Complexity Reduction in PTS based OFDM System: A Survey

Devinder Kumar
UIET, Panjab University, Chandigarh

Preeti Singh
UIET, Panjab University
Chandigarh

Jaget Singh
UIET, Panjab University
Chandigarh

ABSTRACT

These days, Orthogonal Frequency Division Multiplexing (OFDM) is a more attractive technique used in wireless communication systems. It has high capacity of data transmission. The major disadvantage of OFDM is Peak to Average Power Reduction which arises mainly due to increase in number of sub-carriers. Partial transmit sequence (PTS) is one of the best technique among all the proposed techniques to reduce the Peak-to-Average Power Ratio (PAPR). It has been found that the phase angles should lie in between 0^0 to 360^0 for best optimized result. But in this way, computational complexity increases exponentially with increase in sub-blocks. In this paper, a comparative analysis of different already existing optimization algorithms like Exhaustive Search Algorithm (ESA), Simulated Annealing (SA), Particles Swarm Optimization (PSO), Genetic Algorithm (GA), Electromagnetism (EM) and Bacteria Foraging Optimization (BFO) used to reduce the computational complexity of phase factors by finding optimal phase factors has been carried out. Finally, the performance of the said algorithms has been compared on the basis of PAPR reduction.

Keywords

OFDM, phase factors, partial transmit sequence, PAPR, multi-carrier modulation.

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) system is one in which parallel multi-carrier transmission scheme is used. In this scheme, high-rate serial data stream is split up into a set of low-rate sub streams, each of which is provided a separate frequency and modulated on a separate sub-carrier to reduce the carrier to interference ratio. A number of applications and standards which use OFDM include Digital Audio Broadcasting (DAB), WiFi (IEEE 802.11a/g/j/n), World Wide Interoperability for Microwave Access (WiMAX-IEEE 802.16), Digital Video Broadcasting (DVB), Mobile Broadband Wireless Access (MBWA-IEEE802.20) and Ultra Wide Band Wireless Personal Area Network (UWB Wireless PAN-IEEE 802.15.3a) [2,3].

The output OFDM signal is in the form of superposition of multiple sub-carriers. In this, OFDM signal has many carriers with same phases. In such cases, instantaneous output power of different sub-carriers after combination might increase abruptly and become much higher than the certain average power of the system. In this way, large Peak-to-Average Power Ratio (PAPR) problem arises in OFDM system. High PAPR is one of the most critical problems in OFDM system. To avoid high PAPR problem, one alternative solution is to use those amplifiers that have larger trade-off range. But with high PAPR, transmit signals require power amplifiers with very high power scope to handle the PAPR problem but these kinds of amplifiers are very costly and expensive. If the peak power is too much high, it could be out of the scope of the linear power amplifiers and produce non-linear distortion problem which degrade the performance of the OFDM system. OFDM system could face serious problem in practical applications when no technique has been employed to reduce the high PAPR [4-6]. On the other side, certain algorithms have been introduced and proved to have a good performance of high PAPR reduction. Recently, various solutions have been proposed to solve the high PAPR problem, like selective mapping (SLM) [8, 9], partial transmit sequence (PTS) [10-12], companding transform [13, 14], and active constellation extension (ACE) [15, 16]. From literature, PTS has been proved one of the effective techniques to reduce PAPR in OFDM. But in this technique a problem of complexity arises. It becomes more complex and difficult to find the optimal phase combinations when the number of sub-carriers and the order of modulation are increased [7-12].To reduce the computational complexity, many extensions of ordinary PTS approach have been proposed recently. In this paper, an overview of the optimization algorithms like Exhaustive search algorithm (ESA) [1], Simulated Annealing (SA) [9], Genetic Algorithm (GA) [6], Particle Swarm Optimization (PSO) [8], Electromagnetism (EM) [10] and Bacteria Foraging Optimization (BFO) [21] with the existing PTS method has been carried out. These algorithms are used to search the optimal combination of phase factors with reduced complexity. In this way, the need for optimizing the phase angles is a must to ensure a better solution and hence better performance [7].

The rest of the present paper is organized as follows. In Section 2, a typical OFDM system is explained with PAPR problem then explanation of ordinary PTS approach. Then PSO, EM and BFO are discussed to search the optimal combination of phase factors for PTS in Section 3. In Section 4, comparison of existing algorithms on the basis on PAPR and computations has been made. The conclusion of the survey is given in Section 5.

