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Improved Response of Genetic Simulated Annealing Algorithm for PAPR Reduction in OFDM System using PTS Technique

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Abstract

Objectives: Orthogonal Frequency Division Multiplexing (OFDM) which is a wide band digital modulation technique has high peak to average power ratio. An advanced Genetic Simulated Annealing Algorithm (GSAA) is here proposed to reduce Peak to Average Power Ratio (PAPR). **Statistical Analysis:** A hybrid of Genetic and Simulated Annealing Algorithms (SAA) is implemented with two different channels Additive White Gaussian Noise (AWGN) and Rayleigh Fading which improved the performance of PAPR. Compensation of effects as well as reduction in PAPR is achieved. **Findings:** Though the known method GSAA reduces PAPR by avoiding the computational complexity, local maxima, yet the resultant PAPR is between 5dB and 6dB. The proposed method, proceeds further by incorporating AWGN and Rayleigh Fading channels in the hybrid of GSAA. Implementing the hybrid algorithm with the two proposed channels reduces PAPR between 3dB and 4dB. Hence this method proves to be effective in reduction of PAPR.

Keywords: AWGN, Genetic Simulated Annealing Algorithm, OFDM, PAPR, PTS

1. Introduction

OFDM is a digital multi-carrier modulation technique. OFDM is combination of two well known processes, Modulation and Multiplexing. Modulation is process in which mapping of information is done by changing the carrier characteristics like phase, amplitude, frequency or combination. And Multiplexing is method of sharing bandwidth with other independent data channels. In the recent years, OFDM finds its applications in DAB, DVB-T, standard like IEEE 802.16. OFDM signal is advantageous as it is robust against ISI and fading with high spectral efficiency. In addition to the advantages it also has some draw backs; one of it is high PAPR. High PAPR degrades efficiency of linear power amplifier.

To reduce PAPR various techniques such as clipping[1], block coding, Tone Rejection (TR), Tone Injection (TI), Selective Mapping (SLM)[2,3], Partial Transmit Sequence(PTS)[4] etc have been introduced. Among these techniques, PTS is efficient and widely used optimization technique. But PTS needs an exhaustive search of the possible phase factors to obtain optimal PAPR performance. The computational load becomes impractical while the number of sub-blocks and phase factors increases. So to reduce computational complexity the optimization algorithms such as Genetic Algorithm (GA), simulated annealing algorithm are used.

GA is a search algorithm based on the concept of survival of fitness[5,6]. GA when implemented with PTS reduces the PAPR along with low computational

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complexity[7,8]. But in GA there is a chance of getting caught at local maxima which deviates from the best solution. Hence using GSAA-PTS technique PAPR performance can be improved by obtaining a best solution[6]. In order to reduce the PAPR to more extent this paper presents a novel approach through advanced GSAA.

In this paper GSAA-PTS is implemented with AWGN channel. The PAPR performance improves with AWGN when compared with Rayleigh fading channel. Remaining paper is organized as follows. Section II depicts the concept of PAPR in OFDM systems, GA-PTS and GSAA-PTS. Section III presents the concept of advanced GSAA with PTS. Eventually section IV and section V exhibits the simulation results and conclusion respectively.

2. System Model

2.1 Basics of OFDM and PAPR

The OFDM system is spectrally efficient by carrying more data per unit bandwidth. It consists of closely spaced orthogonally modulated carriers. OFDM system with 'N' subcarriers can be formulated as

$$X(n) = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_i \exp(j2\pi\, in/N) \tag{1}$$

Where n=0,1,2,…….N-1 and $x = [x_0, x_1, \ldots\ldots x_{n-1}]$ constitute the data symbols.

The PAPR can be defined as the ratio of peak power to the average power. As the peak power increases the detection efficiency of OFDM receivers become sensitive to non-linear devices such as DAC and high power amplifiers. It can be constituted as

$$\text{PAPR}\,[x(n)] = \frac{\max[|x(n)|^2]}{E|x(n)^2|} \tag{2}$$

Where $E|x(n)^2|$ represents the expected value.

