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Performance Analysis of GA-PTS for PAPR Reduction in OFDM System

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***Abstract*— A low-complexity technique for reducing the PAPR of an OFDM system is presented which is known as partial transmit sequence (PTS). However, this scheme requires an extreme search over all combination of allowed phase factor. So, to reduce searching complexity there are different optimization algorithms. One of a novel and sub-optimal PAPR reduction approach is genetic algorithm based PTS technique which has less computational complexity than the PTS technique. In this algorithm, firstly population get initialized, then selection of chromosome are done after selection, crossover and mutation are performed for generating new population. The simulation result shows the performance of PAPR by adopting GA-PTS scheme.**

Keywords*— OFDM (Orthogonal Frequency Division Multiplexing), PAPR (Peak-to-Average Power Ratio), PTS (Partial Transmit Sequence), GA (Genetic algorithm), CCDF (complementary cumulative distribution function)

I.INTRODUCTION

In mid of 60s, Parallel data transmission by means of frequency division multiplexing (FDM) concept was published. The terms of discrete multi-tone (DMT), multichannel modulation and multicarrier modulation (MCM) are widely used in the telecommunications and sometimes they are used compatible with OFDM [1].OFDM is a digital multi-carrier modulation technique that divides the data over a large number of orthogonal sub-carriers. In the OFDM system, an input data is divided into a number of parallel data streams, one intended for different subcarriers. Then, with a modulation scheme such as Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK) each subcarrier get modulated. OFDM has several advantages such as, it is robust against ISI caused by multipath and provide maximum spectral efficiency. But it also has disadvantages as it is sensitive to Doppler shift. It is also susceptible to frequency synchronization problems and having high PAPR [2]. High PAPR uplifts a maximum requirement to linearity of transmit power amplifier, but numerous amplifiers are nonlinear and have the tremendous range, and when OFDM signal passed through nonlinear power amplifier, it may suffer from spectral spreading [3]. The PAPR or Crest Factor of the OFDM systems can be reduced by using various PAPR reduction techniques as clipping [10] , block coding [11], tone rejection (TR) [15,16] , tone injection (TI) [15,16] , selective mapping (SLM) [13] , partial transmit sequence(PTS) [14] etc. Among these technique, PTS is a promising technique. PTS is the probabilistic technique which scrambles an input data block and transmit one of them with the minimum PAPR so that the probability of incurring high PAPR can be reduced, but the searching complexity of optimum phase factor is high when the number of subcarrier and sub-block increases. [17, 18, 19].

In order to cure this problem, many techniques are introduced in recent years. In [20], GA-PTS perform better than the gradient descent and iterative flipping based PTS and has lower computational load than the PTS and GD-PTS. So in this paper, genetic algorithm is used to analysis the performance of PAPR in OFDM signal.

II.PRELIMINARIES

A. PAPR of OFDM signal:

Let $X = \{X_0, X_1, \dots\dots, X_{N-1}\}$ be an input block of N symbols used to modulate the sinusoidal signals$\{\varphi_m(t) = e^{j2\pi\frac{n}{T}t}, n =$ *0,1,......,N−1* , where*, 1/T* is bandwidth of each subcarrier. An OFDM signal is represented as.

$$x\{t\} = \frac{1}{N}\sum_{n=0}^{N-1} X_n\varphi_n(t), 0 \leq t \leq T \quad (1)$$

The PAPR is defined as the ratio of the maximum to average power of an OFDM signal.

$$PAPR\big(x(t)\big) = \frac{\max\limits_{0 \leq t \leq T} |x(t)|^2}{E\{|x(t)|^2\}} \quad (2)$$

Where, $E\{.\}$ denotes expectation. Large peak cause saturation in power the performance of PAPR reduction technique is measured by calculating CCDF of PAPR.

$$CCDF = P_r(PAPR > PAPR_0) \\ = 1 - (1 - \exp(-PAPR_0))^N \quad (3)$$

Amplifier leads to inter modulate the product among the subcarrier and disturbing out-of-band energy. Therefore, it is desirable to reduce the PAPR. Peak to average power ratio of OFDM is about 11.5 dB while CCDF is about 0.01.