2. OFDM SYSTEM MODEL

The basic block diagram of the OFDM system is shown in figure 1. In OFDM system, data block of length N is represented by a vector. Duration of any symbol in the set $X(k)$ is N and represents one of the sub carriers set. If the *N* sub carriers chosen to transmit the signal are orthogonal to each other, fk be the bandwidth of each subcarrier and NT is the duration of the OFDM data block $X(k)$. The complex data block for the OFDM signal to be transmitted is given by inverse Fast Fourier transform ($FFT)$ relation as follows:

$$x(t) = \frac{1}{N}\sum_{k=0}^{N-1} X(k)e^{j2\Omega fkt} \quad \text{where } 0 < t < NT \qquad (1)$$

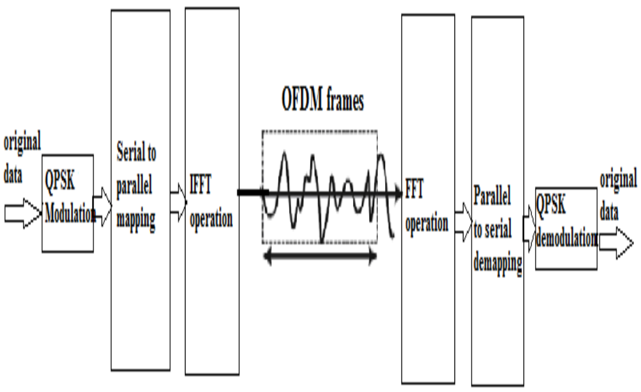

Figure 1: Block diagram of simple OFDM system

The Peak to average power ratio (PAPR) is expressed as,

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]} \qquad (2)$$

where, *x(t)* represents the transmitted OFDM signals which is obtained by taking IFFT of modulated input symbols $X(k)$ and $|x(t)|$ represents peak output power, E[|x(t)|²] is average output power and E denotes the expected value. For an OFDM system with N sub-carriers, the peak power of received signals is N times the average power when phase values are the same. The PAPR of output signal will reach its theoretical maximum at $PAPR = 10\log_{10} N$ [7]. PAPR is normally measured in terms of CCDF (Complementary Cumulative Distribution Function) given as:

$$CCDF(PAPR\,0) = \Pr(PAPR > PAPR\,0) \qquad (3)$$

$CCDF$ of PAPR denotes the probability that the PAPR of the data exceeds the given threshold value $PAPR\,0$. $CCDF$ provides better resolution for low-probability events. Hence, $CCDF$ emphasizes peak amplitude excursions, while CDF (Cumulative Distribution Function) emphasizes minimum values. Using the central limit theorem on OFDM signals, when the time domain signals follow the Gaussian distribution with zero mean x , the amplitude of multi carrier signal has a Rayleigh distribution.

2.1 PTS for PAPR Reduction in OFDM Signal

The block diagram for ordinary PTS (Partial Transmit Sequence) approach is shown in figure 2. In PTS, the input data X which applied at transmitter end is partitioned into V disjointed sub-blocks. The partitioned sub-block X is denoted as

$$X = \sum_{v=0}^{V-1} X^v$$

(4)

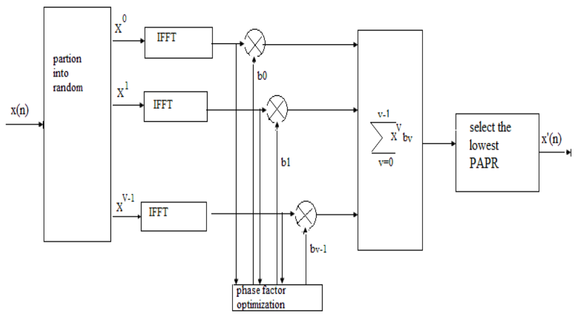

Figure 2 Block Diagram of PTS for PAPR in OFDM system

The sub-block vectors are over sampled when multiple by factor $(L-1)N$ zero padding to measure the continuous-time value of the PAPR. After that over sampled sub-blocks are subjected to Inverse Fast Fourier transform $(IFFT)$ operating with size LN and sub-blocks are transformed. Each sub-block multiple with equal no. of phase factors which given as

$$X = \sum_{v=0}^{V-1} x^v bv \qquad (5)$$

The aim in the PTS is to find the optimal phase factors. In the phase optimization, the phase factor of the first sub-block is taken as $b0 = 1$, and alternative b combinations, where b = [$b1$, $b2$,..., $bv-1$] and w is the number of the phase factors. In sequence bv values are as follows

$$bv = \begin{cases} \pm 1, & if\ w = 2 \\ \pm 1, \pm j & if\ w = 4 \end{cases} \qquad (6)$$