To characterize the performance of PAPR a measuring tool known as CCDF which means complementary cumulative distribution function is used. It can be calculated as

$$\text{CCDF} = \Pr(\text{PAPR} > \text{PAPR}_0) \tag{3}$$

$$= 1-(1-\exp(-\text{PAPR}_0))^N \tag{4}$$

Where PAPR_0 is the threshold value and PAPR is the obtained value.

2.2 PTS Technique in OFDM

PTS is nothing but transmitting a part of data of varying subcarriers which covers all the information to be sent. Hence the incoming data is divided into M disassociate sub blocks. It is shown in the Figure 1.

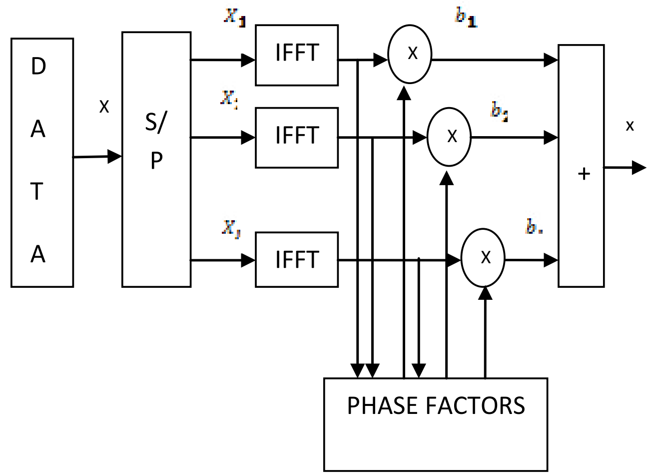

Figure 1. Mechanism of PTS.

Equations that represent the PTS technique in OFDM are as shown

$$X = \sum_{m=1}^{M} X_m \tag{5}$$

$$x_m = \text{IFFT}\{X_m\} \tag{6}$$

$$= \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_i \exp\left(j\frac{2\pi in}{N}\right),\ m=1,2,\ldots,M \tag{7}$$

To the above obtained time domain signals complex phase factors represented by b_m are multiplied. A combination of these phase factors minimize PAPR.

$$b_m = \exp(j\phi_m),\ \phi_m \in [0, 2\pi) \tag{8}$$

2.3 GA with PTS

GA is a heuristic search algorithm used in the search of phase factors to reduce PAPR which is complex using only PTS. It is based on the Darwinian principle known as "survival of fitness" which imitates the process of natural evolution. The algorithm follows the steps as shown below

1. Random generation of a population of n individuals.
2. Calculate the fitness of each individual.

3. Generate new population using the following three operators.

The flow chart of this method is shown in Figure 2.

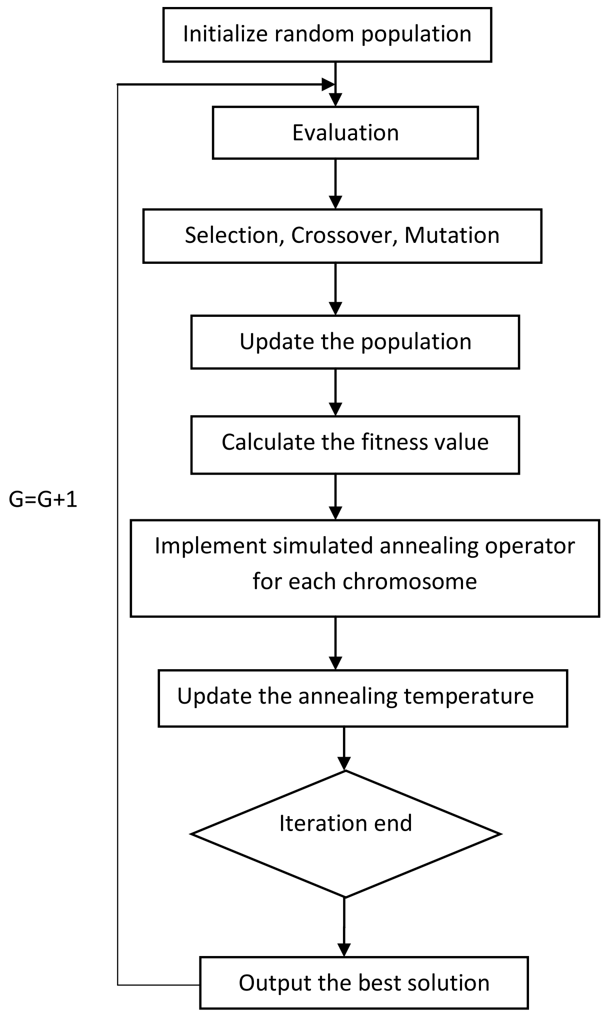

Figure 2. Flow chart of GSAA-PTS.

