	10.321	0.0030
57	10.421	0.0030
58	10.521	0.0020
59	10.621	0.0020
60	10.721	0.0020
61	10.821	0.0010

TABLE 2: CCDF data for PTS technique for PAPR reduction

	CCDF With PTS	
S.No.	Cx1	Cy1
1	2.0234	0.99900
2	2.1234	0.99600
3	2.2234	0.99200
4	2.3234	0.98600
5	2.4234	0.97000
6	2.5234	0.95000
7	2.6234	0.92000
8	2.7234	0.87800
9	2.8234	0.81800
10	2.9234	0.75900
11	3.0234	0.69400
12	3.1234	0.60400

13	3.2234	0.53200
14	3.3234	0.45800
15	3.4234	0.39200
16	3.5234	0.32000
17	3.6234	0.24500
18	3.7234	0.18900
19	3.8234	0.15200
20	3.9234	0.10400
21	4.0234	0.07100
22	4.1234	0.05100
23	4.2234	0.03800
24	4.3234	0.02700
25	4.4234	0.01900
26	4.5234	0.01500
27	4.6234	0.01100
28	4.7234	0.00500
29	4.8234	0.00400
30	4.9234	0.00400
31	5.0234	0.00200
32	5.1234	0.00100
33	5.2234	0.00100
34	5.3234	0.00100

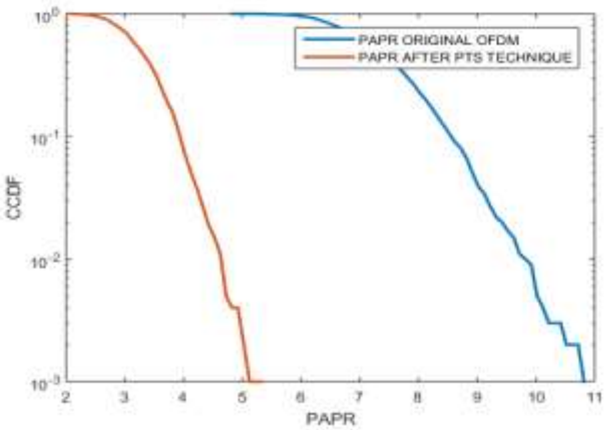

Fig. 3: CCDF of original OFDM and after PTS technique

TABLE 3: CCDF data for proposed PTS technique for PAPR reduction

	CCDF With PROPOSED PTS	
S.No.	Cx1	Cy1
1	1.758	0.999
2	1.858	0.999
3	1.958	0.992
4	2.058	0.990
5	2.158	0.984
6	2.258	0.968
7	2.358	0.951
8	2.458	0.913
9	2.558	0.867
10	2.658	0.798
11	2.758	0.713
12	2.858	0.617
13	2.958	0.515

14	3.058	0.436
15	3.158	0.349
16	3.258	0.263
17	3.358	0.201
18	3.458	0.140
19	3.558	0.084
20	3.658	0.057
21	3.758	0.036
22	3.858	0.026
23	3.958	0.017
24	4.058	0.015
25	4.158	0.010
26	4.258	0.006
27	4.358	0.004
28	4.458	0.004
29	4.558	0.001

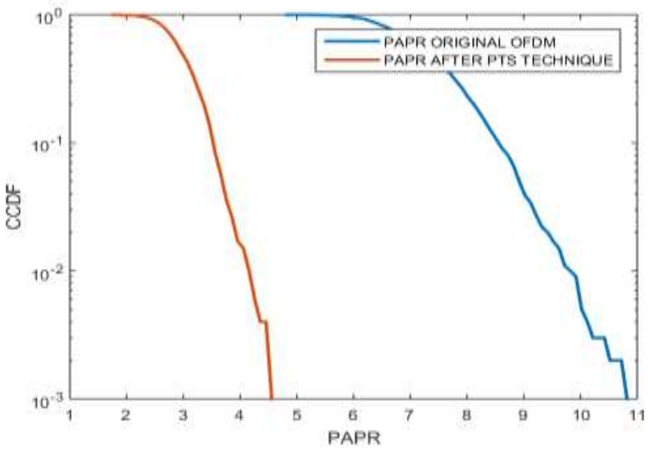

Fig. 4: CCDF of original OFDM and after proposed PTS technique

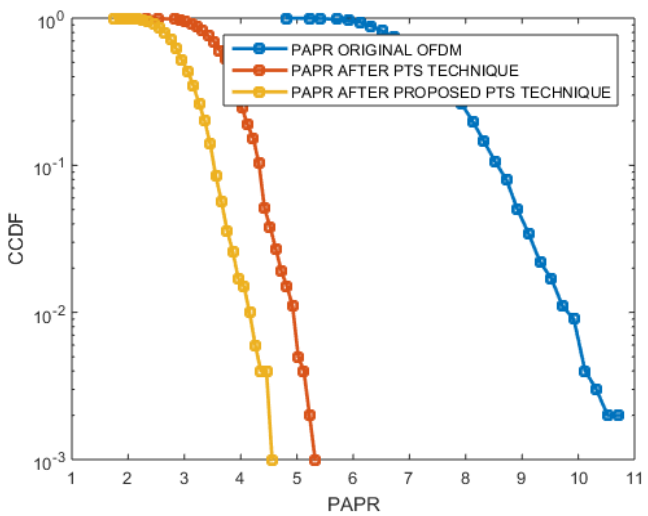

Fig. 5: CCDF of original OFDM, after PTS technique and after proposed PTS technique

Table 1, Table 2 & Table 3 contain the data of PAPR of original signal, after PTS technique and after proposed PTS technique. Fig. 3 shows that PTS technique is better in reducing PAPR while fig. 4 also shows that proposed technique is better in reducing PAR. Fig. 5 is the comparison between PTS and proposed PTS technique.

6. CONCLUSION

The OFDM has several advantages but the biggest disadvantage of OFDM is high PAPR value and due to this high PAPR, systems has to consist of high power amplifier which results in increasing the cost of the system as well as high distortions in output signal where power exceeds the threshold value. This problem is well solved by PTS technique which reduces PAPR very well and better than other available techniques. In our proposed work, in place of single set of phase vectors, two different phase vectors have been introduced. After the use of IFFT, its output is passed through the two different phase factor. At last, these two outputs are combined to form the final signal. This addition of extra phase vector reduces the PAPR further. The CCDF of original OFDM signal by using PTS technique and proposed PTS technique has been plotted and results of proposed PTS technique shows better PAPR reduction than original PTS technique.

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