The signal in time domain is obtained by applying IFFT operation on, that is

$$x = \sum_{v=0}^{v-1} bv\, IFFTx^v$$

(7)

The optimum result can be obtained by selecting one suitable factor combination is $bv = [1,2 \ldots\ldots, v-1]$ .The combination can be given as

$$b = [b1, b2, \ldots bv] = \arg\min(b1, b2, \ldots. bv)\left(\max x = \sum_{v=0}^{v-1} x^v bv\right) \qquad (8)$$

In conventional PTS approach, it requires the PAPR value to be calculated at each step, so the problem arises as an additional burden has to with the extra V-1 times IFFTs operation. Again, more burdens in order to enable the receiver to identify different phases, phase factor b is required to send to the receiver as sideband information. So the redundancy bits account for $(V-1)\log 2$, in which V represents the number of sub-block. At last we can say that huge burden for OFDM system. Therefore, study on how to reduce the computational complexity of PTS has drawn more attentions, nowadays.

3. COMPARATIVE ANALYSIS of EXISTING ALGORITHMS for FINDING OPTIMAL PHASE IN PTS

There are many existing algorithms which are used for finding optimal phase factors in ordinary PTS approach and where optimal phase factors help to reduce Peak to Average Power Reduction in OFDM system. In the following section the comparative analysis of all these techniques with same system parameters has been carried out. All such techniques depend on the following factors:
1. Population based search methods
2. No. of sub- carriers
3. Maximum number of iterations
4. Number of local and global search iterations.

The system parameters of PTS system that have been considered for the performance analysis in terms of PAPR improvement are given in the table 1.

QPSK modulation is employed with N =128 sub-carriers. The phase weighting factors with W= 2, 4, have been used. 10,000 random OFDM frames have been considered, and the Complementary Cumulative Distribution Function (CCDF) of all frames is generated [13].

Table 1: Basic System Parameters of PTS System

System Parameter	Parameter value
1. No. of OFDM frames	10000
2.Modulation format	QPSK
3. No. of sub-carriers	128
4. Over sampling factor	4

The performance comparison in terms of various parameters of the PTS system using different approaches of optimization like Simulated Annealing (SA) [6], Genetic algorithm (GA) [3], Particle swarm optimization (PSO) [5], Electromagnetism (EM) [7] and Bacteria Foraging Optimization (BFO) [19] is given in table 2. The sampling rates increased by 4 times for finding an accurate PAPR. Selecting N =128 and by varying the parameters like number of sub-blocks, V= [2, 4, 8, 16, 32] phase weighting factors W= [2, 4] change in number of iterations [10, 30, 40, 100] and population size = [30, 40], this analysis has been carried.

Table 2 Comparative analysis of various optimization techniques to reduce PAPR in PTS system.

Method	No. of Iterations	Computation Complexity	V	W	Performance (PAPR0=.001)
ESA [1]	__	4^8=65,536	__	_	6.54dB
SA [9]	__	1*3000=3000	8	4	6.7 dB
GA [6]	100	30*100=3000	4	4	6.48 dB
PSO [8]	100 100	30*100=3000 30*100=3000	8 16	2 2	6.5dB 6dB
EM [10]	40 100	30*40=1200 30*100=3000	8 8	4 4	6.43dB 6.3 dB
BFO [21]	10 10	4*30*10=1200 4*40*10=1600	8 8	4 4	6.08dB 6.02 dB

It can be observed from the table that the minimum PAPR has been obtained with Bacteria Foraging Optimization under similar conditions.

4. PROPOSED PTS SYSTEM BASED ON ANT COLLONY OPTIMIZATION (ACO) APPROACH

The proposed PTS system is based on the ACO technique which resembles the social behaviour of a colony of ants for search shortest path among different paths. Ant Communication is established through chemicals which known as ‘pheromones’. The first ant search the food source in randomly way and after found the food sources then it returns to the nest, laying a pheromone trail which help to communicate to each others. Other ants follow different no. of paths at random, and they also laying pheromone trails. A no. of paths is produce having different concentration pheromone. Upcoming ants choose that path having more concentration so that a way a shortest path get can merged. Over time, finishing the attractive strength of paths by evaporate the pheromone trails tarts. The more time it takes for ant to travel down the path and back again, the more time spend on to evaporate the pheromones. If there were no evaporation then paths chosen by the first ants would tend to be excessively attractive to the following ones so this necessary to reduce the attractiveness of pheromones after a certain time. In ordinary PTS based ACO method can be implemented by appropriately changing the ants' location (angles). Similarly, from this behaviour of finding the optimal angles from search space 0^0 to 360^0 helps to reduce Peak to Average Reduction in OFDM system. Ant colony optimization has also an advantage of avoiding the convergence to a locally optimal solution. The flow chart for the proposed PTS system with ACO approach for optimization of phase angles is given below in figure 3.