Selection- Select two parent chromosomes with best fitness from the randomly generated population.
Crossover- Exchange a part of the chromosome with the other. Crossover point can be selected as per the requirement.
Mutation- It determines the variation in genetic characters of population from one generation to the other. Here gene values are altered at certain points known as mutation points.

4. Update the population by adding newly generated off-springs. After repeating the process for certain generations return the best solution.

2.4 GSAA with PTS

GA has a chance of falling at local maxima which might not be the best solution. Hence the annealing operator is added into the GA to search the favourable combination of phase factors. In GSAA-PTS, the chromosomes are represented by binary vectors which are generated randomly. Each chromosome is transformed into a set of phase factors by associating each with $\log_2 W$ bits. The required phase factors are represented in the Table 1.

Table 1. Coding rule for W=4 and M=4

Binary code	Phase factor
00	$b_{1=1}$
10	$b_{2=j}$
01	$b_{3=-1}$
11	$b_{4=-j}$

The channel here used is a Rayleigh fading channel. Here the annealing temperature is updated after each iteration.

3. Advanced GSAA Algorithm

Advanced GSAA is implemented using AWGN channel. The advanced algorithm is a combination of GA and simulated annealing algorithm with the use of AWGN channel which is the main touchstone.

The following is the mechanism of advanced algorithm

Step 1-Initialize the population by random generation from solution space which can be calculated as $P=[\mathbf{h_1}, \mathbf{h_2}, \ldots \mathbf{h_n}]$

Step 2-Then calculate the fitness value of each chromosome in the population using the following fitness function

$$\text{Fitness}(x) = \frac{1}{10\log_{10}\mathbf{PAPR(x)}} \quad (9)$$

Step 3-Roulette wheel algorithm is used to select $(1-\mathbf{C_p})C$ solutions and consider them as population of next generation along with the remaining population. The probability of selection of chromosome is

$$\Pr(\mathbf{h_k}) = \mathbf{f_k} \Big/ \sum_{k=1}^{C} \mathbf{f_k} \quad (10)$$

Step 4-One point crossover is done with C_p C/2 pairs of chromosomes. This operation is performed on the chromosomes which are not being selected in selection step.
Step 5- Mutation is carried out with a probability of $\mathbf{M}_p$.
Step 6-Send the obtained offspring's along with remaining population into new generation.
Step 7-Calculate the fitness value or cost function of randomly selected individual from new population .Term it as $C_{old.}$
Step 8-Generate a new neighbouring solution and estimate its cost function. Name it as $C_{new.}$
Step 9-Compare the two cost functions.

If $C_{new.} < C_{old.}$: move to new solution. Consider new solution as the reference solution.

If $C_{new.} > C_{old.}$: move to the new solution. Consider old solution as the reference solution.

Step 10-Calculate the acceptance probability as

$$A = e^{\frac{C_{old}(-C_{new})}{T}}, \quad T = \alpha T \qquad (11)$$

The parameters used in this algorithm are tabulated in Table 2.

Table 2. Representation of some parameters

Symbol	Definition
P	Population of present generation
C	Number of chromosomes in population
C_p	Crossover probability
h_k	Kth chromosome in population
f_k	Fitness value of kth chromosome
M_p	Mutation probability
T	Annealing temperature
α	Annealing factor
C_{old}	Old cost function
C_{new}	New cost function

4. Results and Discussion

In this part of the paper simulation results of original OFDM system are compared with GA-PTS, GSAA-PTS, and AGSAA-PTS algorithms. Simulations are performed in MATLAB. Here number of subcarriers, N= 64,128 with QPSK modulation. The number of disjoint blocks, M=4 and W=16 which denotes the number of allowed phase angles.