B. PTS :

In PTS technique, an input data block is divided into M disjoint sub-block X_M, Where, $X_M = \left[X_0^{(m)}, X_1^{(m)}, \ldots \ldots, X_{N-1}^{(m)}\right]^T, m = 1, \ldots \ldots, M$. Therefore, we have $X = \sum_{m=1}^{M} X_m$. Now, inverse fast fourier transform (IFFT) is used to convert M sub-block into time domain signal. And these time domain signal is expressed as

$$x_m = IFFT\{X_m\} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k^{(m)} \, exp\left(j\frac{2\pi kn}{N}\right), m = 1,2, \ldots, M. \quad (4)$$

Now output of IFFT which is in time domain format get multiplied by phase factor which can be given as

$$b_m = \exp(j\varphi_m) \,.\, \varphi_m \,\epsilon [0,2\pi] \quad (5)$$

Now resulting time domain signal after combinations are given by

$$X = \sum_{m=1}^{M} b_m . x_m \quad (6)$$

Usually, $\varphi_m = {}^{2\pi\omega}/_{W}, \omega = 0,1, \ldots \ldots, W-1$, Where, W is the number of allowed phase angle. When M and W increases, the computational load become more this reduces performance of the signal.

So, to find phase factor which minimize the PAPR is our main objective. The best phase factor is expressed as

$$\{b_1, b_2, \ldots \ldots, b_m\} = argmin_{\{b_1, b_2, \ldots, b_m\}} \left\{ max \left| \sum_{m=1}^{M} b_m . x_m \right|^2 \right\} \quad (7)$$

Figure1. Shows the block diagram of partial transmit sequence. The improvement in performance of PAPR reduction is obtained when the number of sub block is increased in the PTS. But when this simulation is performed for different sub blocks, the computational load is increasing with increase in the number of sub blocks & phase factors. For 4 sub blocks, the searching complexity is 2^4. Similarly for 8 & 16 sub blocks this searching complexity of optimum phase factor is 256 & 65536 respectively, which are very large.

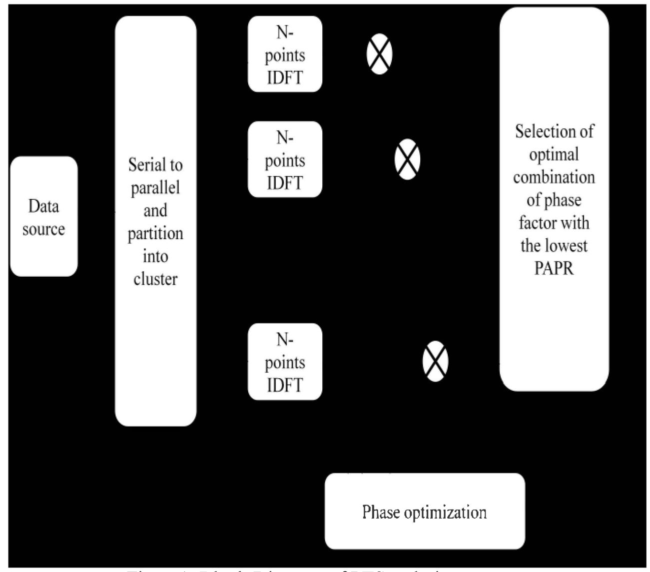

Figure1. Block Diagram of PTS technique.

C. GA-PTS

High computational complexity is one of the major limitations of PTS technique. In [20], the GA is merged with PTS technique to overcome by this setback. In 1960s and 1970s genetic algorithms were introduced by John Holland. The fundamental nature of genetic algorithms includes the encoding of an optimization function or we can say the chromosome is represented by a set of functions into arrays of binary strings and the exploitation of these strings by genetic operators or mutation. The main aim of this process is to find out the optimum solution to the problem concerned. The selection mechanism of GA-PTS is as follows.

- In genetic algorithm binary vector are used as chromosomes. So that binary bit string provides genetic information.
- Now, chromosomes of initial population get randomly selected and PAPR of each chromosome get calculated by repeated addition of the PTS with set of phase factor. Let us consider phase factor =4 (+1,-1,+j,-j).
- The fitness value of each chromosome is calculated by the cost or fitness function written as

$$fitness(x) = \frac{1}{10log_{10}PAPR(x)} \quad (8)$$

- On the basis of fitness value chromosome are selected by selection process which is known as roulette wheel algorithm.
- Chromosomes which get selected by roulette wheel selection process are used for generating (offspring) the chromosomes of next population.

- The process of generating offspring is known as crossover. After crossover, mutation is performed.
- Now upgrade the population and measure fitness value to generate new chromosome randomly. Now go back to step (2) if maximum number of generation G is not achieved.
- The chromosome with maximum fitness value is picked out and they decode according to the coding rule to obtain the phase factor [4]. The genetic algorithm can be represented in the following pseudo-code form.