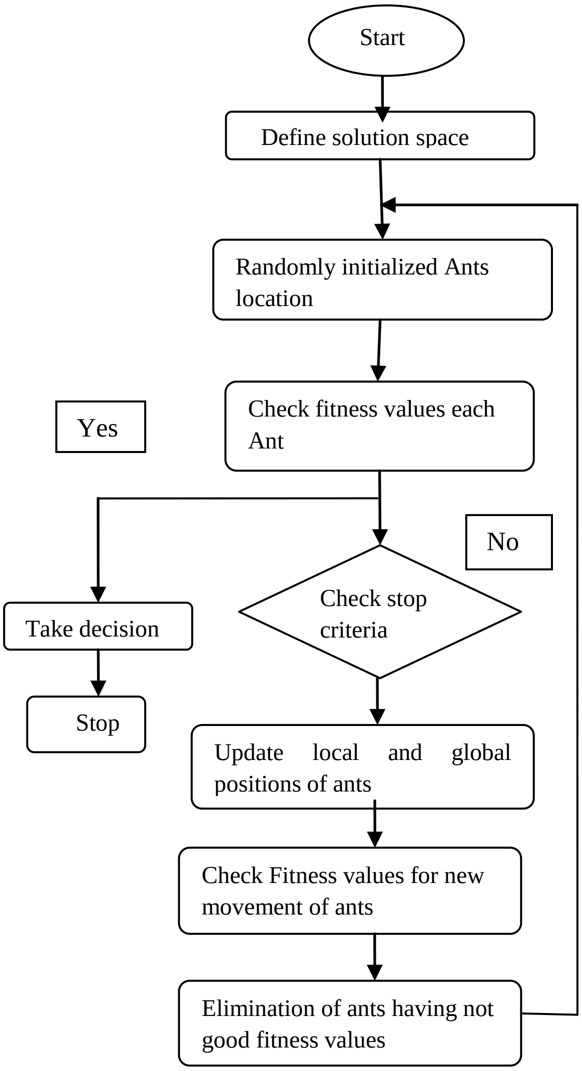

Figure 3: Flow chart for PTS using ACO approach to reduce PAPR in OFDM system.

5. CONCLUSION

Algorithms like ESA, SA, PSO, EM, GA and BFO are used to decrease PAPR value and to increase the accuracy in OFDM system. The amount of complexity is compared and validated against the ordinary PTS approach. It is found to be comparatively less. In the present paper the Modified Ant Colony Optimization algorithm (ACO) is proposed to find the optimal angle which help to decrease the PAPR value in OFDM System and hence further increases the accuracy of OFDM system. The objective of the proposed work is to make ACO computationally more efficient.

6. REFERENCES

[1] S. H. Muller and J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences," IEE Electron. Lett., vol. 33, no. 5, pp. 368-369, Feb. 1997.

[2] Tao Jiang and Yiyan Wu,"An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals," IEEE Trans. Broadcast,, Vol. 54, No. 2, June 2008.

[3] Seung Hee Han, and Jae Hong Lee," Modified Selected Mapping Technique for PAPR Reduction of Coded OFDM Signal," IEEE Trans. Broadcast,, VOL. 50, NO. 3, SEPTEMBER 2004 H.

[4] Taewon Hwang, Chenyang Yang, Gang Wu, Shaoqian Li, Geoffrey Ye Li, "OFDM and Its Wireless Applications: A Survey," IEEE Transactions on Vehicular Technology, Vol. 58, No. 4, pp. 1673-1693, May 2009.

[5] S. H. Han and J. H. Lee, "An overview of peak-to-average power ration reduction techniques for multicarrier transmission," IEEE Wireless Communication, Vol. 12, pp. 56-65, April 2005.