In Figure 3, comparison of Original OFDM with PTS, GA-PTS and GSAA-PTS is shown. Numbers of subcarriers used are 64.The PAPR of Original OFDM is nearly 10.5dB and that of GA-PTS is between 6dB and 7dB. Coming to GSAA-PTS it results between 5dB and 6dB. Hence, there is a reduction in PAPR using GSAA-PTS when compared with the other two methods which is approximately equal to PTS. Results are shown for different generations like G=5,10 and population of P=10,20.

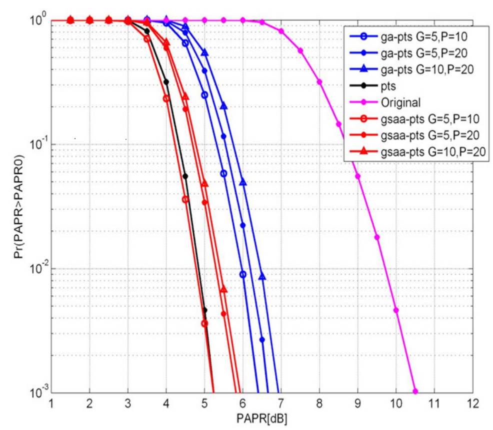

Figure 3. Comparison of PAPR of GA-PTS and GSAA-PTS with original PTS having 64 subcarriers.

From Figure 4 we can observe GSAA-PTS with N=64 subcarriers which is implemented with AWGN channel. The result shows that performance of PAPR is increased when compared with figure 3 which is implemented using Rayleigh fading channel with N=64 subcarriers. PAPR obtained is 3.54dB and 5.1dB.

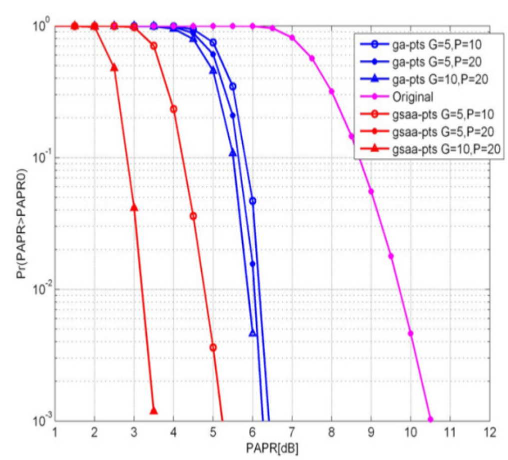

Figure 4. Comparison of PAPR CCDF of GA-PTS and AGSAA-PTS with 64 subcarriers.

In Figure 5 we can see that the PAPR is reduced to 3.5dB for N=128 when G=5 and P=10. But it has increased to 11dB in when G=5,P=20 and G=10,P=20. However the advanced algorithm has improved PAPR performance when compared to its implementation with Rayleigh fading channel and other techniques.

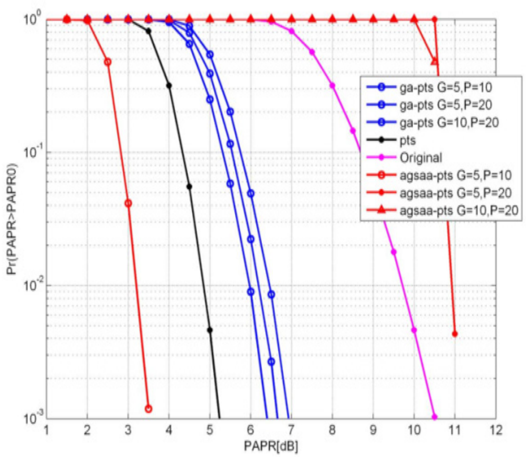

Figure 5. Comparison of PAPR CCDF of GA-PTS and AGSAA-PTS with original PTS having 128 subcarriers.

5. Conclusion

The simulation results prove that the PAPR performance increased with AGSSA algorithm. The results depict the reduction in PAPR compared with GA-PTS, GSAA-PTS and normal PTS. There is a reduction of 1.6dB when compared with GSAA-PTS provided the generations are lower. If the generations increase the performance again degrades.

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