Choose initial population

Evaluate the fitness of each individual in the population $fitness(x) = \frac{1}{10log_{10}PAPR(x)}$

Repeat

Select best-ranking individuals through roulette wheel selection process to reproduce. Here, probability of selection of h_i is $P_r(h_i) = {f_i}/{\sum_{i=1}^{R} f_i}$

Breed new generation through crossover and mutation (genetic operations) and give birth to offspring.

Evaluate the individual fitness of the offspring.

Replace worst ranked part of population with offspring.

Until <terminating condition>

III. SIMULATION

In our simulation, all experiment are performed in MATLAB 7.10.0(R2010a), according to configuration parameter of GA-PTS which is shown below in TABLE 1, QPSK modulation was employed with number of sub-carrier is about 128. The 128 sub-carrier were divided into four sub-blocks and 1000 OFDM blocks were chosen randomly.

TABLE 1. The Parameter of GA-PTS

Parameter	Value
Number of population	50
Number of generation	5,10,20
Crossover probability	0.8
Mutation probability	0.05
Number of sub-carrier	128
Modulation Technique	QPSK Modulation
Phase Factor	(1,j,-1,-j)
Number of disjoint sub-blocks	4

Crossover probability is usually selected between 0.1 and 1 & the probability of mutation is usually between 1 and 2 tenths of a percent. So here, crossover probability is about 0.8 and mutation probability is about 0.05 is selected.

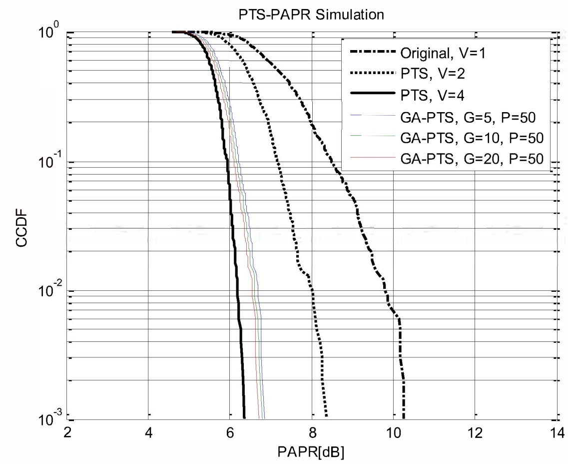

Figure 2. PAPR CCDF of GA-PTS with 128 subcarriers.

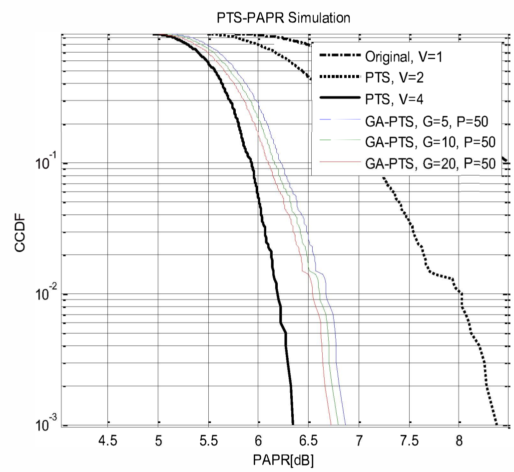

Figure 3. Zoom-in-view of GA-PTS with 128 sub-carriers.

In Figure 2, the CCDF verses PAPR reduction are shown with 128 sub-carriers and Figure 3. Is the zoom-in version of Figure 2. It is observed that, when CCDF=0.001, the PAPR of original OFDM and PTS are 10.26 dB,6.346 dB, the PAPR for GA-PTS with population size of 50 and generation of 5,10 and 20 are 6.865 dB,6.79 dB and 6.72 dB respectively.

TABLE 2. Performance analysis of GA-PTS .

Generation	Population	PAPR	CCDF
5	50	6.865dB	0.001
10	50	6.79 dB	0.001
20	50	6.72 dB	0.001

From Figure 2, Conclusion can be made that original PTS gives promising result, but it having higher computational load as compare to GA-PTS.

VI.CONCLUSION

In this paper, our main objective is to reduce PAPR of OFDM signal. Here, PTS with genetic algorithm is used. Genetic algorithm is a novel searching technique. GA-PTS require less number of iteration to produce good result. Here, result is analyzed by taking different value of generation. When generation is 5, 10, and 20 and population is about 50, then PAPR are 6.865 dB, 6.79 dB and 6.72 dB respectively. From this analysis we can conclude that by increasing the value of generation the PAPR get reduced.

REFERENCES

[1] Hiroshi Harda, Ramjee Prasad, "OFDM for wireless Communication System", Arctech House,2004.