[6] Marco Lixia, Maurizio Murroni, Vlad Popescu, "PAPR reduction in Multicarrier Modulations using Genetic Algorithms," Proceedings of 12th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), pp. 938-942, May 2010

[7] Seog Gcun Kang, Jeong Goo Kim, Eon Kyeong Joo, "A Novel Subblock Partition Scheme for Partial Transmit Sequence OFDM," IEEE Transactions on Broadcasting, Vol. 45, No. 3, pp. 333-339, Sep. 1999.

[8] Ho-Lung Hung, Yung-Fa Huang, Cheng-Ming Yeh, Tan-Hsu Tan, "Performance of Particle Swarm Optimization Techniques on PAPR Reduction for OFDM Systems," Proceedings of IEEE International Conference on Systems, Man, Cybernetics (SMC), pp. 2390-2395, Oct. 2008

[9] Tao Jiang, Weidong Xiang, Paul C. Richardson, Jinhua Guo, Guangxi Zhu, "PAPR reduction of OFDM signals using partial transmit sequences with low computational complexity," IEEE Transactions on Broadcasting, Vol. 53, No. 3, pp. 719-724, Sep. 2007.

[10] Jung-Chieh Chen, "Partial Transmit Sequences for PAPR Reduction of OFDM Signals with Stochastic optimization Techniques," IEEE Transactions on Consumer Electronics, Vol. 56, No. 3, pp. 1229-1234, Aug. 2010.

[11] Jung-Chieh Chen, "Partial Transmit Sequences for Peak-to-Average Power Ratio Reduction of OFDM Signals with the Cross-Entropy Method," IEEE Signal Processing Letters, Vol. 16, No. 6, pp. 545-549, June 2009.

[12] Jung-Chieh Chen, "Application of Quantum-Inspired Evolutionary Algorithm to Reduce PAPR of an OFDM Signal Using Partial Transmit Sequences Technique,"

IEEE Transactions on Broadcasting, Vol. 56, No. 1, pp. 110-113, March 2010.

[13] Yajun Wang, Wen Chen, Chintha Tellambura, "A PAPR Reduction Method Based on Artificial Bee Colony Algorithm for OFDM Signals," IEEE Transactions on Wireless Communications, Vol. 9, No. 10, pp. 2994-3000, Oct. 2010.

[14] Sung-Soo Kim, Myeong-Je Kim, T. Aaron Gulliver, "A New PTS for PAPR Reduction by Local Search in GA," Proceedings of International Joint Conference on Neural Networks Canada, pp. 2370-2373, July 2006.

[15] Hsinying Liang, Yan-Ru Chen, Yung-Fa Huang, Chia-Hsin Cheng, "A Modified Genetic Algorithm PTS Technique for PAPR Reduction in OFDM Systems," Proceedings of the 15th Asia-Pacific Conference on Communications (APCC), pp. 182-185, Oct. 2009.

[16] L. J. Cimini, N. R. Sollenberger, "Peak-to-Average Power Ratio Reduction of an OFDM Signal Using Partial Transmit Sequences," IEEE Communications Letters, Vol. 4, No. 3, pp. 86–88, March 2000.

[17] Ho-Lung Hung Yung-Fa Huang, Cheng-Ming Yeh, Tan-Hsu Tan "Performance of Particle Swarm Optimization Techniques on PAPR Reduction for OFDM Systems" IEEE International Conference on Systems, Man and Cybernetics 2008.

[18] A. Ratnaweera, S. K. Halgamuge and H. C. Watsom, "Self-organizing hierarchical particle swarm optimizer with time-varying acceleration coefficients," IEEE Trans. Evol. Comput., vol. 8, no. 3, pp. 240-255, June 2004.

[19] M. Clerc and J. Kennedy, "The particle swarm—explosion, stability, and convergence in a multidimensional complex space," IEEE Trans. Evol. Comput., vol. 6, no. 1, pp. 58–73, Feb. 2002.

[20] Marco Lixia, Maurizio Murroni, Vlad Popescu"PAPR reduction in Multicarrier Modulations using GeneticAlgorithms" 12th International Conference on Optimization of Electrical and Electronic Equipment, OPTIM 2010

[21] Neha Gupta, Garima Saini "Performance Analysis of BFO for PAPR Reduction in OFDM" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-5, November 2012

[22] Yong Soo Cho Chung ,Jaekwon Kim, Chung G. Kang "MIMO- OFDM WIRELESS COMMUNICATIONS WITH MATLA" John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop, # 02-01, Singapore 129809,copyright 2010