[2] Jiang T., Wu Y., "An Overview: Peak-to-average power ratio reduction techniques for OFDM signals", *IEEE Trans. Broadcasting*, vol. 54, No. 2, pp. 257–268, June 2008.

[3] Wang, Xia, Songhua He, and Tao Zhu. "A Genetic-Simulated Annealing Algorithm Based on PTS Technique for PAPR Reduction in OFDM System." In *Computer Applications and Communications (SCAC), 2014 IEEE Symposium on*, pp. 120-124. IEEE, 2014.

[4] H. Liang, Y. R. Chen, Y. F. Huang, and C. H. Cheng, "A Modified Genetic Algorithm PTS Technique for PAPR Reduction in OFDM Systems," in Proc. *IEEE Asia-Pacific Conference on Communication*, 2009, pp. , Oct. 2009

[5] Pradabpet, C., S. Yoshizawa, Y. Miyanaga, and K. Dejhan. "Searching phase optimize in PTS-APPR method by GA for PAPR reduction in OFDM-WLAN systems." In *Innovative Technologies in Intelligent Systems and Industrial Applications, 2009. CITISIA 2009*, pp. 393-397. IEEE, 2009.

[6] Hung, Ho-Lung. "Using evolutionary computation technique for trade-off between performance peak-to average power ration reduction and computational complexity in OFDM systems." *Computers & Electrical Engineering 37.1*,pp-57-70,2011.

[7] Y. Zhang, Q. Ni, H. H. Chen,and Y. Song, "An Intelligent Genetic Algorithm for PAPR Reduction in a Multi-Carrier CDMA Wireless System," in Proc. *IEEE Wireless Communications and Mobile Computing Conference,* 2008, pp. 1052–1057, Aug. 2008.

[8] S. H. Han and J. H. Lee," PAPR reduction of OFDM signals using a reduced complexity PTS technique". *Signal Processing Letters, IEEE*, *11*(11), pp. 887-890.2004

[9] [ung Chein Chen , "Partial transmit sequence for PAPR reduction of OFDM signals with the cross entropy methods," *IEEE signal Processing* vol. 16, no. 6,pp- 545-548, June 2009.

[10] Li, Xiaodong, and Leonard J. Cimini Jr. "Effects of clipping and filtering on the performance of OFDM." In *Vehicular Technology Conference, 1997, IEEE 47th*, vol. 3, pp. 1634-1638. IEEE, 1997.

[11] Jones, Awinings E., Tim A. Wilkinson, and S. K. Barton. "Block coding scheme for reduction of peak to mean envelope power ratio of multicarrier transmission schemes." *Electronics letters* 30, no. 25, pp. 2098-2099,1994.

[12] J. Tao and Z. Guangxi, "Nonlinear companding transform for reducing peak-to-average power ratio of OFDM signals," *IEEE Trans. Broadcast*., vol. 50, no. 3, pp. 342–346, Sep. 2004.

[13] M. Breiling, S. H. Muller-Weinfurtner, and J. B. Huber, "SLM peak power reduction without explicit side information," *IEEE Commun. Lett.,* vol. 5, pp. 239–241, June 2001.

[14] Yang, Lin, Ru-Shan Chen, Yun-Ming Siu, and Kwok-Kai Soo. "PAPR reduction of an OFDM signal by use of PTS with low computational complexity." *Broadcasting, IEEE Transactions on* 52, no. 1, 83-86, 2006.

[15] Han, Seung Hee, and Jae Hong Lee. "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission." *Wireless Communications, IEEE* 12.2,pp- 56-65,2005.

[16] Tellado, Jose. *Multicarrier modulation with low PAR: applications to DSL and wireless*. Vol. 587. Springer Science & Business Media, 2006.

[17] Jiang T., Wu Y., An Overview: Peak-to-average power ratio reduction techniques for OFDM signals, *IEEE Trans. Broadcasting*, vol. 54, No. 2, pp. 257–268, June 2008.

[18] Choudhury, Peyali, "Comparison and analysis of PAPR reduction techniques in OFDM."*IEEE Trans. Inform. Theory*,pp- 2397-2417,1999.

[19] Ankita, Er, and Anand Nayyar. "Review of various PTS (Partial Transmit Sequence) techniques of PAPR (Peak to Average Power Ratio) reduction in MIMO-OFDM." *IEEE transactions on wireless communication signal Processing* vol. 9, no. 10,pp-199-202, March 2013.

[20] S. S. Kim, M. J. Kim, and T. A. Gulliver, "PAPR Reduction of OFDM Signals Using Genetic Algorithm PTS Technique," *IEICE Trans. Commun*., vol. E91–B, no.4, pp. 1194–1197, Apr. 2008.